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THE LAND USE PLANNING AND ANALYSIS SYSTEM OF THE SYSTEMS RESEARCH NETWORK IN ASIA

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ABSTRACT

Agricultural systems in South and Southeast Asia are being challenged by the requirements of increased productivity, more diversified products, and environmental protection. Optimizing future land use in such complex situations requires new partnerships between planners, scientists and decision makers and new methodologies and tools that can support decision-making on the most beneficial use of land and other natural resources. The Systems Research Network for Eco-regional Land Use Planning in Tropical Asia (SysNet) was established in late 1996 to develop methodologies for exploring alternative options for agricultural land use and rural development. The methods and tools that are needed to analyse various scenarios of future land use in order to guide policy changes are operationalized into a land use planning and analysis system (LUPAS) which has three main methodology components: (i) land evaluation; (ii) scenario construction; and (iii) multiple goal linear programming (MGLP).

This paper describes LUPAS and illustrates the capability of this modeling framework by discussing a few examples from an on-going study for the province of Ilocos Norte, Philippines. The results imply that water availability is an important constraint to agricultural development and improving the irrigation systems would result in higher productivity and more income for the province.

KEYWORDS: agricultural development; land use planning; linear programming; systems approach.

1 Introduction

As population in Asian urban centers more than double in the next 25 years, rural population will remain stable. This means more mouths to feed with lesser people involved in food production. With the closing in of the cultivation frontier and the accelerating growth in urban population in many Asian countries, food production must be increased considerably to meet the needs of the growing population. However, there will be less arable land and less water available for agricultural production as a result of conflicting interests from industry, urban areas and agriculture that are all competing for increasingly scarce natural resources. Multiple claims on land need to be addressed by analysing various land use options while taking into account the various productivity, socio-economic, and ecological goals and aspirations of the community of land users.

Land use planning consists of various steps. The SysNet methodology aims at exploring alternatives for agricultural land use and development to assist in *strategic planning.* In an interactive process with stakeholders, SysNet methods and tools are then tailored to local conditions. The aim of analysing various scenarios is to finally come up with a feasible plan for agricultural production and associated land use for a given region. The four study regions of SysNet include: Haryana State, India; Kedah-Perlis Region, Malaysia; Ilocos Norte Province, Philippines; and Can Tho Province, Vietnam (Roetter et al., 1998).

Results of scenario analyses consist of options for optimum land use under a given set of goals and constraints and the associated goal achievements. Results further indicate required policy changes and the scope for new agricultural production technologies that can satisfy the multiple goals for a given region.

