Multi-scale land use analysis for agricultural policy assessment: A model-based study in Ilocos Norte province, Philippines

Promotor: Prof. dr. ir. H. van Keulen
Hoogleraar bij de leerstoelgroep Plantaardige Productiesystemen

Co-promotoren: Dr. ir. M.K. van Ittersum
Universitair hoofddocent,
Leerstoelgroep Plantaardige Productiesystemen
Dr. ir. R.A. Schipper
Universitair docent,
Leerstoelgroep Ontwikkelingseconomie

Promotiecommissie:
Prof. dr. W.J.M. Heijman (Wageningen Universiteit)
Prof. dr. J. Feyen (Katholieke Universiteit Leuven, België)
Dr. ir. B.A.M. Bouman (IRRI, Philippines)
Dr. M. Hossain (IRRI, Philippines)

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Alice G. Laborte

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Abstract

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Pressures on the natural resources, especially land and water, continue to increase as a result of an ever-increasing world population and continuing economic growth. These pressures originate from the many claims of stakeholders at different scales on the limited resources, and are aggravated by their different and often conflicting goals. Discussions on alternative resource uses, prioritizing different goals, and formulation and implementation of land use policies would greatly benefit from a quantitative assessment of the economic, social and environmental benefits and costs associated with the alternatives. In this study, a multi-scale and model-based approach was developed and applied in support of joint-learning, policy discussions and decision-making with respect to agricultural land use. The methodology was operationalized, in consultation with stakeholders, for the province of Ilocos Norte in the northwest of the Philippines, and its most populous municipality, Batac.

Six optimization models with different specifications were developed for different spatial scales: one for the farm, four for the municipal and one for the provincial scale. Results of the farm household analysis show the comparative attractiveness of alternative agricultural technologies, although adoption behaviour with respect to these technologies is different for poor, average and better-off households. The provincial analysis provides a quantitative assessment of the trade-off involved in prioritizing economic goals over social goals of food self-sufficiency and increased employment in agriculture. Results of the municipal analysis show that limited markets, inadequate infrastructure and resource endowments of farm households strongly affect resource use and goal achievement in Batac. As the effects of these factors in the model are significant, ignoring them may result in misleading simulation results and, hence, policy conclusions.

The multi-scale approach was used to quantify the effects of agricultural policies pertaining to attainment of food self-sufficiency goals, liberalization of rice prices, infrastructure improvements and volumetric water pricing on income, food production, resource use, and environmental indicators at the farm, municipal and provincial scales. Food self-sufficiency goals can be achieved but conflict with economic objectives. Liberalization of rice prices results in lower income for farmers but benefits rice consumers as a result of lower rice prices. Irrigation improvements can contribute to increased rice production, however, at the expense of income. Similarly, volumetric water pricing can result in more efficient water use at the farm and municipal scale, but at the expense of income in the short-run. Many of these results seem trivial, but the model-based analyses result in quantitative estimates for the effects on the economic, agricultural and environmental dimensions of the problem.

It is anticipated that model-based analyses has a potential to play a key role in participatory land use policy formulation. Results from the multi-scale approach presented in this thesis can provide valuable information for policy development and assessment. This may enhance transparent discussions among stakeholders on the implications of various objectives and priorities at different scales for resource use. This also allows *ex-ante* analysis of agricultural and natural resource use policies, including assessment of the potentials of new agro-technologies.

Keywords: Linear programming; Natural resource use; Policy analysis; Farm household modelling; Regional modelling; Philippines

Preface

In 1998, I joined the Systems Research Network for Ecoregional Land Use Planning in South and Southeast Asia (SysNet), a project coordinated by the International Rice Research Institute (IRRI) in collaboration with National Agricultural Research Systems in four countries and Wageningen University and Research centre (WUR). Through this project, I learned about developing models for regional land use analysis and had opportunities to interact with planners and policymakers in the four case study sites (India, Malaysia, Philippines and Vietnam). I would like to thank Reimund Roetter, then SysNet Project Coordinator for hiring me and for the many professional opportunities. My work with SysNet formed the foundation for the research described in this thesis. Through this project I met Herman van Keulen and Martin van Ittersum, who later became my promoter and co-promoter, respectively. Thank you Herman for your support and for always finding time to go over my drafts and making sure that the content and English are both sound. Thank you Martin for your guidance and insightful comments which greatly improved this thesis. I am grateful to you both for the visits to IRRI and Ilocos Norte in between my first and last periods here in Wageningen, and the many email communications which helped me get through the times when I was not exactly sure what to do. Rob Schipper, my other co-promoter provided the much needed input by putting an economist's point of view in the discussions. I am very fortunate to have an excellent supervision team.

