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SysNet Tools II: The MGLP User Interface for Interactive Land Use Scenario Anaylsis

A.g. Laborte, B. Nuñez, C. Dreiser, and R. Roetter

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TECHNICAL BULLETIN

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Preface

This bulletin describes the Web-based user interface to the multiple goal linear programming (MGLP) models developed by the Systems Research Network for Ecoregional Land Use Planning in support of natural resource management in tropical Asia (SysNet). The project, lasting from 1996 to 2000, was one of the land use systems methodology development projects coordinated by the International Rice Research Institute (IRRI). The network consisted of five partners: national agricultural research and extension systems (NARES) of India, Malaysia, the Philippines, and Vietnam, and IRRI. Study regions included Haryana State (India), the Kedah-Perlis Region (Malaysia), Ilocos Norte Province (Philippines), and Can Tho Province (Vietnam). The main purpose of SysNet was to develop and apply methodologies and tools for improving the scientific basis for land use planning at the subnational level. These include crop simulation models, technical coefficient generators, mapping techniques, and MGLP models.

During the last two years of the project, the different local interest groups ("stakeholders") were increasingly involved in formulating agricultural development objectives/future land use scenarios and in refining the SysNet modeling framework to ensure that the most important "what-if" questions were addressed. To reach a consensus on feasible options, scenario analyses need to be conducted interactively with the different interest groups. To facilitate this, and in response to requests from local stakeholders, between October 1999 and August 2000, the (Web-based) MGLP user interface (UI) was developed and tested. Because technical documentation of the UI has been often requested by NARES scientists, regional planners, and resource managers from Asia, and students interested in regional land use scenario analysis, it is presented in the form of an IRRI Technical Bulletin.

This bulletin has four sections. The first describes how the interactive multiple goal linear programming (IMGLP) technique is used for scenario analyses. The second describes the file structure and technical aspects of the modeling system. The third part discusses the capabilities and limitations of the current version. Finally, the "Getting started" section provides instructions on how to install the interface on a personal computer and access it either off-line or via the Internet.

The contributions of the SysNet teams and stakeholders from Malaysia and the Philippines to this publication are acknowleged. Special thanks go to Bill Hardy (IRRI) for his meticulous editing of this publication.

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September 2001

SysNet Tools II: the MGLP user interface for interactive land use scenario analysis

Introduction

SysNet has developed tools and methodologies for exploring agricultural land use options to assist decision makers in determining how best to use agricultural land. These tools were operationalized into a decision support system called LUPAS (land use planning and analysis system).

The three main methodology parts of LUPAS are (Fig. 1) (i) land evaluation including assessment of resource availability, land suitability, and yield estimation, (ii) scenario construction based on policy views, and (iii) land use optimization in the form of a multiple goal linear programming (MGLP) model (Roetter and Hoanh 1999).

LUPAS integrates biophysical and socio-economic data, thereby allowing the system to determine not only what is biophysically feasible but also socially acceptable land use options.

In optimizing land use, different scenarios are analyzed based on quantitative land evaluation, quantified input-output relationships for current and alternative production activities, and the formulation of constraints and policy views as mathematical functions.

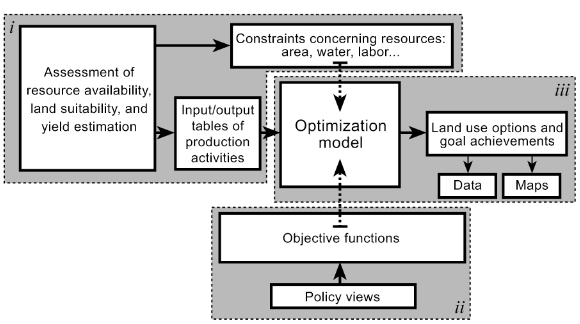


Fig. 1. Structure of the SysNet land use planning and analysis system (LUPAS): (i) land evaluation, (ii) scenario construction, and (iii) land use optimization.

Optimization results (goal achievements and land use allocation) reveal the extent to which various goals can be met with the technical and physical constraints, thus providing trade-offs between costs and benefits incurred in attaining the various goals.

The participation of stakeholders is an important component of the SysNet integrated approach. The stakeholders, consisting of local scientists and planners in the region, participated in various workshops where they were consulted about issues regarding goals and land use policies in their respective regions. Information supplied by stakeholders and that derived from policy documents were used in developing the MGLP model. In turn, preliminary results were presented to the stakeholders and their comments were solicited and used to further improve the methodology (Roetter and Laborte 2000).

Realizing the need for a tool to facilitate interaction with stakeholders, a Web-based user interface was developed to allow for interactive sessions with stakeholders (Fig. 2). In these sessions, the stakeholders can identify the scenarios they are particularly interested in and view results of optimization runs. The interface gives immediate results and allows for comparison of model runs, thus facilitating discussions about relevant scenarios and results of optimizations.

The system allows for joint learning and selected scenario runs can serve as a basis for negotiating alternative options for land use among different stakeholders.

Aside from enhancing interaction among stakeholders, the system is made available via the Internet, thus making the system and information generated accessible to more people.

This technical report describes the MGLP user interface. The next section describes the interactive MGLP (IMGLP) technique and how it is used for scenario analyses. The “Development and technical details” section describes the file structures and technical aspects of the system. “Features of the

Fig. 2. Interactive session with stakeholders in Kedah-Perlis, Malaysia, June 2000.

SysNet MGLP interface" describes the capabilities and limitations of the current version of the system. Finally, "Getting started" gives instructions on how to install and access the interface via the Internet or a personal computer.

The MGLP user interface described in this report is part of a set of tools developed for land use analysis in Asia. See Annex 1 for a description of other tools developed under the framework of the SysNet Project.

Interactive scenario analysis based on the IMGLP technique

The system is based on the interactive multiple goal linear programming (IMGLP) technique (De Wit et al 1988). This was used to determine optimal options for agricultural development in a region where many stakeholders have various (often conflicting) land use objectives.

Different land use scenarios are defined by specifying the objective to be optimized (e.g., maximize income) subject to technical and physical constraints (e.g., resource availability, production targets).

This is an iterative process. Initially, each of the objective functions is optimized without putting restrictions on the other goals. These are called the zero rounds. The results of the zero rounds show the highest and lowest values for each objective. In succeeding runs, stakeholders identify the objective to be optimized and impose tighter bounds on the goal with the lowest value that they consider least acceptable. This will yield new results and stakeholders are again asked to identify the value that they find least acceptable. The process continues till the stakeholders arrive at acceptable results (De Haan et al 2000).

Results of optimizations reveal the extent to which the different goals can be met and facilitate the calculation of trade-offs incurred in attaining the various goals.

Different stakeholders have different priorities and will put different weights on objectives. It is a challenge to get the stakeholders together to discuss and negotiate on the best option. This can be partly achieved by providing stakeholders with the tools to facilitate interaction and discussions.

The SysNet MGLP Web-based user interface was developed to enhance stakeholder interaction. This tool allows stakeholders to formulate scenarios by identifying objectives and specifying model constraints, perform model runs, and view results immediately in the form of tables, maps, and graphs.

This system was developed for two SysNet case study regions: Ilocos Norte Province, Philippines, and Kedah-Perlis Region, Malaysia. The system was used in presenting results of scenario runs to stakeholders during the final meetings in the respective regions: May 2000 for Ilocos Norte and June 2000 for Kedah-Perlis. There were also hands-on sessions during the final meetings where stakeholders had the chance to try out the system.

Development and technical details

Software

The system uses some existing software to perform certain tasks required. As much as possible, shareware software was selected to avoid problems of distribution and licensing. The "Getting started" section provides instructions for installing the following software.

The *Xitami Web Server for Windows* (http://www.imatix.com/) is the default server for the SysNet MGLP. Technically, other servers can be used in its place. However, references to the *cgi-bin* and *webpages* subdirectories specified in the Perl scripts and batch files need to be changed accordingly to account for differences in subdirectory names.

To do a model run, compare scenarios, and modify default values, Perl scripts are used to execute the necessary commands. *ActivePerl* (http://www.activestate.com/) is the shareware program used to evaluate the Perl scripts.

XPRESS-MP is the optimization software used (http://www.dash.co.uk). The model is programmed to get inputs and store outputs in ASCII text format and a Perl script runs the Console version of XPRESS-MP in the background. This is a commercial software so it is not included in the installation CD-ROM. If you would like to do new model runs, you would need to have a licensed copy of this software. An alternative optimization software that is not too costly is now being explored to allow stakeholders to have access to this tool.

When a new run is submitted, land allocation maps are created for each cropping system in the model. The software *TifIdris* creates TIF (tagged image format) files using a palette file and a base map. Each of the TIF files generated is converted to GIF (graphical interchange format) using the software *2GIF* (http://www.fcoder.com).

Files and directory structure

Files and some software needed by the system are stored in the *cg i-bin* and *webpages* subdirectories, i.e., c:\xitami\cgi-bin and c:\xitami\webpages. The structure is given in Figure 3.

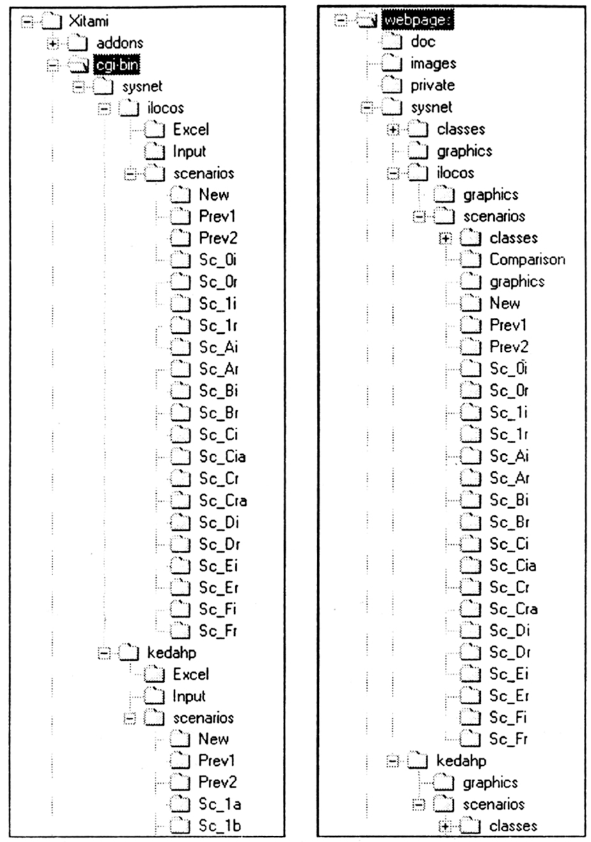


Fig. 3. The structure of the *cgi-bin* and *webpages* subdirectories.

CGI-BIN files

The *cgi-bin* subdirectory contains the Console version of XPRESS-MP, the *2GIF* software, and batch files needed in running system commands.

<u>Batch files</u>

- *initialize.bat* – used to reset all changeable values to the default, e.g., amount of available labor, demand per product.
- *reset_bounds.bat*, *reset_demand.bat*, *reset_labor.bat* – to reset values of corresponding variable to the default.
- *del_prev_run.bat* – to prepare the subdirectories for the results of the new model run. This will delete the third-to-last model run (stored in the subdirectory *Prev2*), move the second to the last run to *Prev2*, and move the last run to the subdirectory *Prev1*.
- *run_mod_max.bat* – run the model by maximizing the objective function selected.
- *run_mod_min.bat* – run the model by minimizing the objective function selected.
- *to_gif.bat* – convert the TIF files to GIF.
- *clean_up.bat* – move the files to the proper subdirectory and delete the TIF files.

Batch files used by the Ilocos Norte model have a prefix of IN-, while those for Kedah-Perlis have a prefix of KP-, e.g., IN-initialize.bat and KP-initialize.bat.

Under the *cgi-bin* subdirectory is the *sysnet* subdirectory. This contains files used in creating the land allocation maps.

<u>Base maps</u>

For Ilocos Norte, the files are
IN_L2000.IMG, IN_L2000.DOC
IN_L20 10.IMG, IN_L2010.DOC
For Kedah-Perlis, the files are
KP_LU.IMG, KP_LU.DOC

<u>Files for generating new maps</u>

TIFIDRIS.EXE
IDRISI.ENV
PALETTE.PAL

Under the *sysnet* subdirectory are the subdirectories for each of the models: *Ilocos* and *KedahP*. Here, the parameter file is *mod_par.txt*, in which the variable reference names, Perl scripts, and the XPRESS-MP programs are located.

<u>Reference names</u>

Goals.txt – goal names and units
Luts.txt – production system names

Products.txt – product names
Muni.txt/Dist.txt – subregional names
Tech.txt – technology level names

Perl script files

- *RunModel.pl* – executed when a new model run is submitted
- *Compare.pl* – for comparing two scenarios
- *ShowLabor.pl, ShowBounds.pl, ShowDemand.pl, ShowTargets.pl* – to show default values of certain variables, e.g., available labor, upper and lower bounds for goals, demand per product, targets per product
- *SaveLabor.pl, SaveBounds.pl, SaveDemand.pl, SaveTargets.pl* – to save new values entered by the user and use these in succeeding model runs
- *ResetLabor.pl, ResetBounds.pl, ResetDemand.pl, ResetTargets.pl* – to reset values to default

The first two letters of the Perl script files indicate the case study region for which the files are used. So, KP-RunModel.pl is for the Kedah-Perlis case and IN-RunModel.pl is for the Ilocos Norte case.

Optimization files

The XPRESS-MP programs for Kedah-Perlis are *KedahP.mod* and *KedahPPost.mod*, referring to the optimization and post-optimization programs (see Annex 2). For Ilocos Norte, the optimization files are *Ilocos2000.mod* and *Ilocos2010.mod* for the year 2000 and 2010 scenarios, respectively. Instructions for post-optimization are stored in the file *IlocosPost.mod*.

Under each model subdirectory (*Ilocos* and *KedahP*) are the following subdirectories: *Excel*, *Input*, and *Scenarios*.

Excel

This subdirectory contains the original input files in MS Excel format, where one can see how the values used in the optimization are derived.

The files and contents for Ilocos Norte are

- *IN-Indices.xls* – reference names for goals, technology levels, land use types, municipalities, etc.
- *IN-InOut.xls* – input-output relations for each production activity and land unit
- *IN-Other.xls* – product and product group relations, promising combinations, labor sharing matrix
- *IN-Resource2000.xls* – available resources, demand, and targets for the year 2000
- *IN-Resource2010.xls* – available resources, demand, and targets for the year 2010
- *IN-Options.xls* – contains a macro that converts specified columns and rows in the Excel files to comma-delimited text files for use by the optimization model

For Kedah-Perlis, the files and contents are

- *Kedah-Indices.xls* – reference names for goals, technology levels, land use types, districts, etc.
- *Kedah-InOut.xls* – input-output relations for each production activity and land unit.
- *Kedah-Other.xls* – available resources, demand, and targets
- *Kedah-Promising.xls* – promising combinations of production activities and land units for each of the MADA scenarios
- *KPOptions.xls* – contains a macro that converts specified columns and rows to comma-delimited text files for use by the optimization model

Input

This subdirectory contains the input files in ASCII comma-delimited format. These files are derived directly from the Excel files by running the macro in the file *IN-Options.xls* or *KP-Options.xls*.