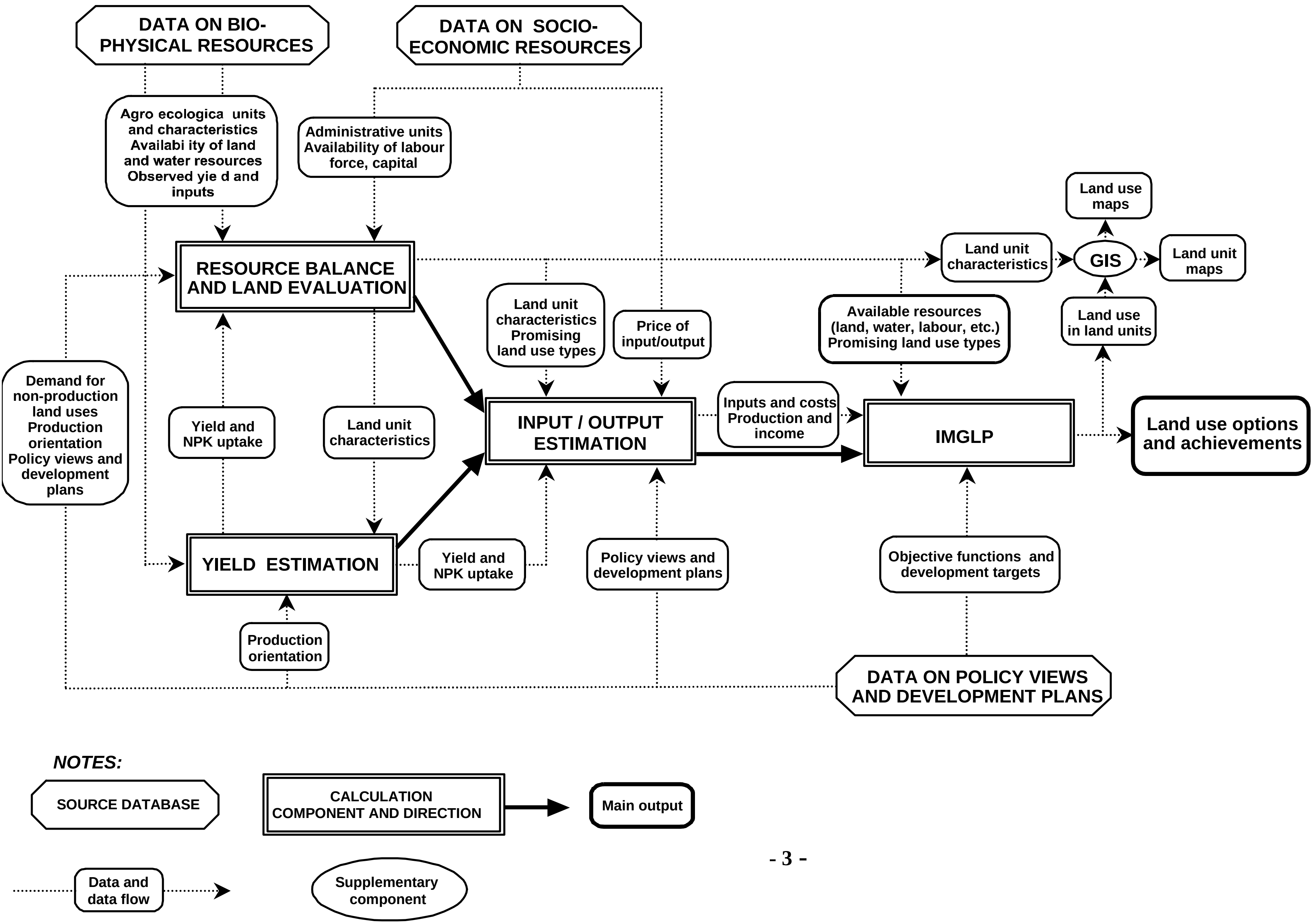
In this paper, the land use planning and analysis system (LUPAS), a decision support system developed by SysNet, is described. LUPAS is an operational system for exploratory land use analysis based on the concepts of the interactive multiple goal linear programming (IMGLP) method. IMGLP has been applied since the early '90s in various country studies (e.g. Veeneklaas et al., 1991; Stoorvogel et al., 1995). So far, however, there has not been any efficient computer system linking the various tools such as agro-ecological models, and GIS into a common modeling framework. LUPAS, designed for regional scale applications, represents such modeling framework.

This paper also exemplifies the analytical features and capacity of LUPAS for scenario analysis. For that purpose, a few examples are presented from an on-going study for the province of Ilocos Norte, Philippines. These illustrate the combined effects of alternative water management options and production technologies on achieving regional goals such as rice production, non-rice production, employment and income from agricultural activities, and the associated shifts in land use allocations.

2 LUPAS: Land use planning and analysis system

For optimizing land use under different sets of multiple goals, different scenarios are analysed based on dynamic land evaluation, quantified input-output relationships for current and alternative production activities, and the formulation of constraints and policy views as mathematical functions. There are two types of results of the optimization: goal achievements, and the corresponding land use allocations.
The structure of the operational system for land use planning and analysis (LUPAS) is illustrated in Figure 1.

Fig. 1 The operational structure of LUPAS



The three main methodology components of LUPAS are: (i) land evaluation; (ii) scenario construction based on policy views; and (iii) multiple goal linear programming (MGLP) model (Hoanh et al., 1998).

Land evaluation includes not only the assessment of the suitability of land for specific uses but also the assessment of resource availability, yield estimation, and input-output relations of current and alternative production activities. In this methodology component, land units and their characteristics are identified and promising production activities are determined. The yield levels from promising production activities in each land unit are estimated using crop models or expert knowledge. Crop models are applied to estimate potential and attainable crop yields. Potential yields are determined by crop characteristics and given radiation and temperature regime, while attainable yields refer to the best available management practices. This would serve as a reference for determining the possibilities for improving resource use efficiencies in different physical environments. For each yield level, the corresponding input-output relations are calculated; and both biophysical and technical constraints to promising production activities are identified.

