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Abstract: Currently, in many of the highly productive lowland areas of E and SE Asia a trend to further intensification and diversification of (agricultural) land use can be observed. Growing economies and urbanization also increase the claims on land and water by non-agricultural uses. As a result, decisions related to the management and planning of scarce resources become increasingly complex. Technological innovations at the field/farm level are needed but not sufficient – changes in resource use at regional scale will also be essential. To support decision-making in such situations, we advocate a multi-scale modelling approach embedded in a solid participatory process. To this end, the Integrated Resource Management and Land use Analysis (IRMLA) Project is developing an analytical framework and methods for resource use analysis and planning, for four sites in Asia. In the envisaged multi-scale approach, integration of results from field, farm, district and provincial level analysis is based on Interactive multiple goal linear programming (), Farm Household Modelling (FHM), production ecological concepts and participatory techniques. The novel approach comprises the following steps: (i) Inventory/quantification of current land use systems, resource availability, management practices and policy views, (ii) Analysis of alternative, innovative land use systems/technologies, (iii) Exploration of the opportunities and limitations to change resource use at regional scale under alternative future scenarios, (iv) Modelling decision behavior of farmers and identification of feasible policy interventions, and (v) Synthesis of results from farm to regional level for negotiation of the most promising options by a stakeholder platform. In the current paper, the operationalization of a dual-scale approach is illustrated by the outputs (development scenarios, promising policy measures and innovative production systems) from various component models for the case study Ilocos Norte, Philippines. A procedure is discussed for the integration of results from the different model components at two different decision making levels (farm and province).

***Keywords**:* land use conflicts; scenario analysis; bio-economic models; rice-based farming, Philippines.

1. INTRODUCTION

Agricultural systems in East and South-east Asia are being challenged by the simultaneous requirements for increased productivity, more diversified products and reduced environmental impact, creating potential conflict situations in land use objectives among various stakeholder groups. Current land use policies in general inadequately take into consideration multiple objectives and the increased complexity of current resource management decisions [Walker, 2002; Lu *et al.*, 2004]. In such situations, effective systems analysis tools at different scales are required to identify conflicts and design sustainable land use systems and supportive policy options [Van Ittersum *et al.*, 1998].

Since the early 1980s, a range of complementary analytical frameworks and operational tools have been developed [Stoorvogel & Antle, 2001]. On the basis of their objectives we can distinguish explorative and predictive tools. Explorative tools analyse the potential (im)possibilities of strategic natural resource use configurations, often at regional or farm scale. To this purpose, a frequently used procedure is interactive multiple goal linear programming () (De Wit *et al.*, 1988). models generate optimal land use options under different sets of objectives and constraints. Regional models as operationalized in the SysNet project [Roetter *et al.*, 2004] form one of the major building blocks of the IRMLA approach to multi-scale analysis.

So-called predictive tools are required to analyse the likely land use changes in the short term as a result of introducing alternative agricultural policies and technologies [Bouman *et al.*, 2000]. For example, the technique of farm household modelling (FHM) is applied for simulating the impact of feasible changes in policy and technology choice for different (model) farm groups in a study area [Kruseman and Bade, 1998]. FHM is the second major tool in the IRMLA project.

In most cases, the various modelling approaches, whether exploratory or predictive have been applied separately at a single scale. This can only shed partial light on solutions to agricultural and environmental policy problems which are essentially of a multi-scale nature. Policy makers at the provincial level, for instance, have only a limited number of variables that they can control. Variables such as choice of crop, area cultivated and fertilizer and pesticide rates are decided by a huge number of other decision makers, i.e. farmers, which apply different criteria. Candler *et al*. [1981] addressed this problem and examined the potential contribution of multilevel programming to solve two-level (public – private interest) conflicts. They detected a range of algorithmic problems in multilevel programming. Solutions were only found for special cases. To make things even more complicated, public interest at one level (e.g. province) may be in conflict with the public interest at another level (e.g. municipality). Integration of results from different scales remains a rsearch challenge [Bouman et al., 2000]. In this paper we do not intend to resolve the problems inherent to multilevel programming. Rather we want to demonstrate that, as a first step, combination of farm household modelling and regional multiple goal linear programming embedded in participatory processes can overcome shortcomings of single-level modelling. This will be illustrated by confronting results from regional level explorations with farm household level analysis of the best land use strategy. The result from this dual-scale analysis will help to identify the options for promoting more resource-use efficient production technologies than presently practiced in Ilocos Norte province, Philippines.