Scenarios

This subdirectory contains all text output of the optimization runs. The outputs for one run are stored in one subdirectory. *New* contains the output for the last run, *Prev1* for the second-to-last run, *Prev2* for the third-to-last run, and those beginning with *Sc* refer to runs for the predefined scenarios.

Webpages files

The *webpages* subdirectory contains all pre-created files (static) and those created after a model run (output files).

Static pages

\sysnet\SysNetMGLP.htm – the welcome screen (Fig. 12 on page 13)

Model comparison initial screen
\sysnet\ilocos\CompareRuns.htm (see Fig. 4 on page 6)
\sysnet\kedahp\CompareRuns.htm

Predefined scenarios screen
\sysnet\ilocos\index_webuser.htm
\sysnet\kedahp\index_webuser.htm

Model input form
\sysnet\ilocos\index_modelrun.htm
\sysnet\kedahp\index_modelrun.htm

Initial screen for viewing/editing default values
\sysnet\ilocos\ViewEdit_Bounds.htm
\sysnet\ilocos\ViewEdit_DemTar.htm
\sysnet\ilocos\ViewEdit_Labor.htm
\sysnet\kedahp\ViewEdit_Bounds.htm
\sysnet\kedahp\ViewEdit_DemTar.htm
\sysnet\kedahp\ViewEdit_GrpArea.htm
\sysnet\kedahp\ViewEdit_Multipliers.htm
\sysnet\kedahp\ViewEdit_Labor.htm

Output files

These files are generated after a model run or a model comparison. They are located in the *webpages\sysnet\kedahp\scenarios* or *webpages\sysnet\ilocos\scenarios* subdirectories.

Model comparison files are located in the C*omparison* subdirectory, while the latest runs are stored in the *New*, *Prev,* and *Prev2* subdirectories.

Text files

- *KP.ASC* and *IN.ASC* – the output files for Kedah-Perlis and Ilocos Norte models, respectively. The columns refer to the variable names, dual values, and shadow prices
- *outAchiev.txt* – achievements by goal
- *outProdn.txt* – production by crop/product
- *outArea.txt* – land allocation by land unit (code) and crop
- *outLutTech.txt* – land allocated by municipality/ district, cropping/production system, and technology

HTML files

- *outDesc.htm* – description of model run
- *outGoal.htm* – goal achievements
- *outAlloc.htm* – graph of allocation by cropping/ production system
- *outProdn.htm* – graph of production per product

GIF files

CRComb.gif is the combined land allocation map showing the dominant production system group per land unit. For the Ilocos Norte model, the production groups are single rice, double rice, triple rice, rice with major dry-season crops (tomato, garlic, onion, white corn, sweet pepper, and mungbean), rice with minor dry-season crops (sweet potato, eggplant, vegetables, peanut, watermelon), rice with non-food crops (tobacco, cotton, yellow corn), and other triple systems (rice-white corn-mungbean, rice-yellow corn-mungbean, rice-garlic-mungbean).

The production groups for the Kedah-Perlis model are rice-based, tobacco-based, vegetables, fruits, plantation crops, and agroforestry products.

A map of allocation for each production system is also created. Five classes represent allocation as a percentage of available area per land unit: 1–20%, 21–50%, 51–75%, 76–90%, and > 90%. The file names are CR01.gif for production system 1, CR02.gif for production system 2, and so on.

For Ilocos Norte, the files refer to the following cropping systems: rice-white corn (CR01), rice-yellow corn (CR02), rice-garlic (CR03), rice-mungbean (CR04), rice-peanut (CR05), rice-tomato (CR06), rice-tobacco (CR07), rice-fallow (CR08), double rice (CR09), rice-cotton (CR10), rice-sweet potato (CR11), rice-onion (CR12), rice-sweet pepper (CR13), rice-eggplant (CR14), rice-vegetable (CR15), mungbean (CR16), sugarcane (CR17), root crops (CR18), triple rice (CR19), rice-garlic-mungbean (CR20), rice-white corn-mungbean (CR21), rice-yellow corn-mungbean (CR22), and rice-watermelon (CR23).

For Kedah-Perlis, the cropping systems and corresponding files are rice-rice (CR01), rice-tobacco (CR02), rice-leafy vegetables (CR03), rice-fallow (CR04), tobacco-fallow (CR05), tobacco-leafy vegetables (CR06), leafy-trelly-leafy vegetables (CR07), chilli-fallow (CR08), durian (CR09), mango (CR10), rubber (CR11), oil palm with animals (CR12), oil palm (CR13), sugarcane (CR14), starfruit (CR15), banana (CR16), sentang (CR17), and teak (CR18).

How the system works

Data preparation

The data files are stored in MS Excel files. When changes are made to any of these files, the macro in *Options.xls* needs to be re-run for the new values to be used. After opening the file (*KPOptions.xls* or *IN-Options.xls*), press Ctrl+Shift+P to run the macro. This will create the comma-delimited files in the *Input* subdirectory. The batch file *Initialize.bat* also needs to be re-run to reset the values of certain variables (e.g., demand, labor) to the new default values.

If no changes are made to the Excel files, there is no need to run the macro and the batch file.

New model run

After filling in the model input form and submitting a model run, the Perl script RunModel.pl converts the input stream into a text file (*cgi-bin\mod_par.txt*). This parameter file is then used as an input to the XPRESS-MP optimization and post-optimization programs.

The optimization is executed by running the Console version of XPRESS. The outputs of the optimization and post-optimization are the files *KP.ASC*/*IN.ASC*, *outAchiev.txt*, *outProdn.txt*, *outArea.txt*, and *outLutTech.txt*.

Land allocation maps are created for each cropping system in the model. The same Perl script creates a palette file (*Palette.pal*). For each map unit, the percent area allocated to each cropping system is calculated and mapped. For the combined map, the cropping systems are grouped and the most dominant group per map unit is displayed. The software *TifIdris* creates TIF files from the palette file and the Idrisi base map. Each of the TIF files generated is converted to GIF using the software *2GIF*.

The htm files *outDesc.htm*, *outGoal.htm*, *outAlloc.htm*, and *outProdn.htm* are then generated and saved to the *New* subdirectory. Prior to this, the contents of the *Prev2* subdirectory are deleted, then *Prev1* files are copied to *Prev2* and *New* files are copied to *Prev1*.

Model comparison

Upon selection of two runs to be compared, the Perl script *Compare.pl* (*IN-Compare.pl* or *KP-Compare.pl*) reads the model output text files in the corresponding subdirectory (e.g., *New* for the last run, *Prev1* for the second-to-last run) and generates the following htm files: *outAlloc.htm*, *outDesc.htm*, *outGoal.htm*, *outMapAlloc.htm*, and *outProdn.htm*. These files are saved in the *\scenarios\Comparison* subdirectory.

Features of the SysNet MGLP user interface

Viewing predefined scenarios

Upon selection of the case study, the predefined scenarios screen will appear. On the right frame are some case study characteristics and on the left is the scenario list (Fig. 4).

On selection of a scenario run, the frame on the right will show the optimization results grouped into four sections (Fig. 5). The "Goal achievements" section shows the value for the goal optimized as well as the associated values for the other goals and percentage of resources (land, labor, and water) used. You can switch to other screens by clicking on the respective item. "Scenario description" gives infor-

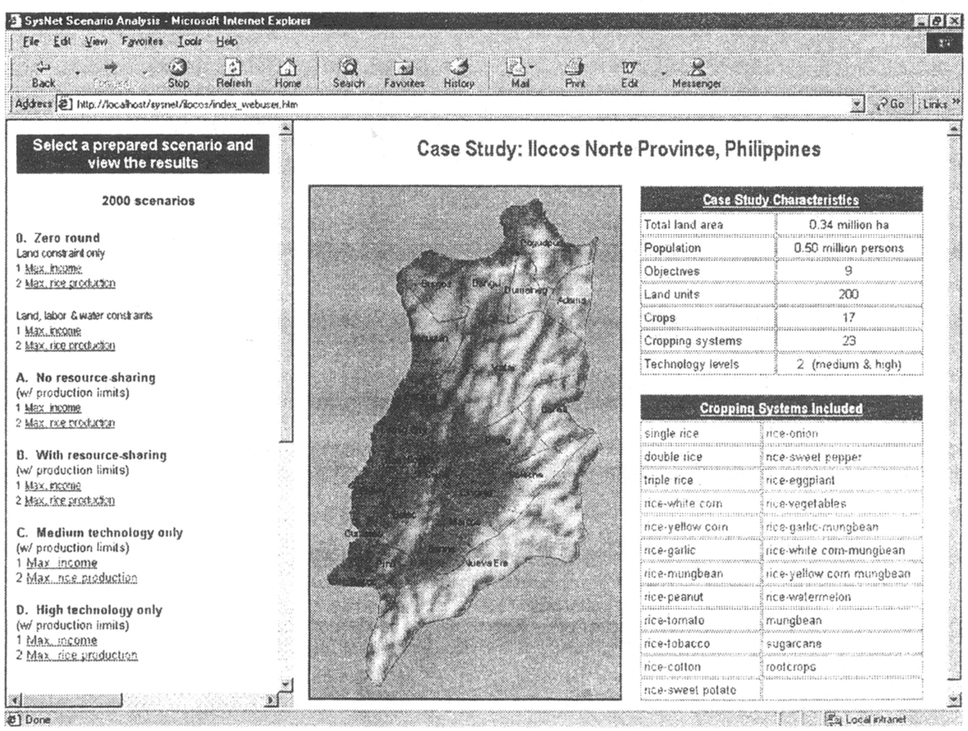


Fig. 4. The predefined scenario section for the Ilocos Norte case study.

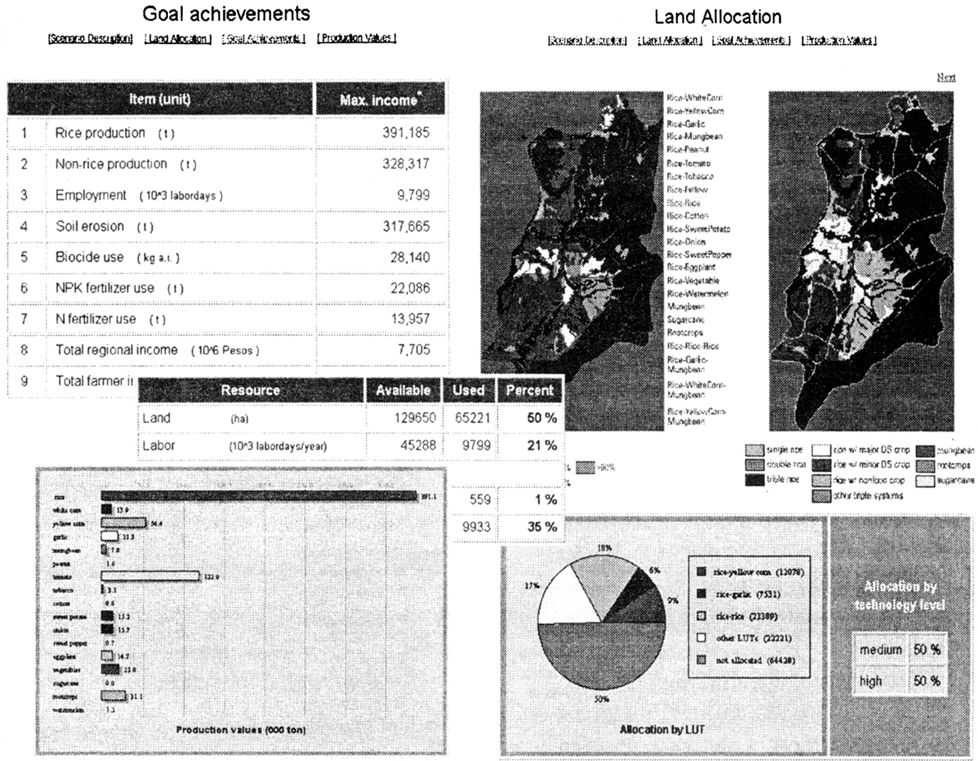


Fig. 5. Sample output of optimization runs: "Goal achievements," "Land allocation," and "Production values" sections.

mation on the objective function, constraints, and optimization settings used in the optimization. "Land allocation" shows the spatial distribution as well as the share of each land use type in the total land allocated.

The map on the left shows the distribution of a cropping/production system in each land unit (as % of available land), while the map on the right shows the combined map showing the dominant system per land unit. The "Production values" section displays the amount of production per crop/product resulting from the scenario run.

Model run

If you are interested in a particular scenario that is not in the scenario list, you may submit a new run. To do this, scroll down to the end of the scenario list frame and click on the link "Request a Model Run."

This will open up a new window where you can set the objective to optimize by selecting from a drop-down list, select the constraints to be imposed, and set other optimization settings.

When the necessary options have been selected, click on the "Submit" button. If you are running the model on your computer (i.e., not via the Internet), be sure that you have a licensed copy of XPRESS-MP and that the "dongle" (hardware key) is inserted in the LPT1 port.

After the model is run, the right-hand portion of the screen will show the log. It will indicate whether the set of options you are running has a feasible solution ("Optimal solution found") or not ("Infeasible"). Also, if Console XPRESS is not properly installed or the dongle is not in place, you will get error messages in the model log.

When an optimal solution is found, you can view the results by going back to the predefined scenarios window and clicking on Last Run (in the "Latest scenario runs requested" section). The outputs generated are as in Figure 4.

The interfaces for the two case regions are somewhat different in this aspect since different characteristics were considered important in each region. The model input form for the case studies is discussed below in separate sections.

Ilocos Norte Province

Figure 6 shows the whole list of settings that may be changed and/or selected when making a new model run.

Objective function

You can select from five objective functions: maximize rice production, minimize labor use, maximize employment in agriculture, minimize fertilizer use, and maximize income.

Optimization settings

The optimization can be performed for the whole province (default) or for a certain group of municipalities. To select a municipality, put a check on the box beside the municipality name.

Note, however, that the study is meant for the regional level. Although optimizations can be done for each municipality, the current model is not detailed enough to produce reliable results at the level of a municipality.

You can select from two technology levels: medium, or the current average farmers' practice, or high, the current best farmers' practice (Lansigan et al 2000). You can set the model to use either of the technology levels or both.

Resources such as land, labor, and water are calculated for both 2000 (current situation) and 2010 (future). You may choose to optimize for either year.

Resource constraints

The resource constraints included are agricultural land, labor, and irrigation water.

For labor, there are three options to choose from: no labor sharing (labor cannot move from one municipality to another), with sharing among neighboring municipalities (labor can move freely from one municipality to neighboring municipalities), and with sharing among all municipalities (labor can move freely within the province). The default values are estimated to be 45% of the rural population. The values can be viewed or changed by clicking on the View/edit values button.

For irrigation water, there are two options: no water sharing (water cannot move from one land unit to the next) and with water sharing (water can be shared among land units belonging to the same irrigation system).