Scenario construction is a highly interactive process. Objective functions, as well as, actual and possible future socio-economic constraints to promising production activities are formulated based on the prevailing policy views in the region. The participation and cooperation of stakeholders is an important factor in this integrated approach. To have impact, the type of scenarios to be considered and the results of the analysis need to be discussed with those who have a stake in the development of the region (Roetter and Hoanh, 1999) (Figure 2).

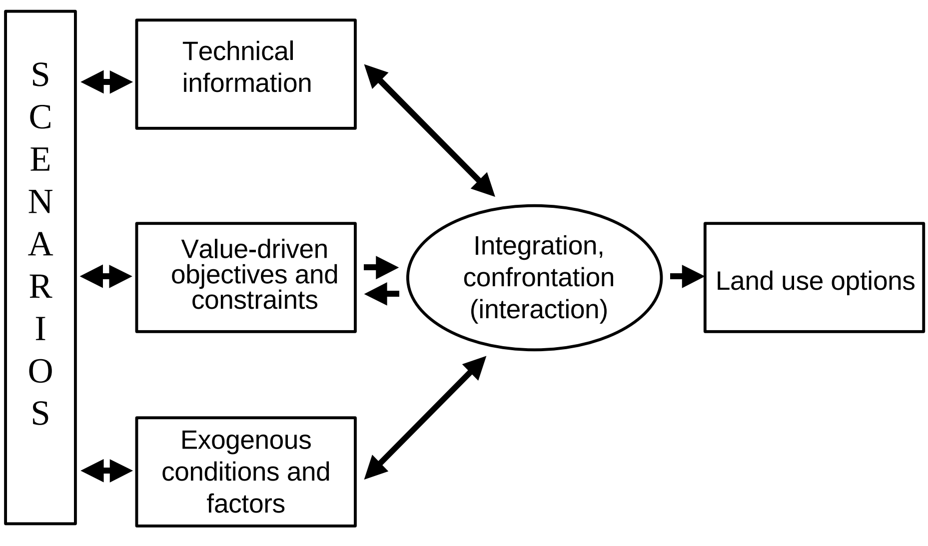


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Fig. 2 Concepts underlying the IMGLP Technique as applied to exploratory land use analysis

The technique of interactive multiple goal linear programming (IMGLP) (De Wit et al., 1988) is used to deal with the conflicting land use objectives of the stakeholders. This method is used to determine feasible options for agricultural development in a region. With this, land use options under various policy views are explored by using the technique of linear programming, i.e., an objective is optimized while taking into account a set of given constraints. This method provides a way by which promising production activities and technologies in a region can be analysed in view of their contribution to development goals, taking into consideration the limited resources available and the diverse and often conflicting objectives of different interest groups (stakeholders) regarding land use and regional development. Results for a given region reveal the extent to which the various goals can be met under the given technical and physical constraints, and provide estimates of the trade-offs between costs and benefits incurred in attaining the various goals.

The continuous interaction between scientists and stakeholders will lead to various iterations in model building and formulation (Figure 3).

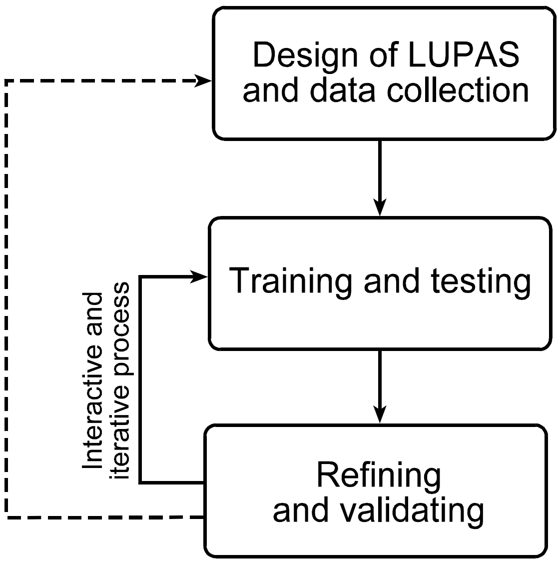

Fig. 3 The iterative process in developing a system for land use planning and analysis: The SysNet experience

All data on available resources, and input-output relations for land use activities are linked to an optimization model via the mathematical programming software XPRESS-MP (1997).