Nico de Ridder supervised me early on particularly during my first six months in Wageningen. Marrit van den Berg helped me in refining the farm household model and municipal model with endogenized prices. I could not have done these models without her help. I also thank my supervisors at IRRI, Mahabub Hossain and Suan Pheng Kam for their input in the initial phase of this research.

Several past and present scientists and researchers at IRRI were helpful in the conduct of this study. I benefited a lot from discussions with Chu Thai Hoanh on regional land use modelling and ideas on possible directions to take in performing multi-scale analysis. Mercy Sombilla generated supply and demand elasticity estimates for certain commodities using IFPRI's IMPACT model. Christian Witt and Flor Palis provided materials and helpful discussions on site specific nutrient management and integrated pest management, respectively. I thank my colleagues at the Geographic Information System-Image Processing Laboratory and Social Sciences Division (SSD) for their support. Specifically, I thank Esther Marciano and Doris Malabanan for their help in setting up my farm survey. Doris, Josie Narciso, Joyce Luis, Shiela Valencia and Nel Garcia provided me with socio-economic data and helped check some

references I needed when I was in Wageningen. Pie Moya, Zeny Huelgas, and Tess Tiongco were helpful in explaining some economic terms and concepts. Annie Boling of Crop, Soil and Water Sciences and Pat Borlagdan of Agricultural Engineering provided answers to some questions on irrigation and water-related issues. Tess Rola of Communications and Publications Services took on the difficult task of translating the summary in Filipino. *Maraming salamat!*

This research involved several trips to Ilocos Norte and several people there helped in making the trips productive. The SysNet and IRMLA team members from Mariano Marcos State University (MMSU) facilitated some of the stakeholder meetings. Epifania Agustin, Director for Research of MMSU and team leader of IRMLA-Philippines, provided valuable input and facilitated meetings with experts at MMSU on livestock, nutrient and pest management. Leah Tute answered promptly my many data and information requests. The Municipal Agricultural Office of Batac headed by Merryline Gappi helped me in contacting farmers and shared their insightful assessments of the agricultural situation in Batac. Several farmers and stakeholders in Ilocos Norte patiently sat through the interviews and meetings, and shared their views with us. *Agyaman nak kanyayo!*

Xiang Bi, Willy Pradel, and Anne Gerdien Prins, MSc students from Wageningen, analyzed the farm survey data and developed the farm household model which formed the basis of the model presented in this book. I thank them for their hard work. Thanks are also due to Tommie Ponsioen who developed TechnoGIN during his internship at IRRI with the SysNet Project and further refined it while working for IRMLA.

I am indebted to Gon van Laar for doing a wonderful job in editing this thesis, and Pepijn van Oort and Barbara Sterk for the Dutch summary. I appreciate very much your help with this thesis and your friendship.

Thanks to Mirla Domingo, Ramil Gutierrez and Helen Malabrigo from IRRI, and Ria van Dijk and Charlotte Schilt from Wageningen for providing excellent administrative support. I am grateful to Arnel Rala and Sidky Macatangay from IRRI, and Marcel Lubbers, Eelco Meuter and the staff from TUPEA for the operational help with computers and software.