Goal restrictions

Lower and/or upper bounds for the goals can be imposed. Check the corresponding box where you

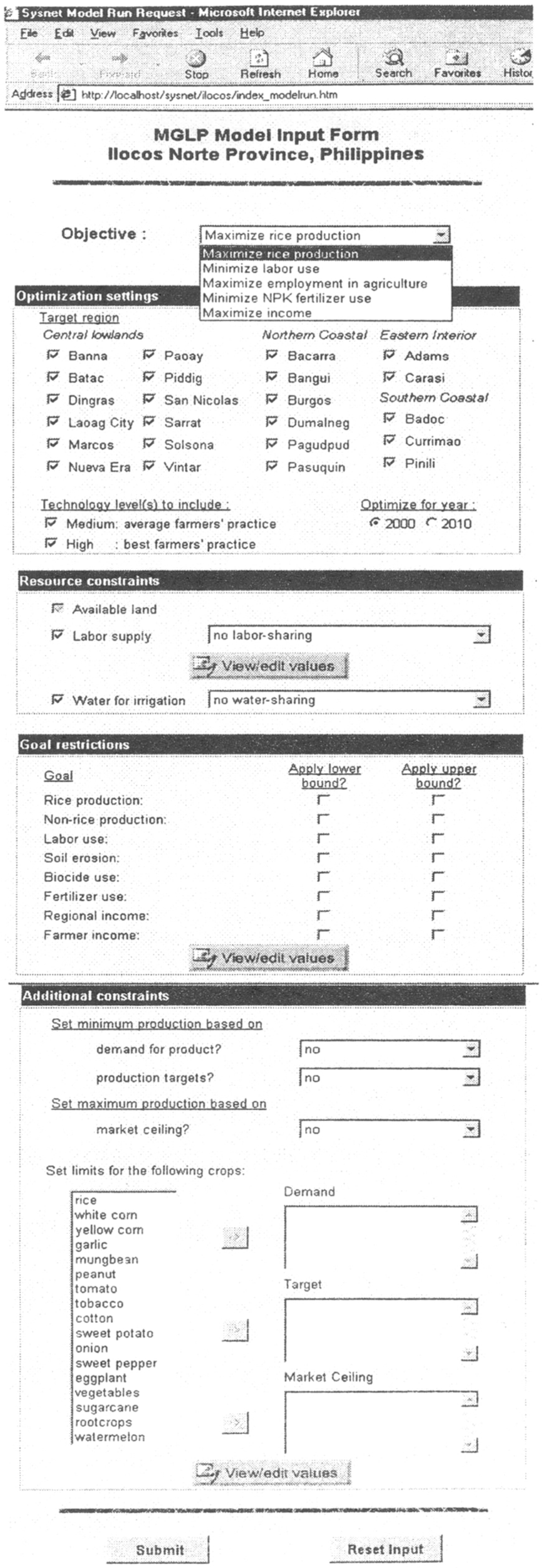


Fig. 6. The model run request form for the Ilocos Norte case study.

want to impose goal limits. Click on the View/edit values button to see or change the default bounds.

Additional constraints

Limits on production may also be set based on local product demand, production targets, and market ceilings. The constraints could be imposed at the provincial level or at the municipal level.

To identify the crops to include, click on the crop (you can use Ctrl+Click for multiple selections) and click on the arrow corresponding to the box.

The default values can be viewed and changed using the View/edit values button.

Kedah-Perlis Region

Figure 7 shows the whole list of settings that can be changed and/or selected when making a new model run.

Objective

You can select to optimize from 12 objective functions: maximize rice production, maximize annual non-rice production, maximize oilpalm production, maximize rubber production, maximize income, minimize labor use, minimize pesticide use, minimize fertilizer use, minimize water use, maximize labor efficiency, maximize water use efficiency, and minimize soil erosion

Optimization settings

The whole region (default) can be used as the target for optimization or only a certain group of districts can be included in the analysis. To select a district, put a check on the box beside the district name.

Resources such as land, labor, and water are calculated for three years: the current situation (2000) and future (2010 and 2020). You can select for which year the model will be optimized.

You can select from three technology levels (Ismail et al 2000). You can set the model to use any of the three. In addition, you can specify the proportion of the area to be allocated per technology level. If the total of the proportion does not equal 100%, the model will select the proportion that will result in the highest optimal value.

The MADA area (Muda Agricultural Development Authority) is currently being planted to rice only. There are three optional scenarios besides the current one for looking at what will happen if this area is opened up to other cropping systems: (1) rice-based, (2) all cropping systems except perennials, and (3) all cropping systems.

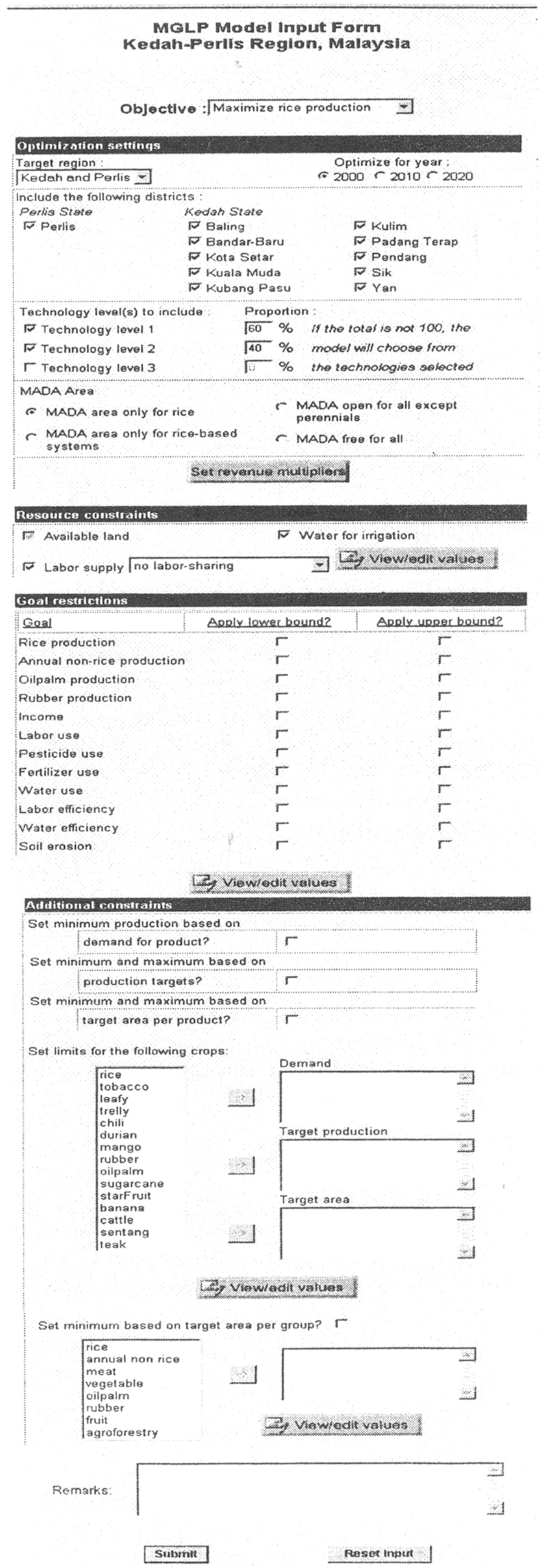


Fig. 7. The model run request form for the Kedah-Perlis case study.

Resource constraints

Agricultural land, labor, and irrigation water are the resource constraints included in the model.

There are three options for labor: no labor sharing (labor cannot move from one district to another), with sharing among neighboring districts (labor can move freely from one district to neighboring districts), and with sharing among all districts (labor can move freely within the region).

Goal restrictions

Similar to the Ilocos model, lower and/or upper bounds for the goals can be imposed. Check the corresponding box where you want to impose goal limits and click on the View/edit values button to see or change the default bounds.

Additional constraints

Limits on production and area can also be set based on local product demand and production and area targets.

To identify the crops to include, click on the crop (you can use Ctrl+Click for multiple selections) and click on the arrow corresponding to the box.

The default values can be viewed and changed using the View/edit values button.

Model comparison

In addition to doing new model runs, the system can compare two model runs. This facilitates the calculation of trade-offs between two runs.

To compare model runs, go to the end of the predefined scenarios list and click on Compare model runs (Fig. 8). This will open a new screen where you can select two runs. After selecting, click on the Compare button. Figure 9 shows some of the outputs of model comparisons.

Getting started

You can access the SysNet MGLP interface in two ways: remotely via the Internet or using the system installed on your computer.

To install the system on your PC, follow the installation instructions below. To use the Internet, proceed to the section on "Accessing the MGLP interface."

Installation instructions

The SysNet Toolkit contains installation routines for different tools for land use analysis including a guided set of steps for installing the SysNet MGLP user interface and its component software. You can also install these manually. If you are following the guided installation (recommended), proceed to section A or go to section B. Section C indicates the configuration settings of the different software and your browser to make the system function properly.

A. Guided installation

Insert the SysNet Toolkit CD-ROM into your CD-ROM drive. A menu will appear showing the different SysNet Tools that you can install. Select the option "Web-based inter face" under the MGLP models section. This will bring up another menu listing the different software that needs to be installed (Fig. 10).

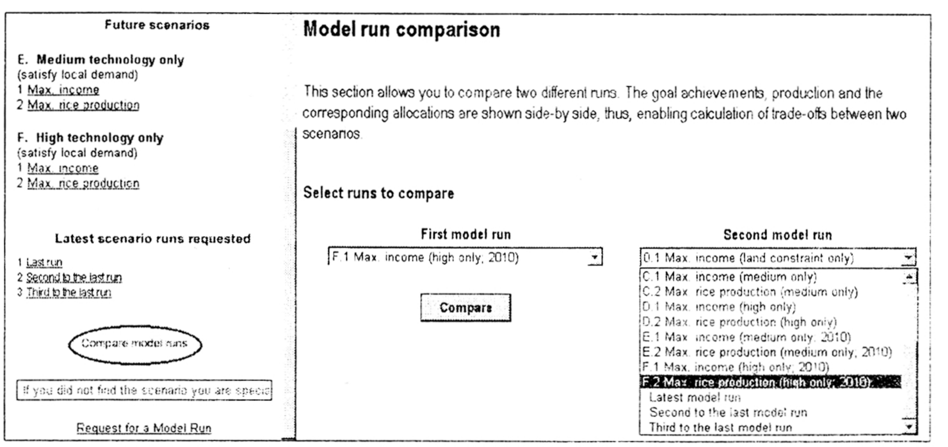
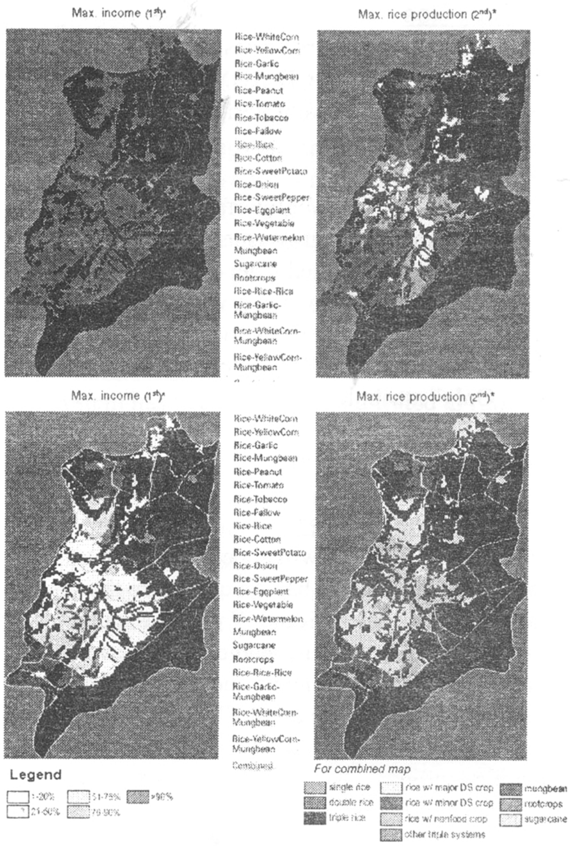


Fig. 8. Selecting model runs to compare.



	Item (unit)	Max. income (1st run)*	Max. rice production (2nd run)*
1	Rice production (t)	409,835	819,467
2	Non-rice production (t)	2,314,992	62,809
3	Employment (10^3 labordays)	14,304	16,729
4	Soil erosion (t)	439,835	464,784
5	Biocide use (kg a.i.)	159,516	25,980
6	NPK fertilizer use (t)	41,750	31,982
7	N fertilizer use (t)	21,170	21,600
8	Total regional income (10^6 Pesos)	40,608	4,996
9	Total farmer income (10^6 Pesos)	40,917	4,880

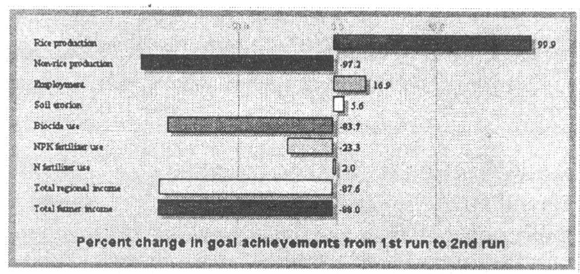


Fig. 9. Outputs of model comparison.

1. Xitami Web Server

Click on Xitami Web Server and another menu will appear. Select the default options and install the files in the *C:\XITAMI* subdirectory of your hard disk. You must enter a username and password (your choice). Note that the username and password are case-sensitive.

2. XPRESS-MP

XPRESS-MP is a commercial software and hence is not included in the installation CD-ROM. If you have a licensed copy (a dongle or hardware key is required to run this software), exit the SysNet Toolkit and put your XPRESS-MP CD-ROM into your CD-ROM drive. The Welcome screen containing a menu of available options will appear. Click on Install Products and then Console XPRESS to start the installation. Be sure to change the destination folder to *C:\XITAMI\CGI-BIN*. Follow the instructions on the screen to complete the installation.

If you do not have a licensed copy of XPRESS-MP, you can only view existing runs (predefined scenarios) and not make new model runs.

3. ActivePerl

Just click on *ActivePerl* and install it in any subdirectory of your hard disk.

4. 2GIF

Click on *2GIF* and be sure to change the destination subdirectory to *C:\XITAMI\CGI-BIN*.

5. Copy other files

Click on this to copy required files including Perl scripts needed to run model comparisons and view results of predefined scenario runs.

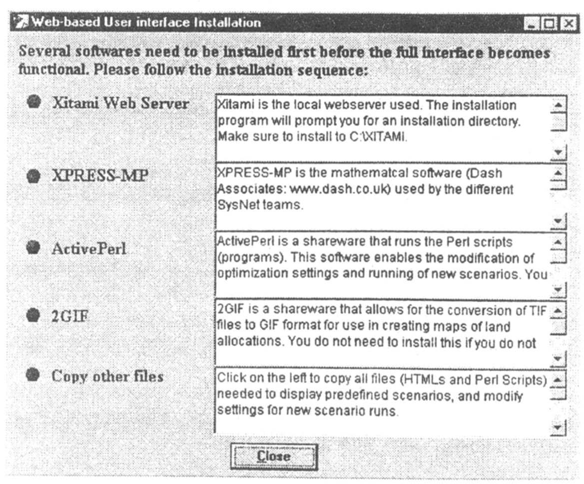


Fig. 10. The Web-based user interface installation menu.