2. CASE STUDY CHARACTERIZATION

2.1 Land use issues and agricultural development perspectives for Ilocos Norte

According to current local government views, agriculture will maintain its central role in the economic development of Ilocos Norte province. However, agriculture will increasingly compete for land with for instance industrialization, recreation parks and tourism areas. Competition for scarce natural resources, particularly land and water, is evident in the most recent provincial development plan, which includes conversion of some agricultural areas into other uses. Such conversion will not spare the strategic agriculture and fisheries development zones identified in earlier plans, such as Dingras municipality. The provincial plan sets boundary conditions on future availability on agricultural land resources. Recent dialogues between scientists and Ilocano stakeholders on agricultural land use issues revealed that assessment of trade-offs between rice production, diversification of production and farmers' income was a major issue for the Ilocos Norte province as well as for Dingras municipality. Environmental issues, such as nitrate pollution and excessive pesticide residues needed to be addressed as well [Roetter and Wolf, 2003].

2.2 Site description

Ilocos Norte Province, in northwestern Luzon, Philippines, has a population of nearly 0.5 million people and a total land resource of 0.34 million ha, of which 46% is covered by forests. Mean annual rainfall ranges between 1650 mm in the southwest to more than 2,400 mm in the eastern mountain ranges. On average, 6-7 typhoons per year cross the province (mostly between August and November). About 38% of the total area is classified as agricultural land [Roetter et al., 2000]. Rice-based production systems prevail. Rice is grown in the wet season (June-October), whereas diversified cropping (tobacco, garlic, onion, maize, sweet pepper and tomato) is practiced in the dry season, using irrigation (mainly) from groundwater. A well-developed marketing system facilitates this relative intensive production system of rice and cash crops [Lucas *et al.*, 1999]. Dingras has a population of 33,300 persons and a total land resource of 17,310 ha, of which 55% is agricultural land.

3. DEVELOPMENT AND IMPLEMENTATION OF MODELS AND DATABASES

3.1 Regional level

A total of 200 land units were defined by overlaying biophysical characteristics (irrigated areas, annual rainfall and distribution, slope and soil texture) and administrative units, comprising 22 municipalities and one township. The total area available for agriculture for the year 2010 was estimated at 119,850 ha (assuming an overall land use conversion rate of 7% from agriculture to non-agricultural uses) [Roetter *et al.*, 2000]. The land use types (LUTs) included in this study comprise (i) single cropping of root crops, sugarcane, and rice followed by fallow; (ii) double cropping: two rice crops, rice in rotation with (yellow or white) corn, garlic, mungbean, peanuts, tomato, tobacco, cotton, potato, onion, sweet pepper, eggplant, and vegetables; (iii) triple cropping: three rice crops, and rice in rotation with garlic and mungbean, with (white or yellow) corn and mungbean, and with water melon and mungbean. The available resources for agriculture such as land, labor-force and irrigation water were quantified per land unit and per month. Provincial demand for agricultural products was assessed on the basis of information on per capita demand and projected population from the Provincial Planning Office. Details on the procedures applied to assess resource availability and constraints have been described in previous studies [Roetter *et al.*, 2000; Laborte *et al.*, 2002].

An model developed for Ilocos Norte province [Roetter *et al.*, 2004] was applied. Four major agricultural development goals as identified by stakeholders were included: Maximizing farmers' income and rice production, and minimizing nitrogen fertilizer and biocide use (while maintaining a minimum level of income and/or crop production). The specific 'what-if question' addressed is: how does goal attainment (rice production, income, etc.) and land use allocation change, if under given resource availability and a set of available production activities, the production techno-logies change.
Three basic model runs were performed for analysing effects of changes in production technologies on the different land use objectives.

3.2 Farm level

Dingras, one of the 22 municipalities of the province, was chosen for analysis at the household level. For Dingras, six land units were distinguished based on drainage conditions and the presence and duration of surface irrigation. Twenty-two major cropping systems were identified on the basis of an extensive farm household survey. These cropping systems do not all match with cropping systems identified at the provincial level. Dingras is located in the inner lowlands of Ilocos Norte about 10 to 15 km to the East from the main road connecting the provincial capital Laoag with Ilocos Sur. Dingras has a relatively high incidence of triple cropping systems that are less important at the provincial level. One hundred fifty households were covered in an extensive survey and classified into four relatively homogeneous groups based on their land, labor and capital resources. The average resource endowments of each group were used to define representative households. The major characteristics of these households are:

- Medium farm, well drained: 0.92 ha of cultivated land, 64% groundwater irrigation, 74% sharecropped.
- Medium farm, poorly drained: 1.07 ha, 76% surface irrigation, 80% sharecropped.
- Large farm: 1.63 ha, well-drained, 85% surface irrigation, 86% sharecropped.
- Small irrigated farm: 0.83 ha, well-drained, 100% surface irrigation, 94% sharecropped.