Living in another country with a totally different culture and weather is very difficult. Thanks to friends, life during the winter months in Wageningen became bearable. I thank fellow Filipino students for get-togethers, fun trips in and out of Holland and words of encouragement: Annie, Betty, Eric, Geoffer, Mel D., Mel M., Peewee (2000-2001); Arnel, Chito, Ela, Ellaine, Julie, Kap, Roy (2004); Aimee, Armi, Eve, Jobert, Julia, Kim (honorary), Lally, Lane, Mommy Marie, Nelson, Roger, Tin, Tita Sally, Tom and Vicky (2005-2006). I am grateful to Tita Nora and Tito Cees, Tita Merle and family, Eva and Ton, Jean and Dolores for their kindness and warm hospitality. I thank past and present roommates and fellow students at the Haarweg building and specially Zhao Dule, who was also finishing his thesis at the same time as I was, for sharing many tips on how to finish the thesis and keep my sanity. I also thank my friends from all over for the shared meals, beers, conversations and a glimpse to your wonderful culture: Arjan, Deon, Jing, Lizhen, Milagros, Ni, Sander, Surajit, Tashi, Tassi, Tin, Tommie. There are so many more people here in Wageningen, Los Baños and Ilocos Norte who gave me support but it is impossible to name everyone here. To all my friends, thank you.

Finally, I would like to thank my parents and brothers for their support. My father encouraged us to go out and see the world and my mother underscored the value of a good education and working hard towards my goal. I am fortunate to be in a supportive environment that continues to encourage me to pursue my dreams and aspirations.

Alice G. Laborte Wageningen, March 2006

Contents

CHAPTER 1

General introduction

Issues in land use policy formulation

More than ever before, the way in which land is being used has become an issue of widespread concern. The population of the world has surpassed 6 billion; and continues to increase; hence, the demand for food will further grow (World Bank, 2003). Moreover, income of especially the urban population will continue to increase. This will lead on one hand to changes in diets, with larger shares of animal products, and on the other hand to higher demands for land for alternative uses, such as infrastructure, employment, nature and recreation. The associated widening welfare gap between the rural and the urban population provides an incentive for farmers to change land use from growing staple commodities, such as wheat and rice to growing more remunerative commodities, as vegetables and fruits. Expansion and intensification of crop and animal production increase the risks for environmental problems as a result of increased use of agro-chemicals (fertilizers and biocides) and (over-)production of animal manure. As a consequence of all these developments, many different groups of stakeholders have an active interest in the way the land is or will be used.

These claims on land pose increasing challenges to land use and agricultural policy formulation, the aim of which is directed at selecting and adopting the 'best' use of land by systematically assessing its potential and alternative uses, under the prevailing economic and social conditions (FAO, 1993). The 'best' use of scarce resources, however, is subjective and contentious as different (groups of) stakeholders have different goals and aspirations. This calls for development of new methodologies for land use analysis, as a basis for formulation of land use plans and policies.

Potential role of land use analysis

Land use analysis can contribute to effective land use policy formulation by providing a platform for joint-learning about prevailing land use issues and their associated implications. Analyses that provide a quantitative assessment of the trade-offs involved can enhance discussion among stakeholders and facilitate negotiations towards arriving at an agreement about how best to use limited resources. Similarly, land use analysis can be used to evaluate various policies that affect land use. In particular, model-based land use analysis can provide insights in likely effects of policies yet to be implemented. This provides useful information to policy makers and natural resource use managers.

Methodologies for assessing agricultural land use should be based on thorough knowledge of the agro-technical possibilities (e.g., climate, soils), as well as the socio-economic boundary conditions under which land use is taking place. Some land use studies are more biophysically-oriented, and deliberately ignore the current (socio-economic) constraints to identify opportunities or technically possible future situations

(WRR, 1992; Rossing et al., 1997). Other studies, on the other hand, are more oriented towards socio-economic aspects (Kruseman et al., 1995). Recently, studies have been conducted to arrive at a more integrated approach to link biophysical processes with farmers' resource management decisions (e.g., Barbier and Bergeron, 1999; Kruseman and Van Keulen, 2001).

Likewise, the aims and aspirations of the different stakeholders have to be taken into account in land use studies. Goals of stakeholders within the same and at different decision scales vary. Farm households usually attach priority to self-sufficiency of the household and increased welfare. The behaviour of the farmers, being the actual decision-makers, should be considered to examine the scope for land use change. When the response of farmers to certain policies is not taken into account, such policies often do not achieve the desired results. In addition, responses of farmers need to be aggregated, since policies are developed, implemented and evaluated at a higher scale than the farm (Hazell and Norton, 1986). At regional scale, policy makers may have different and in some cases non-complementary goals, such as economic development and environmental protection. An approach that considers different decision-makers and planners at aggregated (municipal, provincial, regional, national) scale on one hand and farmers on the other is therefore crucial. Hence, a multi-scale approach that can support policy discussions and decision-making on rural development, including agricultural land use is the topic of this thesis. The approach is developed and applied using Ilocos Norte in the Philippines as a case.