B. Manual installation

1. Xitami Web Server installation procedure

Insert the SysNet Toolkit CD-ROM into your CD-ROM drive. Use Windows Explorer and go to the *SysNetToolkit\WebInterface* subdirectory. Double-click on the file *bw3224d4.exe*. The installation program will prompt you for an installation directory. Make sure to install *Xitami* in the default directory *C:\XITAMI* (the user interface is set to read the server in the C:\ directory). The set-up procedure will automatically build a program group and icons to run *Xitami*. To configure the server, see section C.1.

2. Console XPRESS installation procedure

If you have a licensed copy of XPRESS-MP, see Section A.2.

3. ActivePerl installation procedure

Go to the *SysNetToolkit\WebInterface* subdirectory, then double-click on the file *ActivePerl_i522e.exe* to install *ActivePerl*. Just follow the installation procedure.

4. 2GIF installation procedure

Go to the *SysNetToolkit\WebInterface* subdirectory, then run *setup.exe* to start the installation. Be sure to change the destination path to *C:\XITAMI\CGI-BIN*. Just follow the installation procedure.

The *2GIF* software included in the installation CD is a shareware version. If you are going to make a new run, the resulting maps will have a URL written on the upper left portion. If you do new model runs and do not want the URL to appear, you can register your copy at the URL http://www.fcoder.com. Fcoder will provide you with a new version of *2GIF* for a nominal fee.

5. Copy files

Copy all files and subdirectories in the following subdirectories from the CD-ROM to your hard disk:

from SysNetToolkit\WebInterface\cgi-bin
to c:\xitami\cgi-bin
and
from SysNetToolkit\WebInterface\webpages\sysnet
to c:\xitami\webpages\sysnet

When files are copied from a CD-ROM, they become "read-only." Go to *every subdirectory* from *c:\xitami\cgi-bin* and *c:\xitami\webpages\sysnet* and select all files, click on Properties, and remove the "Read Only" attribute.

C. Configuration settings

1. Xitami Web Server

Run Xitami. An *X* icon will appear in the lower right-hand part of your status bar. To configure the server, click on this and select Setup. You will then be prompted to enter your username and password. Please note that the username and password are case-sensitive. This will open up the Web-based configuration file. Select Configuration and click on CGI (encircled in Fig. 11). Change the Timeout for CGI Programs to 600 seconds.

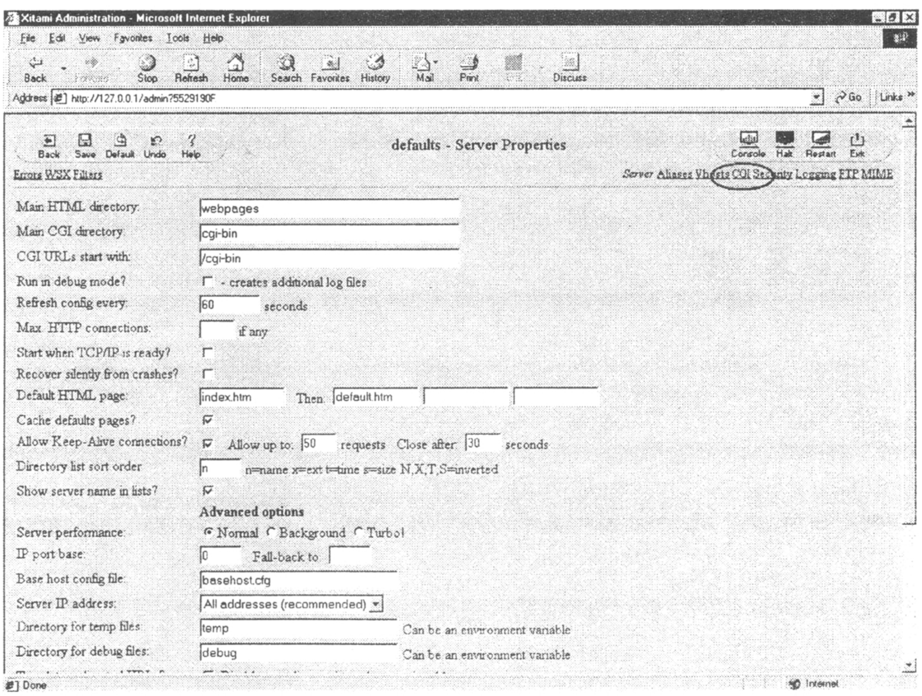


Fig. 11. The Xitami server properties screen.

2. Screen display
The optimization results (tables, graphs, and maps) are configured for a screen area of 1024 by 768. If your screen settings have a lower resolution, you will not see the whole maps and tables on the screen and you would have to use the scroll buttons to see other parts of the screen. If you would like to change your screen settings, go to Control Panel (hit the Start key, then Settings) and select Display. Select the Settings tab and modify the screen area accordingly.

3. Internet browser
The system has been designed and tested to run on Internet Explorer 5. If you have another browser or a lower version of Internet Explorer, you may experience some problems in viewing and making an optimization run. Launch Internet Explorer 5 and go to Tools, then Internet Options. In the Temporary Internet Files section, click on Settings. Check for newer version of stored pages should be set to Every visit to the page. Otherwise, you would have to click on the Refresh button every time you make a new run.

Accessing the MGLP interface

To access the interface via a local server, first run the *Xitami* server (click on the Start button, then select Programs, then Internet Tools, then Xitami).

Launch Internet Explorer 5 and point your browser to the URL
http://localhost/sysnet/sysnetMGLP.htm
or
http://127.0.0.1/sysnet/sysnetMGLP.htm

To access the interface via the Internet, you do not need to install anything on your computer. Just launch Internet Explorer 5 and point your browser to the URL http://irriwww.irri.cgiar.org/sysnet/mglp/SysNetMGLP.htm

The welcome screen will appear (Fig. 12). You can select from the two case studies available: Ilocos Norte Province, Philippines, or Kedah-Perlis Region, Malaysia.

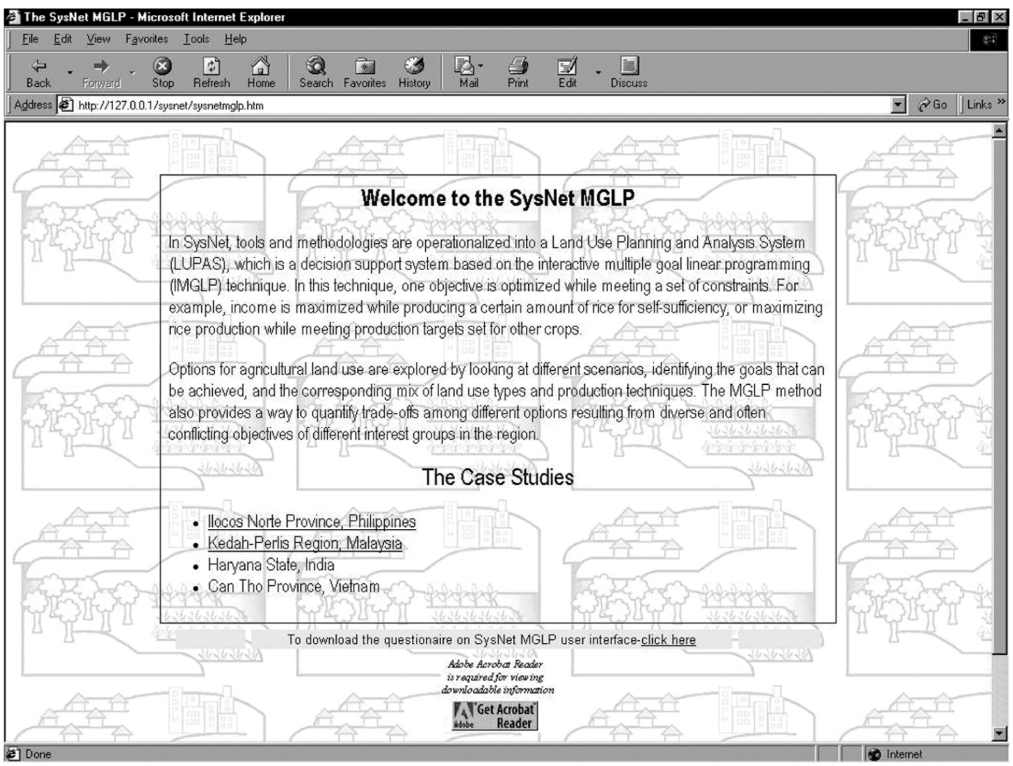


Fig. 12. The SysNet MGLP welcome screen.

References

Dash Associates. 1999. XPRESS-MP user guide and reference manual. Blisworth House, Blisworth, Northants (UK): Dash Associates Ltd. 290 p.

De Haan J, Van Ittersum M, De Ridder N (eds.). 2000. Introductory module quantitative analysis of agro-ecosystems (QUASI-Intro). Wageningen University and Research Centre. 343 p.

De Wit CT, Van Keulen H, Seligman SG, Spharim I. 1988. Application of interactive multiple goal linear programming techniques for analysis and planning of regional agricultural development. Agric. Syst. 26:211-230.

Ismail AB, Tawang A, Malaysian SysNet Team. 2000. Kedah-Perlis Region case study: income from agricultural activities versus rice production. In: RP Roetter, H Van Keulen, HH van Laar, eds. Synthesis of methodology development and case studies. SysNet Reseach Paper Series No. 3. IRRI, Los Baños, Philippines. p 19-29.

Lansigan FP, Pascual CM, Francisco SR, Laborte AG, Lucas MP, Coladilla JO, Dimasuay LB, San Pedro JC, Utrera RT, Marcos TF, Hoanh CT, Roetter RP, Cruz RT, Obien SR. 2000. Exploring agricultural land use options for Ilocos Norte, Philippines. In: RP Roetter, H Van Keulen, AG Laborte, CT Hoanh, HH van Laar, eds. Systems research for optimizing future land use in South and Southeast Asia. SysNet Research Paper Series No. 2. IRRI, Los Baños, Philippines. p 91-102.

Roetter R, Hoanh CT. 1999. Exploring land use options under multiple goals in support of natural resource management at sub-national level. In: NN Kinh, PS Teng, CT Hoanh, JC Castella, eds. Towards an ecoregional approach for natural resource management in the Red River Basin of Vietnam. Ministry of Agriculture and Rural Development, Hanoi, Vietnam, and International Rice Reseach Institute, Los Baños, Philippines. p 29-57.

Roetter RP, Laborte AG. 2000. Stakeholder meetings in the Philippines, Malaysia and Vietnam. In: RP Roetter, H Van Keulen, HH Van Laar. Synthesis of methodology development and case studies. SysNet Reseach Paper Series No. 3. IRRI, Los Baños, Philippines. p 69-76.

Annex 1. The SysNet Toolkit for land use analysis in Asia.

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SysNet has developed tools and methodologies for exploring agricultural land use options in four case study regions in Asia. These tools were operationalized into the so-called land use planning and analysis system (LUPAS), which has four components: resource balance and land evaluation, yield estimation, input-output estimation, and multiple goal linear programming (MGLP).

For each component, various tools and techniques were used. GIS (geographic information systems) and expert systems were used in the resource balance and land evaluation component; crop growth simulation models were applied in yield estimation; technical coefficient generators (TCGs) were used to calculate input-output relationships of production activities; and linear programming models were developed to generate land use options for the case study regions.

The SysNet Toolkit is a CD-ROM that puts together the different tools developed and used by the different SysNet teams. This CD-ROM is menu-driven (Fig. 1) and contains each tool's installation routine and technical documents describing the tool.

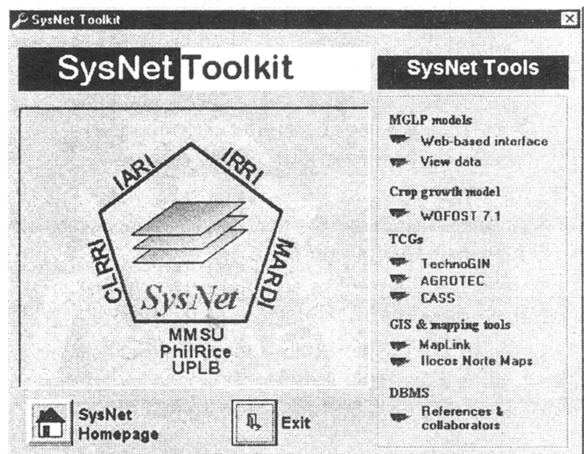

Fig. 1. The SysNet Toolkit main menu showing the different tools for land use planning developed by SysNet.

The tools

MGLP models

At the core of LUPAS is the MGLP model, which is the integrating tool that is used to generate land use options by optimizing an objective (e.g., maximize income) subject to certain constraints (e.g., available resources, production targets).

The models programmed in XPRESS-MP (Dash Associates 1999) along with the data used in the optimization (in Excel format) can be viewed in this section (e.g., available resources and input-output data) for each case study.

For two case study regions, Ilocos Norte Province in the Philippines and the Kedah-Perlis Region in Malaysia, a Web-based user interface was developed. This interface allows users to make an optimization run by selecting an objective and the constraints to impose. The model will optimize, based on the selections, and give output results in tabular, map, and graphical format.

Crop growth simulation model

WOFOST is a computer model that simulates the growth and production of annual field crops. A graphical user interface facilitates the selection of production level, input parameters (e.g., crop, soil, weather data), and output options (Boogaard et al 1998).

Technical coefficient generators (TCGs)

Three different TCGs were developed:

- TechnoGIN, developed for Ilocos Norte Province (Philippines), optimizes fertilizer use and the use of cost models to calculate fertilizer requirements (Ponsioen 2000);
- AGROTEC was developed for Can Tho Province (Vietnam) to describe land use systems, considering crop rotations and flooding as a specific factor that hampers crop production (Jansen 2000); and
- CASS calculates the resource requirement, environmental impact assessment, and cost-benefit analysis of agricultural production systems in Haryana State, India (not documented).

GIS and mapping tools

In SysNet, GIS is used as a supporting tool for resource assessment, delineation of land units, and mapping of land use options and goal achievements. MapLink is a tool that facilitates the linking of data in Excel files to a GIS (Laborte et al 1999).

DBMS (database management system)

The SysNet DBMS has two sections, the references and collaborators databases, containing, respectively, literature relating to agricultural land use and contact addresses of SysNet team members and collaborators (Lopez and Laborte 2000).

References

Boogaard HL, Van Diepen CA, Roetter RP, Cabrera JMCA, Van Laar HH. 1998. User's guide for the WOFOST 7.1 crop growth simulation model and WOFOST Control Center 1.51. DLO-Winand Staring Centre, Wageningen, The Netherlands, Technical Document 52. 144 p.

Dash Associates. 1999. XPRESS-MP reference manual release 11. Dash Associates Ltd., Blisworth House, Blisworth, Northants NN7 3BX, UK. 272 p.

Jansen DM. 2000. AGROTEC: Automated generation and representation of technical coefficients for analysis of land use options. In: RP Roetter, H Van Keulen, AG Laborte, CT Hoanh, HH Van Laar, eds. Systems research for optimizing future land use in South and Southeast Asia. International Rice Research Institute, Makati City, Philippines. p 153-164.

Laborte AG, Roetter RP, Hoanh CT. 1999. SysNet tools: The multiple goal linear programming (MGLP) model and MapLink. IRRI Technical Bulletin No. 6. International Rice Research Institute, Los Baños, Philippines. 31 p.

Lopez C, Laborte AG. 2000. SysNet DBMS user's guide. SysNet Project Technical Report.