GIS (geographic information system) is used as a supporting tool for the delineation of land units, resource assessment, and mapping of results of optimizations. MapLink, a tool for linking input-output data and results of optimizations to a GIS, was developed to facilitate mapping of key variables (e.g., crop yields at defined technology levels, fertilizer requirements) and to show the spatial distribution of the land use options and goal achievements resulting from the optimization runs for different scenarios (Laborte et al, 1999).

Although a common structure of the LUPAS can be adopted, specifications for each case study is needed to better capture the problems and issues involved in land use planning that are relevant to the region. The methodology is tailored to fit the specific conditions of the study region. Workshops with NARS (National Agricultural Research Systems) and stakeholders are conducted to identify the issues in land use planning and to ensure that research outputs will be acceptable to the stakeholders.

3 Application of LUPAS: scenario analysis for Ilocos Norte Province, Philippines

The province of Ilocos Norte covers a total land area of 0.34 million ha. Of these, only 32% are available for agriculture. Rice-based production systems are predominant in the province and during dry season, diversified cropping is practiced.

To illustrate how the LUPAS framework is being used to explore options for natural resources management, three scenarios are considered: (i) without water-sharing, i.e., the available water is restricted to each land unit; (ii) with water sharing, i.e., land units connected by the current irrigation network can share water; and (iii) no constraint on water, i.e., there is sufficient water in all of the land units in the province to support any land use type.

3.1 Model elements and assumptions

Eighteen different agricultural products were considered and 25 land use types (LUTs) which are currently practiced in the province were included in this study. Of these LUTs, 19 are rice-based (e.g., rice-corn, rice-tobacco, rice-rice).

A total of 237 land units were defined by overlaying biophysical characteristics: irrigated areas, annual rainfall and distribution, slope and soil texture; and administrative units comprising of 23 municipalities (Lansigan et al, 1998).

Two production technology levels were considered: current farmers' practice and 'best available practice'. The data for the input-output for the current technology were derived from surveys consisting of 618 farms in the province. The values for the input-output relations for the current technology were derived from the average values for these farms. For 'best available practice', data were derived from studies, results from experimental fields, and estimates based on expert knowledge.

Resource limits such as land devoted to agricultural production, water resources, and available labour for agricultural activities for the entire province and for each administrative unit were determined. Available labour force was considered to be 45% of rural population and labour is assumed to be capable of moving freely within the province at any time. Land area available for agricultural development was determined by excluding areas claimed by settlements, forested areas, water bodies; and areas with unsuitable soil (e.g., rock land, river wash, mountainous soil, severely eroded land). The available water includes rain, ground- and surface water.

Several goals were identified in consultation with stakeholders in the province (Francisco et al., 1998). To simplify discussions, results for four goals will be presented in this paper: maximize rice production, maximize other agricultural production, maximize employment, and maximize farmer income.

3.2 Results

Table 1 shows the results of optimizations under the no water-sharing scenario. The maximum rice production that can be achieved is 533 thousand tons. This can be achieved if all the farmers adopt the technology corresponding to 'best available practice'. Under this optimization, non-rice production will be 220 thousand tons. The resulting land use allocation will require 7.9 million labour days and result in a total farmer income of 5.4 billion pesos.

Table 1 Values of goals without water-sharing

		GOALS			
No	Activity	Maximize rice production (A)	Maximize other production (B)	Maximize employment (C)	Maximize farm. Income (D)
1	Rice production (t)	**532 632**	82 219	193 804	154 449
2	Non-rice production (t)	219 587	**3 627 610**	1 696 823	1 978 396
3	Employment (1000 m-d)	7 897	6 361	**22 153**	5 621
4	Total farmer's income (10^6 P)	5 356	15 724	16 811	**23 142**

When non-rice production is maximized, the employment will be lesser by 20% but the farmer income will be more than three times higher than in 'maximizing rice production' optimization. Maximizing income leads to a total farmer income of 23.1 billion pesos. This is associated with 154 thousand tons of rice and 1.98 billion tons of non-rice production (mango, melon, forage and cotton).

The optimization results for the water-sharing scenario is given in Table 2. When water is shared using the current irrigation network, rice production will increase by 76% compared to the no water-sharing scenario. Figure 4 shows the shift in land use types to more intensive rice cropping systems (3 rice crops in a year) when water is shared. Figure 5 shows the comparative spatial distribution of the different land use types for both with and without water-sharing.