Description of the study area

Overview

The province of Ilocos Norte is situated in the northwestern part of the Philippines (Figure 1). It is bounded in the east by the Cordillera mountain range, in the south by Ilocos Sur province and in the west by the South China Sea. Laoag City is the seat of the provincial government and is about 487 km north-northwest of Manila, the national capital.

The total land area in Ilocos Norte is 0.36 million ha, about one-third of which is classified as agricultural land. Various landforms, from coastal lowlands to steep mountains exist in the province. The relatively fertile lands are concentrated in the narrow coastal plains and inland valleys, plains and alluvial fans. The Cordillera mountain range makes up the eastern portion of the province.

The province comprises 23 administrative units: 22 municipalities and 1 city, and is sub-divided into 557 villages or *barangays*. The total population, according to the Census of Population and Housing in 2000, is 514 thousand with an average annual

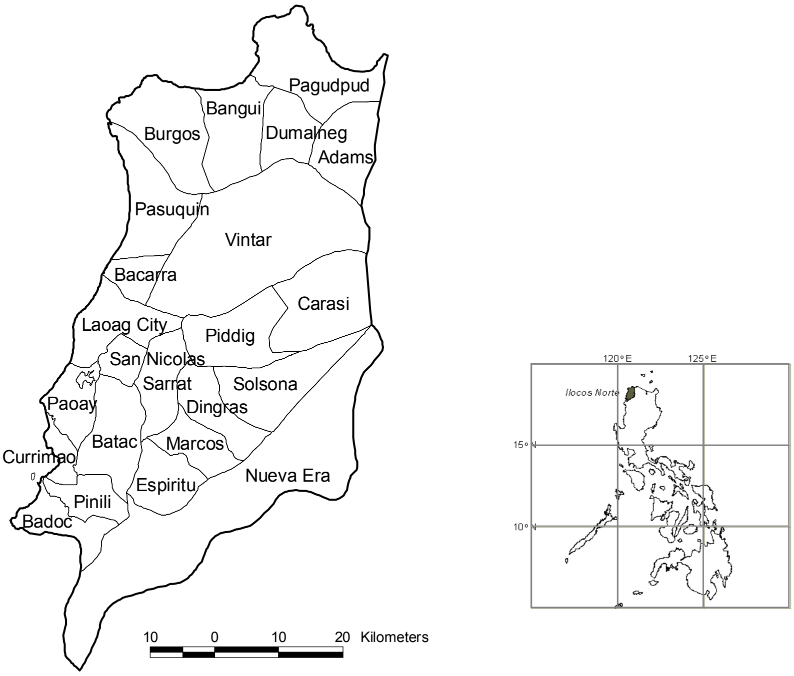

Figure 1. Map of Ilocos Norte province, Philippines.

growth rate of 1.3%. The economically active population (ages 15 to 64) comprises 61% of the total population and for every 10 economically active persons, there are 6 dependents (NSO, 2002).

Ilocos Norte's economy is mostly agriculture-based. The lowland areas are cultivated intensively, while the upland and hilly areas are sparingly used. Agricultural production is characterized by rice-based systems. Rice is usually planted in the wet season (June to October), and a variety of crops is grown in the dry season, e.g., tomato, garlic, onion, sweet pepper, tobacco and mungbean. The province is considered a key grain area for rice and is a major supplier of rice for the whole Ilocos Region[1] and beyond. In addition to rice, the province produces more corn, vegetables, legumes and fruits than the sufficiency level in the province (Cosio et al., 1998). Average farm size, based on the latest census of agriculture and fisheries (2002) is 0.76 ha – 8% lower than in 1991 (NSO, 2004). Land holdings of farmers in Ilocos Norte are fragmented. Based on a sample of 100 farm households in 10 municipalities in Ilocos Norte, farm households have on the average 4 parcels of 0.4 ha each (Lucas et al., 1999).