Ponsioen T. 2000. TechnoGIN: technical coefficient generator for Ilocos Norte. SysNet Project Internal Report. (in prep.)

Source: Roetter RP, Van Keulen H, van Laar HH (eds). 2000. Synthesis of methodology development and case studies. SysNet Research Paper Series No. 3. IRRI, Los Baños, Philippines. p 83-85.

Annex 2. The XPRESS-MP program for Kedah-Perlis.

Optimization part (KedahP.mod)

```
SET CASE
SET CHECK
SET DOUBLE
SET NODYNINDEX
SET NOEXTSUB
SET FILLCHAR=' '
SET NOPAUSE
SET SAVE
SET TRUNCATE
SET UPDIR
SET NOWARN
SET ZTOLCM= .0001
!=========================================================================
! KedahPerlis - INTERACTIVE MULTIPLE GOAL LINEAR PROGRAMMING - Version 2.00
! For land use planning in Kedah-Perlis region, Malaysia
! Developed by IRRI & Malaysia SysNet Team
! Last updated:  17 May 2000
!=========================================================================

DEFINE
!     path is defined in the command line
      OptionsFile = 'mod_par.txt'

! ————————————————————————————————————
! INPUT PROBLEM DIMENSION
TABLES
   ItemNumber(14)

DISKDATA
   ItemNumber  = %path%\Input\ItemNumber.csv

ASSIGN
   NSetting    = ItemNumber(1)                   !No. of settings
   NDist       = ItemNumber(2)                   !No. of districts
   NAEco       = ItemNumber(3)                   !No. of agroecological units
   NDemarc     = ItemNumber(4)                   !No. of demarcations
   NLUT        = ItemNumber(5)                   !No. of land use types
   NTech       = ItemNumber(6)                   !No. of technology levels
   NProduct    = ItemNumber(7)                   !No. of products
   NGoal       = ItemNumber(8)                   !No. of goals
   NMonth      = ItemNumber(9)                   !No. of months
   NPGroup     = ItemNumber(10)                  !No. of product groups
   NPOrient    = ItemNumber(11)                  !No. of production orientation
   NConstraint = ItemNumber(12)                  !No. of constraints
   NYear       = ItemNumber(13)                  !No. of years
   NDAW        = ItemNumber(14)

! —————————————————————————————————————
! SET OPTIMIZATION OPTIONS

INDICES
   OptionsNdx(106)
   MultNdx(4)
```

```
DATA
   OptionsNdx ="Year","ObjFunc","Dist1","Dist2","Dist3","Dist4","Dist5","Dist6",&
        "Dist7","Dist8","Dist9","Dist10","Dist11","NDistSel","MADAArea","Labor",&
        "LaborSharing","Water","TechLev","Tech1P","Tech2P","Tech3P","LRiceBound",&
        "URiceBound","LNonRiceBound","UNonRiceBound","LOilplmBound","UOilplmBound",&
        "LRubberBound","URubberBound","LIncomeBound","UIncomeBound","LLaborBound",&
        "ULaborBound","LPestBound","UPestBound","LFertBound","UFertBound",&
        "LWaterUseBound","UWaterUseBound","LLaborEffBound","ULaborEffBound",&
        "LWaterEffBound","UWaterEffBound","LErosionBound","UErosionBound","Demand",&
        "Demand1","Demand2","Demand3","Demand4","Demand5","Demand6","Demand7","Demand8",&
        "Demand9","Demand10","Demand11","Demand12","Demand13","Demand14","Demand15",&
        "Demand16","PTargt","PTargt1","PTargt2","PTargt3","PTargt4","PTargt5","PTargt6",&
        "PTargt7","PTargt8","PTargt9","PTargt10","PTargt11","PTargt12","PTargt13",&
        "PTargt14","PTargt15","PTargt16","ATargt","ATargt1","ATargt2","ATargt3",&
        "ATargt4","ATargt5","ATargt6","ATargt7","ATargt8","ATargt9","ATargt10",&
        "ATargt11","ATargt12","ATargt13","ATargt14","ATargt15","ATargt16","GTargt",&
        "GTargt1","GTargt2","GTargt3","GTargt4","GTargt5","GTargt6","GTargt7","GTargt8"
  MultNdx = "Rice","Tobacco","Rubber","Oilpalm"

! ————————————————————————————————————
! LIST OF INDICES AND INPUTTING INDICE DATA FROM EXCEL FILE
INDICES
   byDist(NDist)              -m2        ! by district
   byAEco(NAEco)              -m2        ! by agro-ecoregion
   byDAW(NDAW)                -m5        ! by combination of D & A & W
   byLUT(NLUT)                -m2        ! by land use type
   byProduct(NProduct)        -m2        ! by product
   byPGroup(NPGroup)                     ! by product group
   byGoal(NGoal)              -m2        ! by goal
   byTech(NTech)              -m1        ! by technology level
   byMonth(NMonth)            -m3        ! by month
   byDemarc(NDemarc)          -m1        ! by water conditions
   by1Row(1)                             ! get data from Excel file in one row

DATA
   by1Row="1"

DISKDATA
   byDist      = %path%\Input\DistrictName.csv
   byAEco      = %path%\Input\AEcologicalName.csv
   byLUT       = %path%\Input\LandUseName.csv
   byProduct   = %path%\Input\ProductName.csv
   byPGroup    = %path%\Input\PGroupName.csv
   byGoal      = %path%\Input\GoalName.csv
   byTech      = %path%\Input\TechnologyName.csv
   byMonth     = %path%\Input\MonthName.csv
   byDemarc    = %path%\Input\DemarcName.csv
   byDAW       = %path%\Input\DAWCombination.csv


! ————————————————————————————————————
! INPUT OPTIMIZATION OPTIONS

TABLES
   Options(OptionsNdx)
   DistOpt(byDist)
   PrDemandOpt(byProduct)
   PrTargetPOpt(byProduct)
   PrTargetAOpt(byProduct)
   PrTargetAGrpOpt(byPGroup)
   RevenueMult(MultNdx)

DISKDATA -s
  Options = %OptionsFile%
  RevenueMult = %path%\Input\RevenueMult.txt
```

```
ASSIGN
  DistOpt(1)          = Options("Dist1")
  DistOpt(2)          = Options("Dist2")
  DistOpt(3)          = Options("Dist3")
  DistOpt(4)          = Options("Dist4")
  DistOpt(5)          = Options("Dist5")
  DistOpt(6)          = Options("Dist6")
  DistOpt(7)          = Options("Dist7")
  DistOpt(8)          = Options("Dist8")
  DistOpt(9)          = Options("Dist9")
  DistOpt(10)         = Options("Dist10")
  DistOpt(11)         = Options("Dist11")
  PrDemandOpt(1)      = Options("Demand1")
  PrDemandOpt(2)      = Options("Demand2")
  PrDemandOpt(3)      = Options("Demand3")
  PrDemandOpt(4)      = Options("Demand4")
  PrDemandOpt(5)      = Options("Demand5")
  PrDemandOpt(6)      = Options("Demand6")
  PrDemandOpt(7)      = Options("Demand7")
  PrDemandOpt(8)      = Options("Demand8")
  PrDemandOpt(9)      = Options("Demand9")
  PrDemandOpt(10)     = Options("Demand10")
  PrDemandOpt(11)     = Options("Demand11")
  PrDemandOpt(12)     = Options("Demand12")
  PrDemandOpt(13)     = Options("Demand13")
  PrDemandOpt(14)     = Options("Demand14")
  PrDemandOpt(15)     = Options("Demand15")
  PrDemandOpt(16)     = Options("Demand16")
  PrTargetPOpt(1)     = Options("PTargt1")
  PrTargetPOpt(2)     = Options("PTargt2")
  PrTargetPOpt(3)     = Options("PTargt3")
  PrTargetPOpt(4)     = Options("PTargt4")
  PrTargetPOpt(5)     = Options("PTargt5")
  PrTargetPOpt(6)     = Options("PTargt6")
  PrTargetPOpt(7)     = Options("PTargt7")
  PrTargetPOpt(8)     = Options("PTargt8")
  PrTargetPOpt(9)     = Options("PTargt9")
  PrTargetPOpt(10)    = Options("PTargt10")
  PrTargetPOpt(11)    = Options("PTargt11")
  PrTargetPOpt(12)    = Options("PTargt12")
  PrTargetPOpt(13)    = Options("PTargt13")
  PrTargetPOpt(14)    = Options("PTargt14")
  PrTargetPOpt(15)    = Options("PTargt15")
  PrTargetPOpt(16)    = Options("PTargt16")
  PrTargetAOpt(1)     = Options("ATargt1")
  PrTargetAOpt(2)     = Options("ATargt2")
  PrTargetAOpt(3)     = Options("ATargt3")
  PrTargetAOpt(4)     = Options("ATargt4")
  PrTargetAOpt(5)     = Options("ATargt5")
  PrTargetAOpt(6)     = Options("ATargt6")
  PrTargetAOpt(7)     = Options("ATargt7")
  PrTargetAOpt(8)     = Options("ATargt8")
  PrTargetAOpt(9)     = Options("ATargt9")
  PrTargetAOpt(10)    = Options("ATargt10")
  PrTargetAOpt(11)    = Options("ATargt11")
  PrTargetAOpt(12)    = Options("ATargt12")
  PrTargetAOpt(13)    = Options("ATargt13")
  PrTargetAOpt(14)    = Options("ATargt14")
  PrTargetAOpt(15)    = Options("ATargt15")
  PrTargetAOpt(16)    = Options("ATargt16")
  PrTargetAGrpOpt(1)  = Options("GTargt1")
  PrTargetAGrpOpt(2)  = Options("GTargt2")
  PrTargetAGrpOpt(3)  = Options("GTargt3")
  PrTargetAGrpOpt(4)  = Options("GTargt4")
  PrTargetAGrpOpt(5)  = Options("GTargt5")
  PrTargetAGrpOpt(6)  = Options("GTargt6")
  PrTargetAGrpOpt(7)  = Options("GTargt7")
```

```
  PrTargetAGrpOpt(8) = Options("GTargt8")

! ————————————————————————————————————————
! LIST OF INPUT DATA TABLES
TABLES

   DinDAW(NDAW)                              ! District in NDAW combinations
   AinDAW(NDAW)                              ! AEcological zone in NDAW combinations
   WinDAW(NDAW)                              ! Demarc conditions in NDAW combinations
   LutTPromi(NDAW,byLUT,byTech)              ! Promising land use & technology in each
                                             ! ecoregion-district combination
                                             ! =1: promising  =0: not promising
   LutPromi1(byAEco,byDemarc,byTech,byLUT)   ! Promising lut in each ecoregion,
                                             ! water combination MADA scenario 1
   LutPromi2(byAEco,byDemarc,byTech,byLUT)   ! Promising lut in each ecoregion,
                                             ! water combination MADA scenario 2
   LutPromi3(byAEco,byDemarc,byTech,byLUT)   ! Promising lut in each ecoregion,
                                             ! water combination MADA scenario 3
   LutPromi4(byAEco,byDemarc,byTech,byLUT)   ! Promising lut in each ecoregion,
                                             ! water combination MADA scenario 4
   AvaiArea(NDAW)                            ! Available land resource
   AvaiArea2000(NDAW)                        ! Available land resource for year 2000
   AvaiArea2010(NDAW)                        ! Available land resource for year 2010
   AvaiArea2020(NDAW)                        ! Available land resource for year 2020
   AvaiIrri(byDemarc,byMonth)                ! Available irrigation water resource
   AvaiIrri2000(byDemarc,byMonth)            ! Available irrigation water resource(2000)
   AvaiIrri2010(byDemarc,byMonth)            ! Available irrigation water resource(2010)
   AvaiLabor(byDist)                         ! Available labor-force
   AvaiLabor2000(byDist)                     ! Available labor-force for year 2000
   AvaiLabor2010(byDist)                     ! Available labor-force for year 2010
   AvaiLabor2020(byDist)                     ! Available labor-force for year 2020
   LaborSharing(NDist,NDist)                 ! Labor sharing matrix
   Yield(byLUT,byAEco,byDemarc,byTech,byProduct)       ! Yield
   Pesticide(byLUT,byAEco,byDemarc,byTech,byProduct)   ! Pesticide
   Fertilizer(byLUT,byAEco,byDemarc,byTech,byProduct)  ! Fertilizer
   Revenue(byLUT,byAEco,byDemarc,byTech,byProduct)     ! Revenue
   LaborNeed(byLUT,byAEco,byDemarc,byTech,byMonth)     ! Labor needs
   AnnuLaborNeed(NDAW,byLUT,byTech)                    ! Annual labor need
   RatioELabor(byLUT,byAEco,byDemarc,byTech,by1Row)    ! Ratio for Income over Labor
   LaborEff(NDAW,byLUT,byTech)                         ! Labor efficiency
   WaterNeed(byLUT,byAEco,byDemarc,byTech,byMonth)     ! Water needs
   AnnuWaterNeed(NDAW,byLUT,byTech)                    ! Annual water use
   AnnuIrriNeed(NDAW,byLUT,byTech)                     ! Annual irrigation need
   RatioEWater(byLUT,byAEco,byDemarc,byTech,by1Row)    ! Ratio for Income over Water used
   WaterEff(NDAW,byLUT,byTech)                         ! Water efficiency
   LutTIncome(NDAW,byLUT,byTech)                       ! Income by Lut & Tech
   LutTPesticide(NDAW,byLUT,byTech)                    ! Lut-T pesticide
   LutTFertilizer(NDAW,byLUT,byTech)                   ! Lut-T fertilizer
   SoilEro(NDAW,byLUT,byTech)
   TotSoilEro(byLUT,byAEco,byDemarc,byTech,by1Row)     ! Total soil erosion
   LutProdYield(NDAW,byLUT,byTech,byProduct) ! Total yield by LUT & product
   LutGroupYield(NDAW,byLUT,byTech,byPGroup) ! Total yield by LUT & product group
   PPGroup(byPGroup,byProduct)               ! Relation bet. product groups & products
   LutPRelation(byLUT,byProduct)             ! Relation between LUT & products
   LowBound(byGoal)                          ! Low bound of goals
   UpperBound(byGoal)                        ! Upper bound of goals
   Demand(byDist,byProduct)                  ! Demand for district consumption
   Demand2000(byDist,byProduct)              ! Demand for district consumption (2000)
   Demand2010(byDist,byProduct)              ! Demand for district consumption (2010)
   Demand2020(byDist,byProduct)              ! Demand for district consumption (2020)
   RegionalDemand(byProduct)                 ! Demand for regional consumption
   UTargetHa(byProduct)                      ! Area target by product
   UTargetHa2000(byProduct)                  ! Upper bound of area target (2000)
   UTargetHa2010(byProduct)                  ! Upper bound of area target (2010)
   UTargetHa2020(byProduct)                  ! Upper bound of area target (2020)
   LTargetHa(byProduct)                      ! Lower bound of area target
   LTargetHa2000(byProduct)                  ! Lower bound of area target (2000)
   LTargetHa2010(byProduct)                  ! Lower bound of area target (2010)
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   LTargetHa2020(byProduct)                ! Lower bound of area target (2020)
   UTargetTon(byProduct)                   ! Upper bound of production target
   UTargetTon2000(byProduct)               ! Upper bound of production target (2000)
   UTargetTon2010(byProduct)               ! Upper bound of production target (2010)
   UTargetTon2020(byProduct)               ! Upper bound of production target (2020)
   LTargetTon(byProduct)                   ! Lower bound of production target
   LTargetTon2000(byProduct)               ! Lower bound of production target (2000)
   LTargetTon2010(byProduct)               ! Lower bound of production target (2010)
   LTargetTon2020(byProduct)               ! Lower bound of production target (2020)
   TargetHaGroup(byPGroup)                 ! Area target by product group
   TargetHaGroup2000(byPGroup)             ! Area target by product group (2000)
   TargetHaGroup2010(byPGroup)             ! Area target by product group (2010)
   TargetHaGroup2020(byPGroup)             ! Area target by product group (2020)

! INPUT DATA FROM EXCEL FILES

DISKDATA

   AvaiArea2000 = %path%\Input\AvaiArea2000.csv
   AvaiArea2010 = %path%\Input\AvaiArea2010.csv
   AvaiArea2020 = %path%\Input\AvaiArea2020.csv
   AvaiIrri2000 = %path%\Input\AvaiIrri2000.csv
   AvaiIrri2010 = %path%\Input\AvaiIrri2010.csv
   AvaiLabor2000= %path%\Input\AvaiLabor2000.txt
   AvaiLabor2010= %path%\Input\AvaiLabor2010.txt
   AvaiLabor2020= %path%\Input\AvaiLabor2020.txt
   LaborSharing = %path%\Input\LaborSharing.csv
   DinDAW       = %path%\Input\DinDAW.csv
   AinDAW       = %path%\Input\AinDAW.csv
   WinDAW       = %path%\Input\WinDAW.csv
   LutPromi1    = %path%\Input\LutPromising1.csv
   LutPromi2    = %path%\Input\LutPromising2.csv
   LutPromi3    = %path%\Input\LutPromising3.csv
   LutPromi4    = %path%\Input\LutPromising4.csv
   Yield        = %path%\Input\Yield.csv
   Revenue      = %path%\Input\Revenue.csv
   Pesticide    = %path%\Input\Pesticide.csv
   Fertilizer   = %path%\Input\Fertilizer.csv
   LaborNeed    = %path%\Input\LaborNeed.csv
   WaterNeed    = %path%\Input\WaterNeed.csv
   RatioELabor  = %path%\Input\RatioELabor.csv
   RatioEWater  = %path%\Input\RatioEWater.csv
   TotSoilEro   = %path%\Input\TotSoilEro.csv
   PPGroup      = %path%\Input\PPGroup.csv
   LutPRelation = %path%\Input\LutPRelation.csv
   LowBound     = %path%\Input\GoalLBound.txt
   UpperBound   = %path%\Input\GoalUBound.txt
   Demand2000       = %path%\Input\Demand2000.txt
   Demand2010       = %path%\Input\Demand2010.txt
   Demand2020       = %path%\Input\Demand2020.txt
   UTargetHa2000    = %path%\Input\UTargetHa2000.txt
   UTargetHa2010    = %path%\Input\UTargetHa2010.txt
   UTargetHa2020    = %path%\Input\UTargetHa2020.txt
   LTargetHa2000    = %path%\Input\LTargetHa2000.txt
   LTargetHa2010    = %path%\Input\LTargetHa2010.txt
   LTargetHa2020    = %path%\Input\LTargetHa2020.txt
   TargetHaGroup2000= %path%\Input\TargetHaGroup2000.txt
   TargetHaGroup2010= %path%\Input\TargetHaGroup2010.txt
   TargetHaGroup2020= %path%\Input\TargetHaGroup2020.txt
   UTargetTon2000    = %path%\Input\UTargetTon2000.txt
   UTargetTon2010    = %path%\Input\UTargetTon2010.txt
   UTargetTon2020    = %path%\Input\UTargetTon2020.txt
   LTargetTon2000    = %path%\Input\LTargetTon2000.txt
   LTargetTon2010    = %path%\Input\LTargetTon2010.txt
   LTargetTon2020    = %path%\Input\LTargetTon2020.txt
```