A linear programming model was developed for each household type. The models maximize income above subsistence, given the household specific endowment of resources, minimum consumption requirements, limits on off-farm employment and credit, and generic input-output coefficients for crop production and prices for inputs and outputs.

3.3 Three alternative production technologies

Three production technology levels were evaluated in both the regional and farm models: (technology 1) 'average farmers' practice, (technology 2) high yield/high input and (technology 3) 'high yield/improved practice'.
The relevant input-output coefficients for technology 1 were derived from farm surveys in the province, and average values for these farms were applied [Roetter *et al.*, 2000]. For technology 2, the mean of the values with a yield level between the 90th and 95th percentile of the survey data was applied. Fertilizer and pesticide use were assumed 100% higher and labour 70% higher, other inputs remaining identical to those in the average practice. For the 'improved practice' (technology 3), the same, high, yields as in technology 2 were assumed, but labour and biocide inputs remained identical to those in 'average farmers' practice. We assumed higher fertilizer use efficiency than in the first 2 technologies. In comparison to technology 1, average applications of N, P, and K were reduced by 20% for non-rice crops. For rice, a more balanced NPK application was assumed: N was reduced by 40%, of P by 15% and of K increased by 20%.
The relevant input-output coefficients were established by applying the technical coefficient generator TechnoGIN-3 [Ponsioen *et al.*, 2004].

4. RESULTS

4.1 Regional level

We consider two scenarios for presentation: (A) 'maximize farmers' income', and (B) 'minimize N fertilizer use'. For both scenarios, the satisfaction of provincial demand for agricultural products, and available labour and water were introduced as constraints. Results for scenario A (Table 1) show, among others, that if all farmers in Ilocos Norte would apply technology 2, their income would be considerably higher than with technology 1. However, if all farmers would apply the improved, more resource-efficient practice (technology 3), even higher income levels than with technology 2 could be achieved at about 30% lower inputs of fertilizers and pesticides. When the water constraint was removed, farmers' income could further increase by more than 50% [Laborte *et al.,* 2002].

Table 1: Results of the regional explorations (year 2010): A. Maximize Farmers' Income and B. Minimize Nitrogen Fertilizer Use (constraints: land+water+labor and provincial demand for important food crops satisfied)

Variable	Unit	*MAXIMIZE FARMERS'INCOME*		
		tech1	tech2	tech3
Income	10^9 Pesos	**15.3**	**30.4**	**36.6**
Rice	10^3 ton	119	226	241
Employ-ment	10^6 labdays	9.5	17.8	12.1
Biocide	10^3 kg a.i.	75	161.6	79.5
N Fertilizer	10^3 ton	13.5	33.8	15.9
Land used	%	100	91	96
		MINIMIZE N FERTILIZER USE		
		tech1	tech2	tech3
Income	10^9 Pesos	1.0	1.0	1.3
Rice	10^3 ton	113	113	113
Employ-ment	10^6 labdays	2.7	3.5	2.0
Biocide	10^3 kg a.i.	7.2	7.7	4.3
N Fertilizer	10^3 ton	**3.1**	**3.9**	**1.2**
Land used	%	22	17	17

Results for scenario B (Table 1) indicate that application of technology 3 could reduce nitrogen fertilizer use by almost 70% as compared to technology 2, while still meeting the local demand for agricultural products. Income from farming would be slightly higher than for technologies 1 and 2. In scenario B, however, for all technologies only about one fifth of the available land would be used and income from farming would be marginal as compared to scenario A.
For all technologies, in scenario A, total rice production would exceed the current production levels. Site-specific, and more-balanced nutrient and pest management practices could lead to considerably higher incomes at reduced environmental costs, while still satisfying local demand for the main food crop: a clear win-win situation.
A regional explores the ultimate consequences of optimally allocating land to different uses for a given set of objectives at provincial scale. Objectives of decision makers at lower scales are assumed subject to the provincial objectives. In reality, there are many resource managers with different objectives and resource endowments,

and groups using different sets of criteria for guiding their decisions. The possible impact of various alternative policy interventions at farm scale is presented in the following section for different farm types in Dingras municipality.