Table 2 Values of goals with water-sharing

		GOALS			
No	Activity	Maximize rice production (A)	Maximize other production (B)	Maximize employment (C)	Maximize farm. Income (D)
1	Rice production (t)	**943 382**	64 660	197 484	154 449
2	Non-rice production (t)	66 640	**3 717 385**	1 697 588	2 048 650
3	Employment (1000 m-d)	10 135	6 116	**22 730**	5 897
4	Total farmer's income (10^6 P)	7 029	15 795	17 431	**23 359**

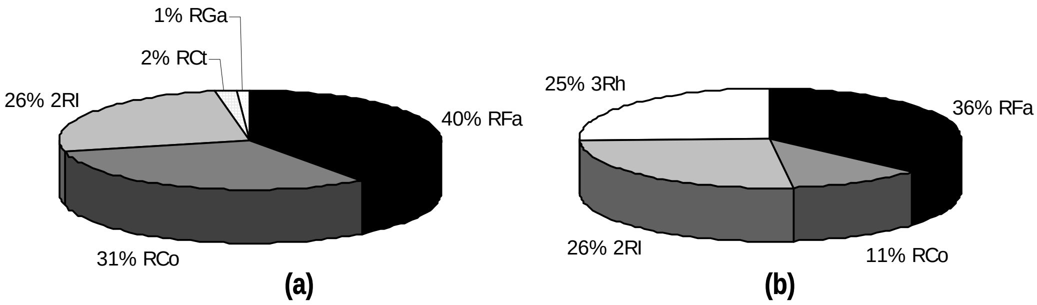

Fig. 4 The land use allocation when rice production is maximized: (a) without water sharing; (b) with water-sharing

(RFa = rice-fallow; RCo = rice-corn; 2RI = rice-rice; RGa = rice-garlic; RCt = rice-cotton; 3Rh = rice-rice-rice)

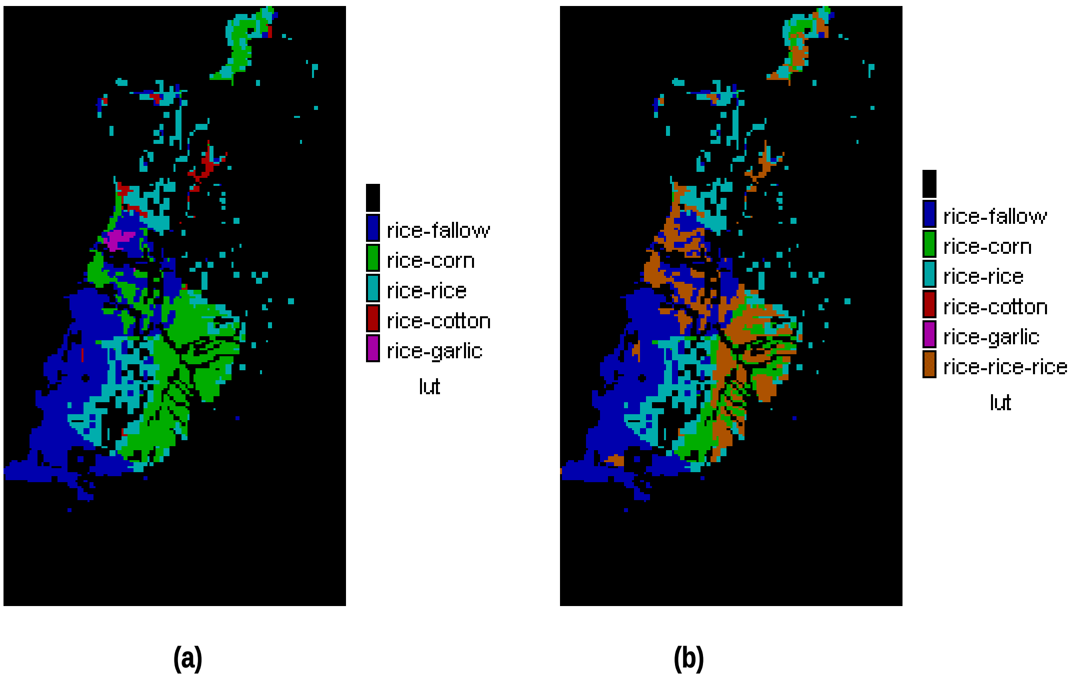

Fig. 5 The spatial distribution of land use allocation when rice production is maximized (a) without water sharing; (b) with water-sharing

Table 3 shows the values of the goals when available water is not included as a constraint. The results show that rice production could be increased by almost 100% compared to the no water-sharing scenario. This allocation will require 10.9 million labor days and result in a total farmer income of 7.2 billion pesos. When farmer's income is maximized, the result will increase by 31% compared with the income under the no water-sharing scenario.