Average annual rainfall in the province is about 2,000 mm, with almost 90% of the rainfall concentrated in the wet season (Figure 2). There are 13 national irrigation

[1] Ilocos region consists of the provinces of Ilocos Norte, Ilocos Sur, Pangasinan, and La Union.

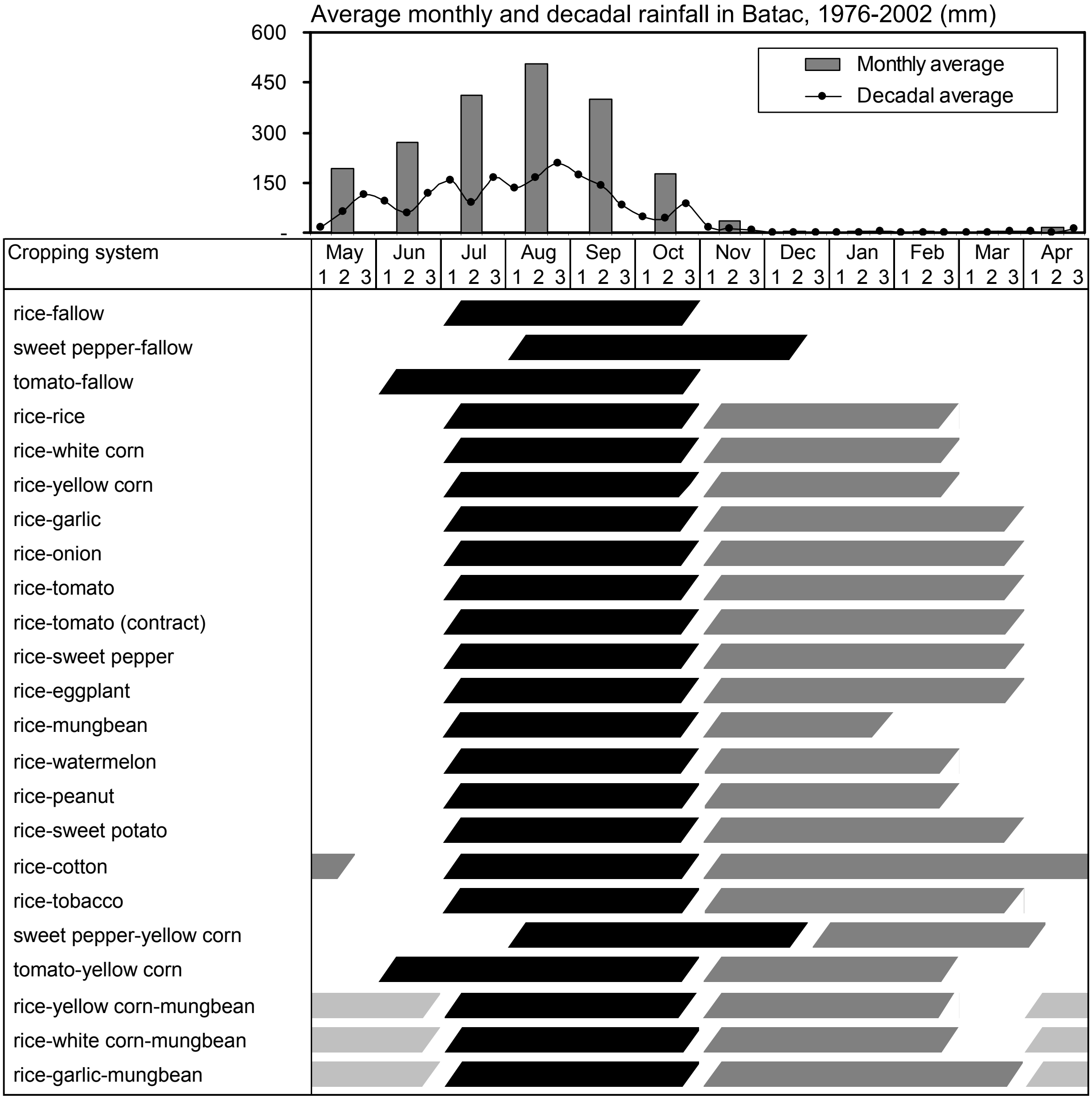

Figure 2. Average rainfall and cropping systems in Ilocos Norte province.

systems operational and 649 communal irrigation systems, constructed by the National Irrigation Administration (NIA) in the province with an aggregate service area of 35,461 ha. The actual irrigated area covered by these systems, however, is only 80% of the supposed service area in the wet season and 40% in the dry season, due to inadequate water availability and inefficient irrigation systems. In addition, farmers own irrigations pumps to supplement the water supply to meet the requirements of crops, especially in the dry season.