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! ASSIGN DATA FROM TEMPORARY ARRAYS TO TABLES
ASSIGN

IF Options("MADAArea") = 1
   FOR (daw=1:NDAW,lut=byLUT,t=byTech): LutTPromi(daw,lut,t) = &
      LutPromi1(AinDAW(daw),WinDAW(daw),t,lut)
ELSE
   IF Options("MADAArea") = 2
      FOR (daw=1:NDAW,lut=byLUT,t=byTech): LutTPromi(daw,lut,t) = &
         LutPromi2(AinDAW(daw),WinDAW(daw),t,lut)
   ELSE
      IF Options("MADAArea") = 3
         FOR (daw=1:NDAW,lut=byLUT,t=byTech): LutTPromi(daw,lut,t) = &
             LutPromi3(AinDAW(daw),WinDAW(daw),t,lut)
      ELSE
         IF Options("MADAArea") = 4
              FOR (daw=1:NDAW,lut=byLUT,t=byTech): LutTPromi(daw,lut,t) = &
                 LutPromi4(AinDAW(daw),WinDAW(daw),t,lut)
          ENDIF
      ENDIF
   ENDIF
ENDIF
   IF Options("TechLev") <> 7
      IF Options("TechLev") = 1
         FOR (daw=1:NDAW,lut=byLUT,t=1:NTech|t<>1): LutTPromi(daw,lut,t) = 0
      ELSE
         IF Options("TechLev") = 2
            FOR (daw=1:NDAW,lut=byLUT,t=1:NTech|t<>2): LutTPromi(daw,lut,t) = 0
         ELSE
            IF Options("TechLev") = 3
               FOR (daw=1:NDAW,lut=byLUT,t=1:NTech|t<>3): LutTPromi(daw,lut,t) = 0
            ELSE
               IF Options("TechLev") = 4
                  FOR (daw=1:NDAW,lut=byLUT,t=3): LutTPromi(daw,lut,t) = 0
               ELSE
                  IF Options("TechLev") = 5
                     FOR (daw=1:NDAW,lut=byLUT,t=1): LutTPromi(daw,lut,t) = 0
                  ELSE
                     FOR (daw=1:NDAW,lut=byLUT,t=2): LutTPromi(daw,lut,t) = 0
                  ENDIF
               ENDIF
            ENDIF
         ENDIF
       ENDIF
   ENDIF
   IF Options("Year") = 2000
      FOR(daw=1:NDAW): AvaiArea(daw) = AvaiArea2000(daw)
      FOR(w=byDemarc,m=byMonth): AvaiIrri(w,m) = AvaiIrri2000(w,m)
      FOR(d=byDist): AvaiLabor(d) = AvaiLabor2000(d)
      TotalAvaiIrri = 3512000
      FOR(d=byDist,p=byProduct): Demand(d,p) = Demand2000(d,p)
      FOR(p=byProduct): LTargetHa(p) = LTargetHa2000(p)
      FOR(p=byProduct): UTargetHa(p) = UTargetHa2000(p)
      FOR(p=byProduct): LTargetTon(p) = LTargetTon2000(p)
      FOR(p=byProduct): UTargetTon(p) = UTargetTon2000(p)
      FOR(g=byPGroup): TargetHaGroup(g) = TargetHaGroup2000(g)
   ELSE
      IF Options("Year") = 2010
         FOR(daw=1:NDAW): AvaiArea(daw) = AvaiArea2010(daw)
         FOR(w=byDemarc,m=byMonth): AvaiIrri(w,m) = AvaiIrri2010(w,m)
         FOR(d=byDist): AvaiLabor(d) = AvaiLabor2010(d)
        TotalAvaiIrri = 3570000
         FOR(d=byDist,p=byProduct): Demand(d,p) = Demand2010(d,p)
         FOR(p=byProduct): LTargetHa(p) = LTargetHa2010(p)
         FOR(p=byProduct): UTargetHa(p) = UTargetHa2010(p)
         FOR(p=byProduct): LTargetTon(p) = LTargetTon2010(p)
         FOR(p=byProduct): UTargetTon(p) = UTargetTon2010(p)
         FOR(g=byPGroup): TargetHaGroup(g) = TargetHaGroup2010(g)
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      ELSE
         FOR(daw=1:NDAW): AvaiArea(daw) = AvaiArea2020(daw)
         FOR(w=byDemarc,m=byMonth): AvaiIrri(w,m) = AvaiIrri2010(w,m)
         FOR(d=byDist): AvaiLabor(d) = AvaiLabor2020(d)
         TotalAvaiIrri = 3570000
         FOR(d=byDist,p=byProduct): Demand(d,p) = Demand2020(d,p)
         FOR(p=byProduct): LTargetHa(p) = LTargetHa2020(p)
         FOR(p=byProduct): UTargetHa(p) = UTargetHa2020(p)
         FOR(p=byProduct): LTargetTon(p) = LTargetTon2020(p)
         FOR(p=byProduct): UTargetTon(p) = UTargetTon2020(p)
         FOR(g=byPGroup): TargetHaGroup(g) = TargetHaGroup2020(g)
      ENDIF
   ENDIF

! CALCULATION FOR ADDITIONAL TABLES

! Calculate total yield by LUT and product group
FOR(daw=1:NDAW,lut=1:NLUT,t=1:NTech,g=1:NPGroup|DistOpt(DinDAW(daw))=1): &
        LutGroupYield(daw,lut,t,g) = SUM(p=1:NProduct | LutPRelation(lut,p)=1 .AND.&
        PPGroup(g,p) = 1) Yield(lut,AinDAW(daw),WinDAW(daw),t,p)

! Calculate total yield by LUT and product
FOR(daw=1:NDAW,lut=1:NLUT,t=1:NTech,p=byProduct|DistOpt(DinDAW(daw))=1): &
        LutProdYield(daw,lut,t,p) = Yield(lut,AinDAW(daw),WinDAW(daw),t,p)

! Calculate regional labor
RegionalLabor = SUM(d=1:NDist|DistOpt(d)=1) AvaiLabor(d)

!Calculate RatioELabor
FOR(daw=1:NDAW,lut=1:NLUT,t=1:NTech|DistOpt(DinDAW(daw))=1): LaborEff(daw,lut,t) = &
        RatioELabor(lut, AinDAW(daw), WinDAW(daw),t,1)

!Calculate TotSoilEro
FOR(daw=1:NDAW,lut=1:NLUT,t=1:NTech|DistOpt(DinDAW(daw))=1): SoilEro(daw,lut,t) = &
        TotSoilEro(lut, AinDAW(daw), WinDAW(daw),t,1)

!Calculate RatioEWater
FOR(daw=1:NDAW,lut=1:NLUT,t=1:NTech|DistOpt(DinDAW(daw))=1): WaterEff(daw,lut,t) = &
        RatioEWater(lut, AinDAW(daw), WinDAW(daw),t,1)

! Calculate regional demand
FOR(p=1:NProduct): &
        RegionalDemand(p) = SUM(d=1:NDist | DistOpt(d)=1) Demand(d,p)

! Adjust revenues of oilpalm , rice, tobacco, & rubber
FOR (lut=byLUT,a=byAEco,w=byDemarc,t=byTech,p=byProduct| p = 'Op' .OR. p = 'OA'): &
        Revenue(lut,a,w,t,p) = Revenue(lut,a,w,t,p) * RevenueMult("Oilpalm")
FOR (lut=byLUT,a=byAEco,w=byDemarc,t=byTech,p=byProduct| p = 'R1' .OR. p = 'R2'): &
        Revenue(lut,a,w,t,p) = Revenue(lut,a,w,t,p) * RevenueMult("Rice")
FOR (lut=byLUT,a=byAEco,w=byDemarc,t=byTech,p=byProduct| p = 'To'): &
        Revenue(lut,a,w,t,p) = Revenue(lut,a,w,t,p) * RevenueMult("Tobacco")
FOR (lut=byLUT,a=byAEco,w=byDemarc,t=byTech,p=byProduct| p = 'Ru'): &
        Revenue(lut,a,w,t,p) = Revenue(lut,a,w,t,p) * RevenueMult("Rubber")

! Income for land use
FOR(daw=1:NDAW,lut=byLUT,t=byTech|DistOpt(DinDAW(daw))=1): &
        LutTIncome(daw,lut,t) =  SUM(p=byProduct) &
        Revenue(lut,AinDAW(daw),WinDAW(daw),t,p) * LutPRelation(lut,p)

! Annual labor need
FOR(daw=1:NDAW,lut=byLUT,t=byTech|DistOpt(DinDAW(daw))=1): &
        AnnuLaborNeed(daw,lut,t) = SUM(m=byMonth) LaborNeed(lut,AinDAW(daw),WinDAW(daw),t,m)