Table 3 Values of goals when constraint on available water is not imposed

		GOALS			
No	Activity	Maximize rice production (A)	Maximize other production (B)	Maximize employment (C)	Maximize farm. income (D)
1	Rice production (t)	**1 030 007**	0	230 203	152 859
2	Non-rice production (t)	0	**4 551 750**	1 862 733	1 896 563
3	Employment (1000 m-d)	10 898	3 930	**23 254**	8 980
4	Total farmer's income (10^6 P)	7 174	13 171	17 528	**30 409**

The results of optimizations indicate that the province will benefit more when the irrigation system is improved. Some areas are underutilized due to insufficient water supply, while other areas have more than the required water. The results imply that water availability is an important constraint to agricultural development and improving the irrigation systems would result in higher productivity and more income for the province.

4 Further research

The few results presented here are part of an on-going study. LUPAS allows multiple goal analysis under more stringent policy views. This means imposing targets for future agricultural production and claims on land for specific non-agricultural uses, as well as, setting minimum acceptable goal achievements, e.g., maximize rice production at a given minimum level of income and employment. Elaboration of such scenarios is currently being done in consultation with stakeholders from Ilocos Norte.

Moreover, the input-output relations of the various production activities need to be examined further to improve estimates of water and labor demands for the various crop production activities at different technology levels.

5 References

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

Francisco SR, Navarrete RL Jr., Dimasuay LB, Lansigan FP, Pascual CM, Lucas MP, Orno JL, Roetter R, Hoanh CT, Laborte AG. Marcos TF, Acosta CG, Agustin EO, Pascua ME, Pascua SR Jr., Utrera RT, Cruz RT, and Obien SR. 1998. A systems approach to agricultural Land Use Planning at the provincial and municipal levels of Ilocos Norte Province, Philippines. In eds R Roetter, CT Hoanh, NV Luat, MK Van Ittersum, and HH Van Laar, 103-109.

Hoanh CT, Roetter R, Jansen DM, Aggarwal PK, Lansigan FP, Lai NX, Bakar IA, and Tawang A. 1998. Generalizing SysNet methodologies for land use planning at the sub-national level. In eds R Roetter, CT Hoanh, NV Luat, MK Van Ittersum, and HH Van Laar, 41-56.

Laborte AG, Roetter R, and Hoanh CT. 1999. SysNet Tools: the multiple goal linear programming model and data links to GIS, IRRI Technical Bulletin in press.

Lansigan FP, Orno JL, Pascual CM, Navarrete NR Jr., Francisco SR, Laborte AG, Hoanh CT, and Roetter R. 1998. Systems methodology development for exploratory agricultural land use planning for Ilocos Norte, Philippines. In eds R Roetter, CT Hoanh, NV Luat, MK Van Ittersum, and HH Van Laar, 73-80.

Roetter R, Hoanh CT. 1999. Exploring land use options under multiple goals in support of natural resource management at sub-national level. Paper presented at the Ecoregional Workshop for the Red River Basin, Hanoi, Vietnam, 6-8 Oct 1997. Eds. PS Teng et al., in press.

Roetter R, Hoanh CT, Luat NV, Van Ittersum MK, Van Laar HH (eds). 1998. Exchange of methodologies in land use planning. Proceedings of an International Workshop held on 15-19 June 1998 at Can Tho City, Vietnam, SysNet Research Paper Series No. 1. IRRI in collaboration with NARS of India, Malaysia, Philippines, Vietnam and Wageningen URC, Los Baños and Wageningen, 168 p.

Stoorvogel JJ, Schipper RA, Jansen DM. 1995. USTED: A methodology for a quantitative analysis of land use scenarios. Neth. Journal of Agricultural Science 43, 5-18.

Veeneklaas FR, Cissé S, Gosseye PA, Van Duivenbooden N, and Van Keulen H. 1991. Competing for limited resources: The case of the fifth region of Mali. Report 4. Development scenarios. CABO/ESPR, CABO, Wageningen, The Netherlands, 144 p.

XPRESS-MP. 1997. User guide and reference manual. Dash Associates Ltd. Blisworth House, Blisworth, Northants NN7 3BX, UK, 290 pp.