4.2 Farm level

Table 2 presents the results of base run simulations and 4 development scenarios for three of the four representative households. The results for the medium farm-poorly drained are not listed, as they are very similar to those of the medium farm-well drained.

In the base run, all model farmers use technology 2 on irrigated land and technology 3 on most of their dryland. The small farmer also uses (average) farmer technology (technology 1) due to credit constraints. Income is clearly highest for the large farmer, who also uses most biocides and nitrogen fertilizer. Income of the small farmer is 16% higher than for the medium farmer, whereas the small farmer uses more than four times as much nitrogen fertilizer and almost three times as much biocides. This difference is explained by the use of the high input technology on irrigated land and the more sustainable improved technology on dryland.

The first policy scenario simulates the removal of all credit constraints, which potentially leads not only to an increase in income but also in the use of agrochemicals. Only the large and the small farmer were credit constrained in the base run. The impact of increased credit availability is low for the large farmer, but high for the small farmer, who uses the additional credit to substitute high-input technology for average farmer technology. This results in an increase of income by 15%, and of nitrogen and biocide use by 23% and 19%, respectively.

At present, there is little off-farm employment, which makes sustainable, labor-intensive production technologies relatively attractive. This could change in the future. Simulations show that the unlimited availability of off-farm employment would lead to an increase in income of 12-16% for all farmers, but to limited changes in the sustainability of agricultural production except for the medium farmer, who increases his biocide use by 40%.

Finally, we evaluated two price-change scenarios to assess the potential of increasing agricultural sustainability through input price policies. The large farmer is affected most by this policy. Changing biocide prices is most effective: a 10% increase in biocide prices results in a 7% decrease in both the use of fertilizers and biocides, while the same increase in fertilizers results in a decrease of 5% for both types of inputs. The other changes are minor.

Table 2: Results of the household simulations for Dingras municipality

	Income (10^3 Pesos)	Rice (ton)	N fer-tilizer (kg)	Biocides (kg a.i.)
Medium farm-well drained				
Base run	301.1	5.0	47	187
Unlimited credit	0%	0%	0%	0%
Unlimited off-farm employment	16%	0%	0%	40%
10% increase in fertilizer prices	0%	0%	0%	0%
10% increase in biocide prices	0%	0%	0%	0%
Large farm				
Base run	656.0	11.8	376	1013
Unlimited credit	3%	6%	3%	1%
Unlimited off-farm employment	12%	-8%	1%	-1%
10% increase in fertilizer prices	-1%	-4%	-5%	-5%
10% increase in biocide prices	-2%	-7%	-7%	-7%
Small irrigated farm				
Base run	348.4	5.1	203	540
Unlimited credit	15%	41%	23%	19%
Unlimited off-farm employment	6%	-1%	0%	0%
10% increase in fertilizer prices	-1%	-1%	-1%	-1%
10% increase in biocide prices	-2%	-3%	-2%	-2%

5. DISCUSSION AND OUTLOOK

There is a need for tremendous agricultural productivity increases in the countries with high population densities in E and SE Asia, such as the Philippines. Such increase can only be achieved sustainably by judicious use of external inputs and natural resources, and supportive policies. Model results for the province show the high potential of the new technologies to improve income and sustainability at the same time, implicitly suggesting that investment in agricultural research and extension is the answer. However, there are some constraints to optimizing resource use efficiency (such as limited access to credit), which cannot be analysed using the regional model. Here, FHM comes in for analysing the constraints and possibilities to adoption of sustainable technologies at the farm level.

Analysis of the effectiveness of different policy instruments (public investment to improve access to credit, off-farm employment and price instruments) in contributing to regional development goals was performed for representative farm types in Dingras municipality. The policy instruments resulted in variable trade-offs between income, rice production and ecological sustainability of agricultural production depending on farm type. Thus, in addition to regional level explorations, FHM analysis shows that increased availability of off-farm employment and capital are likely to hamper adoption of sustainable technologies, while increased prices of agrochemicals appear quite effective in stimulating adoption of these technologies at a only limited decrease in household income. Hence, FHM and regional modelling complement each other. When developed and applied in close interaction with stakeholders, such multi-scale modelling approach can provide valuable information for policy development in relation to natural resource management (van Ittersum et al., 2004). Such process is currently underway in the case study regions of the IRMLA project.

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