! Annual water use
FOR(daw=1:NDAW,lut=byLUT,t=byTech|DistOpt(DinDAW(daw))=1): &
        AnnuIrriNeed(daw,lut,t) = SUM(m=byMonth)&
        WaterNeed(lut,AinDAW(daw),WinDAW(daw),t,m)
```

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! Lut-T pesticide   (kg)
FOR(daw=1:NDAW,lut=byLUT,t=byTech|DistOpt(DinDAW(daw))=1): &
        LutTPesticide(daw,lut,t) = SUM(p=byProduct) &
        Pesticide(lut,AinDAW(daw),WinDAW(daw),t,p) * LutPRelation(lut,p)

! Lut-T fertilizer
FOR(daw=1:NDAW,lut=byLUT,t=byTech|DistOpt(DinDAW(daw))=1): &
        LutTFertilizer(daw,lut,t) = SUM(p=byProduct)&
        Fertilizer(lut,AinDAW(daw),WinDAW(daw),t,p) * LutPRelation(lut,p)

! Calculate available labor and labor needs by group of districts
IF Options("LaborSharing") = 1
   FOR(d=1:NDist,m=byMonth| DistOpt(d)=1): &
        GroupLaborAvai(d,m) = SUM(d2=1:NDist) AvaiLabor(d2) * LaborSharing(d,d2)

   FOR(daw=1:NDAW,lut=byLUT,t=byTech,m=1:NMonth| DistOpt(DinDAW(daw))=1): &
        GLaborNeed(daw,lut,t,m) = SUM(d2=1:NDist| LaborSharing(DinDAW(daw),d2)=1 .AND.&
        DistOpt(d2)=1) LaborNeed(lut,AinDAW(daw),WinDAW(daw),t,m)
ENDIF

!If yield = 0 then set to small number
!To make sure that the Target Production are imposed
FOR(daw=1:NDAW,lut=byLUT,t=byTech,p=byProduct | LutTPromi(daw,lut,t) =0): &
   LutProdYield(daw,lut,t,p)  = 0
IF Options("PTargt") = 1
   FOR(daw=1:NDAW,lut=byLUT,t=byTech,p=byProduct | LutProdYield(daw,lut,t,p) = 0 .AND.&
        LutTPromi(daw,lut,t) =1): &
        LutProdYield(daw,lut,t,p)  = 0.0000000000000000000000000001
ENDIF

! ________________________________________
! VARIABLES FOR OPTIMIZATION:  AREA OF EACH LAND USE TYPE
VARIABLES
        LUArea(NDAW, byLUT, byTech)

! ________________________________________
! OBJECTIVE FUNCTIONS AND CONSTRAINTS
CONSTRAINTS

! The goal with $ at the end will be optimized
! ________________________________________

! OBJECTIVE FUNCTION 1: MAXIMIZE Rice production (ton)
IF Options("ObjFunc") = 1
   Rice: SUM(daw=1:NDAW,lut=byLUT,t=byTech | DistOpt(DinDAW(daw))=1) &
        LutGroupYield(daw,lut,t,"Rice") * LutTPromi(daw,lut,t) * LUArea(daw,lut,t) $
ELSE
   Rice: SUM(daw=1:NDAW,lut=byLUT,t=byTech | DistOpt(DinDAW(daw))=1) &
        LutGroupYield(daw,lut,t,"Rice") * LutTPromi(daw,lut,t) * LUArea(daw,lut,t) > 0
ENDIF
IF Options("LRiceBound") = 1
     LRice: SUM(daw=1:NDAW,lut=byLUT,t=byTech | DistOpt(DinDAW(daw))=1) &
        LutGroupYield(daw,lut,t,"Rice") * LutTPromi(daw,lut,t) * LUArea(daw,lut,t) > &
        LowBound("Rice")
ENDIF
IF Options("URiceBound") = 1
     URice: SUM(daw=1:NDAW,lut=byLUT,t=byTech | DistOption(DinDAW(daw))=1) &
        LutGroupYield(daw,lut,t,"Rice") * LutTPromi(daw,lut,t) * LUArea(daw,lut,t) < &
        UpperBound("Rice")
ENDIF

! OBJECTIVE FUNCTION 2: Annual non-rice production (ton)
IF Options("ObjFunc") = 2
   AnNonRice: SUM(daw=1:NDAW,lut=byLUT,t=byTech | DistOpt(DinDAW(daw))=1) &
        LutGroupYield(daw,lut,t,"AnNonRice") * LutTPromi(daw,lut,t) * LUArea(daw,lut,t) $
ELSE
   AnNonRice: SUM(daw=1:NDAW,lut=byLUT,t=byTech | DistOpt(DinDAW(daw))=1) &
        LutGroupYield(daw,lut,t,"AnNonRice")*LutTPromi(daw,lut,t)*LUArea(daw,lut,t) > 0
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ENDIF
IF Options("LNonRiceBound") = 1
     LAnNonRice: SUM(daw=1:NDAW,lut=byLUT,t=byTech | DistOpt(DinDAW(daw))=1) &
        LutGroupYield(daw,lut,t,"AnNonRice") * LutTPromi(daw,lut,t) * LUArea(daw,lut,t)>&
        LowBound("AnNonRice")
ENDIF
IF Options("UNonRiceBound") = 1
     UAnNonRice: SUM(daw=1:NDAW,lut=byLUT,t=byTech | DistOpt(DinDAW(daw))=1) &
        LutGroupYield(daw,lut,t,"AnNonRice") * LutTPromi(daw,lut,t) * LUArea(daw,lut,t)<&
        UpperBound("AnNonRice")
ENDIF

! OBJECTIVE FUNCTION 3: MAXIMIZE Oilpalm production (ton)
IF Options("ObjFunc") = 3
   Oilpalm: SUM(daw=1:NDAW,lut=byLUT,t=byTech | DistOpt(DinDAW(daw))=1) &
        LutGroupYield(daw,lut,t,"Oilpalm") * LutTPromi(daw,lut,t) * LUArea(daw,lut,t) $
ELSE
   Oilpalm: SUM(daw=1:NDAW,lut=byLUT,t=byTech | DistOpt(DinDAW(daw))=1) &
        LutGroupYield(daw,lut,t,"Oilpalm") * LutTPromi(daw,lut,t) * LUArea(daw,lut,t) > 0
ENDIF
IF Options("LOilplmBound") = 1
     LOilpalm: SUM(daw=1:NDAW,lut=byLUT,t=byTech | DistOpt(DinDAW(daw))=1) &
        LutGroupYield(daw,lut,t,"Oilpalm") * LutTPromi(daw,lut,t) * LUArea(daw,lut,t) > &
        LowBound("Oilpalm")
ENDIF
IF Options("UOilplmBound") = 1
     UOilpalm: SUM(daw=1:NDAW,lut=byLUT,t=byTech | DistOpt(DinDAW(daw))=1) &
        LutGroupYield(daw,lut,t,"Oilpalm") * LutTPromi(daw,lut,t) * LUArea(daw,lut,t) < &
        UpperBound("Oilpalm")
ENDIF

! OBJECTIVE FUNCTION 4: MAXIMIZE Rubber production (ton)
IF Options("ObjFunc") = 4
   Rubber: SUM(daw=1:NDAW,lut=byLUT,t=byTech | DistOpt(DinDAW(daw))=1) &
        LutGroupYield(daw,lut,t,"Rubber") * LutTPromi(daw,lut,t) * LUArea(daw,lut,t) $
ELSE
   Rubber: SUM(daw=1:NDAW,lut=byLUT,t=byTech | DistOpt(DinDAW(daw))=1) &
        LutGroupYield(daw,lut,t,"Rubber") * LutTPromi(daw,lut,t) * LUArea(daw,lut,t) > 0
ENDIF
IF Options("LRubberBound") = 1
     LRubber: SUM(daw=1:NDAW,lut=byLUT,t=byTech | DistOpt(DinDAW(daw))=1) &
        LutGroupYield(daw,lut,t,"Rubber") * LutTPromi(daw,lut,t) * LUArea(daw,lut,t) > &
        LowBound("Rubber")
ENDIF
IF Options("URubberBound") = 1
     URubber: SUM(daw=1:NDAW,lut=byLUT,t=byTech | DistOpt(DinDAW(daw))=1) &
        LutGroupYield(daw,lut,t,"Rubber") * LutTPromi(daw,lut,t) * LUArea(daw,lut,t) < &
        UpperBound("Rubber")
ENDIF

! OBJECTIVE FUNCTION 5: MAXIMIZE Income (1000 RM)
IF Options("ObjFunc") = 5
   Income: SUM(daw=1:NDAW,lut=byLUT,t=byTech | DistOpt(DinDAW(daw))=1) &
        LutTIncome(daw,lut,t) * LutTPromi(daw,lut,t) * LUArea(daw,lut,t) $
ELSE
   Income: SUM(daw=1:NDAW,lut=byLUT,t=byTech | DistOpt(DinDAW(daw))=1) &
        LutTIncome(daw,lut,t) * LutTPromi(daw,lut,t) * LUArea(daw,lut,t) > 0
ENDIF
IF Options("LIncomeBound") = 1
     LIncome: SUM(daw=1:NDAW,lut=byLUT,t=byTech | DistOpt(DinDAW(daw))=1) &
        LutTIncome(daw,lut,t) * LutTPromi(daw,lut,t) * LUArea(daw,lut,t) > &
        LowBound("Income")
ENDIF
IF Options("UIncomeBound") = 1
     UIncome: SUM(daw=1:NDAW,lut=byLUT,t=byTech | DistOpt(DinDAW(daw))=1) &
        LutTIncome(daw,lut,t) * LutTPromi(daw,lut,t) * LUArea(daw,lut,t) < &
        UpperBound("Income")
ENDIF
```

```
! OBJECTIVE FUNCTION 6: MINIMIZE Labor use (labordays)
IF Options("ObjFunc") = 6
   LaborUse: SUM(daw=1:NDAW,lut=byLUT,t=byTech | DistOpt(DinDAW(daw))=1) &
        AnnuLaborNeed(daw,lut,t) * LutTPromi(daw,lut,t) * LUArea(daw,lut,t) $
ELSE
   LaborUse: SUM(daw=1:NDAW,lut=byLUT,t=byTech | DistOpt(DinDAW(daw))=1) &
        AnnuLaborNeed(daw,lut,t) * LutTPromi(daw,lut,t) * LUArea(daw,lut,t) > 0
ENDIF
IF Options("LLaborBound") = 1
     LLaborUse: SUM(daw=1:NDAW,lut=byLUT,t=byTech | DistOpt(DinDAW(daw))=1) &
        AnnuLaborNeed(daw,lut,t) * LutTPromi(daw,lut,t) * LUArea(daw,lut,t) > &
        LowBound("LaborUse")
ENDIF
IF Options("ULaborBound") = 1
     ULaborUse: SUM(daw=1:NDAW,lut=byLUT,t=byTech | DistOpt(DinDAW(daw))=1) &
        AnnuLaborNeed(daw,lut,t) * LutTPromi(daw,lut,t) * LUArea(daw,lut,t) < &
        UpperBound("LaborUse")
ENDIF

! OBJECTIVE FUNCTION 7: MINIMIZE Pesticide use(kg)
IF Options("ObjFunc") = 7
   TPesticide: SUM(daw=1:NDAW,lut=byLUT,t=byTech | DistOpt(DinDAW(daw))=1) &
        LutTPesticide(daw,lut,t) * LutTPromi(daw,lut,t) * LUArea(daw,lut,t) $
ELSE
   TPesticide: SUM(daw=1:NDAW,lut=byLUT,t=byTech | DistOpt(DinDAW(daw))=1) &
        LutTPesticide(daw,lut,t) * LutTPromi(daw,lut,t) * LUArea(daw,lut,t) > 0
ENDIF
IF Options("LPestBound") = 1
     LTPesticide: SUM(daw=1:NDAW,lut=byLUT,t=byTech | DistOpt(DinDAW(daw))=1) &
        LutTPesticide(daw,lut,t) * LutTPromi(daw,lut,t) * LUArea(daw,lut,t) > &
        LowBound("Pesticide")
ENDIF
IF Options("UPestBound") = 1
     UTPesticide: SUM(daw=1:NDAW,lut=byLUT,t=byTech | DistOpt(DinDAW(daw))=1) &
        LutTPesticide(daw,lut,t) * LutTPromi(daw,lut,t) * LUArea(daw,lut,t) < &
        UpperBound("Pesticide")
ENDIF

! OBJECTIVE FUNCTION 8: MINIMIZE Fertilizer use (ton)
IF Options("ObjFunc") = 8
   TFertilizer: SUM(daw=1:NDAW,lut=byLUT,t=byTech | DistOpt(DinDAW(daw))=1) &
        LutTFertilizer(daw,lut,t) * LutTPromi(daw,lut,t) * LUArea(daw,lut,t) $
ELSE
   TFertilizer: SUM(daw=1:NDAW,lut=byLUT,t=byTech | DistOpt(DinDAW(daw))=1) &
        LutTFertilizer(daw,lut,t) * LutTPromi(daw,lut,t) * LUArea(daw,lut,t) > 0
ENDIF
IF Options("LFertBound") = 1
     LTFertilizer: SUM(daw=1:NDAW,lut=byLUT,t=byTech | DistOpt(DinDAW(daw))=1) &
        LutTFertilizer(daw,lut,t) * LutTPromi(daw,lut,t) * LUArea(daw,lut,t) > &
        LowBound("Fertilizer")
ENDIF
IF Options("UFertBound") = 1
     UTFertilizer: SUM(daw=1:NDAW,lut=byLUT,t=byTech | DistOpt(DinDAW(daw))=1) &
        LutTFertilizer(daw,lut,t) * LutTPromi(daw,lut,t) * LUArea(daw,lut,t) < &
        UpperBound("Fertilizer")
ENDIF

! OBJECTIVE FUNCTION 9: MINIMIZE Water use (1000 m3)
!MADA area Only
IF Options("ObjFunc") = 9
   WaterUse: SUM(daw=1:NDAW,lut=byLUT,t=byTech | DistOpt(DinDAW(daw))=1 .AND. &
        WinDAW(daw) = 1) AnnuIrriNeed(daw,lut,t) * LutTPromi(daw,lut,t) * &
        LUArea(daw,lut,t) $
ELSE
   WaterUse: SUM(daw=1:NDAW,lut=byLUT,t=byTech | DistOpt(DinDAW(daw))=1) &
        AnnuIrriNeed(daw,lut,t) * LutTPromi(daw,lut,t) * LUArea(daw,lut,t) > 0
ENDIF
```

```
IF Options("LWaterUseBound") = 1
     LWaterUse: SUM(daw=1:NDAW,lut=byLUT,t=byTech | DistOpt(DinDAW(daw))=1) &
        AnnuIrriNeed(daw,lut,t) * LutTPromi(daw,lut,t) * LUArea(daw,lut,t) > &
        LowBound("WaterUse")
ENDIF
IF Options("UWaterUseBound") = 1
     UWaterUse: SUM(daw=1:NDAW,lut=byLUT,t=byTech | DistOpt(DinDAW(daw))=1) &
        AnnuIrriNeed(daw,lut,t) * LutTPromi(daw,lut,t) * LUArea(daw,lut,t) < &
        UpperBound("WaterUse")
ENDIF

!Show water use for each demarcation area
WaterMADA: SUM(daw=1:NDAW,lut=byLUT,t=byTech | DistOpt(DinDAW(daw))=1 .AND. &
        WinDAW(daw) = 1) AnnuIrriNeed(daw,lut,t) * LutTPromi(daw,lut,t) * &
        LUArea(daw,lut,t) > 0
WaterNMADA: SUM(daw=1:NDAW,lut=byLUT,t=byTech | DistOpt(DinDAW(daw))=1 .AND. &
        WinDAW(daw) = 2) AnnuIrriNeed(daw,lut,t) * LutTPromi(daw,lut,t) * &
        LUArea(daw,lut,t) > 0

! OBJECTIVE FUNCTION 10: MAXIMIZE labor use efficiency (RM/mday)
IF Options("ObjFunc") = 10
   ETLabor: SUM(daw=1:NDAW,lut=byLUT,t=byTech | DistOpt(DinDAW(daw))=1) &
        LaborEff(daw,lut,t) * LutTPromi(daw,lut,t) * LUArea(daw,lut,t) $
ELSE
   ETLabor: SUM(daw=1:NDAW,lut=byLUT,t=byTech | DistOpt(DinDAW(daw))=1) &
        LaborEff(daw,lut,t) * LutTPromi(daw,lut,t) * LUArea(daw,lut,t) > 0
ENDIF
IF Options("LLaborEffBound") = 1
     LETLabor: SUM(daw=1:NDAW,lut=byLUT,t=byTech | DistOpt(DinDAW(daw))=1) &
        LaborEff(daw,lut,t) * LutTPromi(daw,lut,t) * LUArea(daw,lut,t) > &
        LowBound("EffLabor")
ENDIF
IF Options("ULaborEffBound") = 1
     UETLabor: SUM(daw=1:NDAW,lut=byLUT,t=byTech | DistOpt(DinDAW(daw))=1) &
        LaborEff(daw,lut,t) * LutTPromi(daw,lut,t) * LUArea(daw,lut,t) < &
        UpperBound("EffLabor")
ENDIF

! OBJECTIVE FUNCTION 11: MAXIMIZE water use efficiency (RM/1000m3)
IF Options("ObjFunc") = 11
   ETWater: SUM(daw=1:NDAW,lut=byLUT,t=byTech | DistOpt(DinDAW(daw))=1) &
        WaterEff(daw,lut,t) * LutTPromi(daw,lut,t) * LUArea(daw,lut,t) $
ELSE
   ETWater: SUM(daw=1:NDAW,lut=byLUT,t=byTech | DistOpt(DinDAW(daw))=1) &
        WaterEff(daw,lut,t) * LutTPromi(daw,lut,t) * LUArea(daw,lut,t) > 0
ENDIF
IF Options("LWaterEff") = 1
     LETWater: SUM(daw=1:NDAW,lut=byLUT,t=byTech | DistOpt(DinDAW(daw))=1) &
        WaterEff(daw,lut,t) * LutTPromi(daw,lut,t) * LUArea(daw,lut,t) > &
        LowBound("EffWater")
ENDIF
IF Options("UWaterEff") = 1
     UETWater: SUM(daw=1:NDAW,lut=byLUT,t=byTech | DistOpt(DinDAW(daw))=1) &
        WaterEff(daw,lut,t) * LutTPromi(daw,lut,t) * LUArea(daw,lut,t) < &
        UpperBound("EffWater")
ENDIF

! OBJECTIVE FUNCTION 12: MINIMIZE soil erosion (ton/ha/year)
IF Options("ObjFunc") = 12
   EroSoil: SUM(daw=1:NDAW,lut=byLUT,t=byTech | DistOpt(DinDAW(daw))=1) &
        SoilEro(daw,lut,t)* LutTPromi(daw,lut,t) * LUArea(daw,lut,t) $
ELSE
   EroSoil: SUM(daw=1:NDAW,lut=byLUT,t=byTech | DistOpt(DinDAW(daw))=1) &
        SoilEro(daw,lut,t)* LutTPromi(daw,lut,t) * LUArea(daw,lut,t) > 0
ENDIF
IF Options("LErosionBound") = 1
     LEroSoil: SUM(daw=1:NDAW,lut=byLUT,t=byTech | DistOpt(DinDAW(daw))=1) &
```

```
        SoilEro(daw,lut,t) * LutTPromi(daw,lut,t) * LUArea(daw,lut,t) > &
        LowBound("EroSoil")
ENDIF
IF Options("UErosionBound") = 1
     UEroSoil: SUM(daw=1:NDAW,lut=byLUT,t=byTech | DistOpt(DinDAW(daw))=1) &
        SoilEro(daw,lut,t)* LutTPromi(daw,lut,t) * LUArea(daw,lut,t) < &
        UpperBound("EroSoil")
ENDIF

! ————————————————————————————————————————
! CONSTRAINTS DUE TO LIMITED RESOURCES

! CONSTRAINT 1a: Area
Area(daw=byDAW): SUM(lut=byLUT,t=byTech | DistOpt(DinDAW(daw))=1) LutTPromi(daw,lut,t)*&
        LUArea(daw,lut,t) < AvaiArea(daw)

! CONSTRAINT 1b: Area by technology level
IF (Options("Tech1P") + Options("Tech2P") + Options("Tech3P")) = 1
  IF Options("Tech1P") > 0
     TechA1(lut=byLUT) : SUM(daw=1:NDAW,t=1 | DistOpt(DinDAW(daw))=1) &
        LutTPromi(daw,lut,t) * LUArea(daw,lut,t) >= SUM(daw=1:NDAW,t=byTech | &
        DistOpt(DinDAW(daw))=1) LUArea(daw,lut,t) * Options("Tech1P")
  ENDIF
  IF Options("Tech2P") > 0
     TechA2(lut=byLUT) : SUM(daw=1:NDAW,t=2 | DistOpt(DinDAW(daw))=1) &
        LutTPromi(daw,lut,t) * LUArea(daw,lut,t) >= SUM(daw=1:NDAW,t=byTech | &
        DistOpt(DinDAW(daw))=1) LUArea(daw,lut,t) * Options("Tech2P")
  ENDIF
  IF Options("Tech2P") > 0
     TechA3(lut=byLUT) : SUM(daw=1:NDAW,t=3 | DistOpt(DinDAW(daw))=1) &
        LutTPromi(daw,lut,t) * LUArea(daw,lut,t) >= SUM(daw=1:NDAW,t=byTech | &
        DistOpt(DinDAW(daw))=1) LUArea(daw,lut,t) * Options("Tech3P")
  ENDIF
ENDIF

! CONSTRAINT 2a: Total labor use should be less than available labor in the province
IF Options("Labor") = 1
   TLabor(m=byMonth): SUM(daw=1:NDAW,lut=byLUT,t=byTech | DistOpt(DinDAW(daw))=1) &
        LaborNeed(lut,AinDAW(daw),WinDAW(daw),t,m) * LutTPromi(daw,lut,t) * &
        LUArea(daw,lut,t) < RegionalLabor
ENDIF

! CONSTRAINT 2b: Total labor use should be less than labor available in the neighbouring
!                districts assuming labor can move freely among neighbouring districts
IF Options("Labor") = 1 .AND. Options("LaborSharing") = 1
    GDLabor(d2=byDist,m=byMonth): SUM(daw=1:NDAW,lut=byLUT,t=byTech | &
        DistOpt(DinDAW(daw))=1 .AND. DinDAW(daw)=d2) GLaborNeed(daw,lut,t,m) * &
        LutTPromi(daw,lut,t) * LUArea(daw,lut,t) < GroupLaborAvai(d2,m)
ENDIF

! CONSTRAINT 2c: Total labor use for each district should be less than labor available
!                in the district assuming labor cannot move freely
IF Options("Labor") = 1 .AND. Options("LaborSharing") = 0
    DLabor(d=byDist,m=byMonth): SUM(daw=1:NDAW,lut=byLUT,t=byTech | &
        DistOpt(DinDAW(daw))=1) LaborNeed(lut,AinDAW(daw),WinDAW(daw),t,m) * &
        LutTPromi(daw,lut,t) * LUArea(daw,lut,t) < AvaiLabor(d)
ENDIF

! CONSTRAINT 3: Monthly irrigation water needs should be less than water available
!Water constraint only applicable for MADA
!Assumption: Irrigation water in nonMADA in abundant supply
IF Options("Water") = 1
    MIrriWater(m=byMonth): SUM(daw=1:NDAW,lut=byLUT,t=byTech | DistOpt(DinDAW(daw))=1 &
        .AND. WinDAW(daw)=1) (WaterNeed(lut,AinDAW(daw),WinDAW(daw),t,m)) * &
        LutTPromi(daw,lut,t) * LUArea(daw,lut,t) < AvaiIrri(1,m)
ENDIF
```

```
! CONSTRAINT 4: Total of irrigation water needs should be less than water available in
!               all yearround. Water constraint only applicable for MADA
!               Assumption: Irrigation water in nonMADA in abundant supply
IF Options("Water") = 1
    AIrriWater: SUM(daw=1:NDAW,lut=byLUT,t=byTech | DistOpt(DinDAW(daw))=1 .AND. &
        WinDAW(daw) = 1) AnnuIrriNeed(daw,lut,t) * LutTPromi(daw,lut,t) * &
        LUArea(daw,lut,t) < TotalAvaiIrri
ENDIF

! ________________________________________
! OTHER CONSTRAINTS

! CONSTRAINT 1: Total production should be > local demand (ton)
IF Options("Demand") = 1
   LDemand(p=byProduct | p<>'R1' .AND. p<>'R2' .AND. PrDemandOpt(p)=1): &
        SUM(daw=1:NDAW,lut=byLUT,t=byTech | DistOpt(DinDAW(daw))=1) &
        Yield(lut,AinDAW(daw),WinDAW(daw),t,p) * LutPRelation(lut,p) * &
        LutTPromi(daw,lut,t) * LUArea(daw,lut,t) > RegionalDemand(p)

   LDemand("R1"): SUM(daw=1:NDAW,lut=byLUT,t=byTech | DistOpt(DinDAW(daw))=1 .AND. &
        PrDemandOpt(1)=1) LutGroupYield(daw,lut,t,"Rice") * LutTPromi(daw,lut,t) * &
        LUArea(daw,lut,t) > RegionalDemand("R1")
ENDIF

! CONSTRAINT 2: Area should be within limits of target area (ha)
IF Options("ATargt") = 1
   !For nonrice
   LATarget(p=byProduct | p<>'R1' .AND. p<>'R2' .AND. PrTargetAOpt(p)=1): &
        SUM(daw=1:NDAW,lut=byLUT,t=byTech | DistOpt(DinDAW(daw))=1) &
        LutPRelation(lut,p) * LutTPromi(daw,lut,t) * LUArea(daw,lut,t) > LTargetHa(p)
   UATarget(p=byProduct | p<>'R1' .AND. p<>'R2' .AND. PrTargetAOpt(p)=1): &
        SUM(daw=1:NDAW,lut=byLUT,t=byTech | DistOpt(DinDAW(daw))=1) &
        LutPRelation(lut,p) * LutTPromi(daw,lut,t) * LUArea(daw,lut,t) < UTargetHa(p)
   !For rice
   LATarget('R1'): &
        SUM(daw=1:NDAW,lut=byLUT,t=byTech,p=byProduct | (p='R1' .OR. p='R2') .AND. &
        DistOpt(DinDAW(daw))=1 .AND. PrTargetAOpt(1)=1) LutPRelation(lut,p)* &
        LutTPromi(daw,lut,t) * LUArea(daw,lut,t) > LTargetHa("R1")
   UATarget('R1'): &
        SUM(daw=1:NDAW,lut=byLUT,t=byTech,p=byProduct | (p='R1' .OR. p='R2') .AND. &
        DistOpt(DinDAW(daw))=1 .AND. PrTargetAOpt(1)=1) LutPRelation(lut,p) * &
        LutTPromi(daw,lut,t) * LUArea(daw,lut,t) < UTargetHa("R1")
ENDIF

! CONSTRAINT 3: Production should be within limits of production target (ton)
IF Options("PTargt") = 1
   !Target for all nonrice
   UPTarget(p=byProduct | p<>'R1' .AND. p<>'R2' .AND. PrTargetPOpt(p)=1): &
        SUM(daw=1:NDAW,lut=byLUT,t=byTech | DistOpt(DinDAW(daw))=1) &
        LutProdYield(daw,lut,t,p) * LutTPromi(daw,lut,t) * LUArea(daw,lut,t) < &
        UTargetTon(p)
   LPTarget(p=byProduct | p<>'R1' .AND. p<>'R2' .AND. PrTargetPOpt(p)=1): &
        SUM(daw=1:NDAW,lut=byLUT,t=byTech | DistOpt(DinDAW(daw))=1) &
        LutProdYield(daw,lut,t,p) * LutTPromi(daw,lut,t) * LUArea(daw,lut,t) > &
       LTargetTon(p)
   !Target for Rice
   UPTarget('R1'): &
        SUM(daw=1:NDAW,lut=byLUT,t=byTech | DistOpt(DinDAW(daw))=1 .AND. &
        PrTargetPOpt(1)=1) LutGroupYield(daw,lut,t,"Rice") * LutTPromi(daw,lut,t) * &
        LUArea(daw,lut,t) < UTargetTon("R1")
   LPTarget('R1'): &
        SUM(daw=1:NDAW,lut=byLUT,t=byTech | DistOpt(DinDAW(daw))=1 .AND. &
        PrTargetPOpt(1)=1) LutGroupYield(daw,lut,t,"Rice") * LutTPromi(daw,lut,t) * &
        LUArea(daw,lut,t) > LTargetTon("R1")
ENDIF
```

```
! CONSTRAINT 4: Area should be greater than the area target (ha)
IF Options("GTargt") = 1
   GTarget(g=byPGroup | PrTargetAGrpOpt(g)=1): &
        SUM(daw=1:NDAW,lut=byLUT,t=byTech,p=byProduct | DistOpt(DinDAW(daw))=1) &
        PPGroup(g,p) * LutPRelation(lut,p) * LutTPromi(daw,lut,t) * LUArea(daw,lut,t) > &
        TargetHaGroup(g)
ENDIF

GENERATE
```

Post-optimal program (KedahPPost.mod)

```
SET CASE
SET CHECK
SET DOUBLE
SET NODYNINDEX
SET NOEXTSUB
SET FILLCHAR=' '
SET NOPAUSE
SET SAVE
SET TRUNCATE
SET UPDIR
SET WARN
SET ZTOLCM= .0001
SET NOECHO
! ---------------------------------------
! POST OPTIMAL PROCESSING:   OUTPUT SUMMARY DATA

RESTORE
IF infeasibilities = 0

! LIST OF OUTPUT TABLES
TABLES
        DAWArea(NDAW,byLUT)
        OptProduction(byProduct)
        OptAreaDLutTech(byDist,byLUT,byTech)
        Achievement(byGoal)

! CALCULATION FOR EACH TABLE
ASSIGN

! Goal values
Achievement(1)  = Rice
Achievement(2)  = AnNonRice
Achievement(3)  = Oilpalm
Achievement(4)  = Rubber
Achievement(5)  = Income
Achievement(6)  = LaborUse
Achievement(7)  = TPesticide
Achievement(8)  = TFertilizer
Achievement(9)  = WaterUse
Achievement(10) = ETLabor
Achievement(11) = ETWater
Achievement(12) = EroSoil

! Total area of each land use type in each DAW
DAWArea(daw=1:NDAW,lut=byLUT | DistOpt(DinDAW(daw))=1) = &
        SUM(t=byTech) LutTPromi(daw,lut,t) * LUArea(daw,lut,t)

! Total production of each product in each aldn unit
OptProduction(p=byProduct) = SUM(daw=1:NDAW,lut=byLUT,t=byTech |DistOpt(DinDAW(daw))=1)&
        LutProdYield(daw,lut,t,p) * LutTPromi(daw,lut,t) * LUArea(daw,lut,t)
```

```
! Total area of each lut & tech in each district
OptAreaDLutTech(d=byDist,lut=byLUT,t=byTech) = SUM(daw=1:NDAW | DinDAW(daw)=d .AND. &
        DistOpt(DinDAW(daw))=1) LutTPromi(daw,lut,t) * LUArea(daw,lut,t)

!-------------------------
! OUTPUT DATA TO FILE

DISKDATA -os
        outArea.txt = DAWArea
        outAchiev.txt = Achievement
        outProdn.txt = OptProduction
        outLutTech.txt = OptAreaDLutTech

! END THE MODEL

ENDIF
QUIT
```

Technical Bulletin

No. 1	Schoenly K, Zhang W. 1999. IRRI Biodiversity Software Series. I. LUMP, LINK, and JOIN: utility programs for biodiversity research.
No. 2	Zhang W, Schoenly K. 1999. IRRI Biodiversity Software Series. II. COLLECT1 and COLLECT2: programs for calculating statistics of collectors' curves.
No. 3	Zhang W, Schoenly K. 1999. IRRI Biodiversity Software Series. III. BOUNDARY: a program for detecting boundaries in ecological landscapes.
No. 4	Zhang W, Schoenly K. 1999. IRRI Biodiversity Software Series. IV. EXTSPP1 and EXTSPP2: programs for comparing and performance-testing eight exploration-based estimators of total taxonomic richness.
No. 5	Schoenly K, Zhang W. 1999. IRRI Biodiversity Software Series. V. RARE, SPPDISS, and SPPRANK: programs for detecting between-sample differences in community structure.
No. 6	Laborte AG, Roetter R, Hoanh CT. 1999. SysNet Tools: the multiple goal linear programming model (MGLP) and Maplink.
No. 7	Murty MVR, Kondo M. 2001. UPLAND: a simulation model for water balance in upland

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