The Provincial Government of Ilocos Norte envisions that the province will be self-sufficient in food and become an agro-industrial center in the Northern Luzon Growth

Table 1. Some characteristics of various decision levels that affect agricultural land and resource use in Ilocos Norte province, Philippines.

Level	Decision-makers	Goals	Decision areas
National	President Law-makers (Senate and Congress) Departments and government gencies (e.g., National Economic and Development Authority, Finance, Housing and Land Use Regulatory Board, Public Works, Agriculture, National Irrigation Administration)	Food security (rice self-sufficiency) Poverty alleviation Economic growth Social equity Employment Environmental protection	National development plan Taxation Subsidies Infrastructure Interest rate Research and extension
Region (Ilocos region[a])	Regional Development Council Regional Agriculture and Fisheries Council Regional Tripartite Wages and Productivity Board	Food security Economic growth Employment Environmental protection	Regional development plan Subsidies Infrastructure Research and extension Minimum wage
Province (Ilocos Norte)	Governor Provincial Development Council Provincial Planning and Development Office Provincial Agriculture Office	Food security Economic growth Employment Environmental protection	Provincial development plan Subsidies Infrastructure Extension
Municipality (Batac)	Mayor Municipal Development Council Municipal Planning and Development Office Municipal Agriculture Office	Food security Economic growth Employment Environmental protection	Municipal development plan Subsidies Infrastructure Extension
Farm	Farm household	Subsistence Cash income Risk reduction	Resource allocation Production plan Investment strategies

[a] Ilocos region consists of the provinces of Ilocos Norte, Ilocos Sur, Pangasinan, and La Union.

Corridor. Policies and programmes in the province are geared towards that vision. Table 1 gives some characteristics of various decision levels that affect agricultural land and resource use in Ilocos Norte province.

Batac municipality Batac, the most populous municipality in Ilocos Norte, is 15 km south of Laoag City, the provincial capital, and 472 km north of Manila and has a population of 47,682, which is an average of 3 persons per ha, based on the Census of Population and Housing of 2000 (NSO, 2002). It has 43 villages, 29 of which are classified as rural. The annual population growth rate between 1995 and 2000 was at 0.9%, lower than that of the province.

The municipality has a total land area of 16 thousand ha, of which two-thirds are in use for agriculture, mostly in rice-based cropping systems. As in the whole province, rice is usually planted in the wet season (June to October), while in the dry season a variety of crops is grown, using mainly groundwater for supplemental irrigation.

Constraints and opportunities (PGIN, 1999)

Based on a series of participatory and consultative workshops, key informant interviews, assessment surveys and analyses of secondary data, the core problems identified for agricultural and rural development in Ilocos Norte are the low levels of agro-fishery productivity and income. Among the major contributing factors are: land constraints (more than 70% of the land area is vulnerable to soil erosion and sedimentation problems), scarcity of labour during peak labour months, resulting in high farm labour costs, high costs of farm inputs, limited capital investment, under-developed and inefficient irrigation systems, low level of farm mechanization, inefficient extension service, limited access to improved production technologies, low farm gate prices, poor condition of farm-to market roads, seaports and airports, natural calamities and the threats of the El Niño and La Niña phenomena (Figure 3).

The major effects of low levels of agricultural productivity and income are:

- Subsistence farming and food insecurity in rainfed and inaccessible areas;
- Increased inflow of imported food crops from other provinces and from abroad;
- Limited outflow of farm surpluses to other provinces and poor export prospects;
- Urban and overseas migration in search of better employment opportunities;
- Low living standards among farming households.

Despite the constraints, the province has favourable prospects for agriculture and rural development. Ilocos Norte has appreciable surface- and groundwater resources for agriculture. Expansion and improvement of current irrigated areas could increase cropping intensity and boost production. The province's proximity to East Asian countries means a high potential for exports of key products to these countries. An

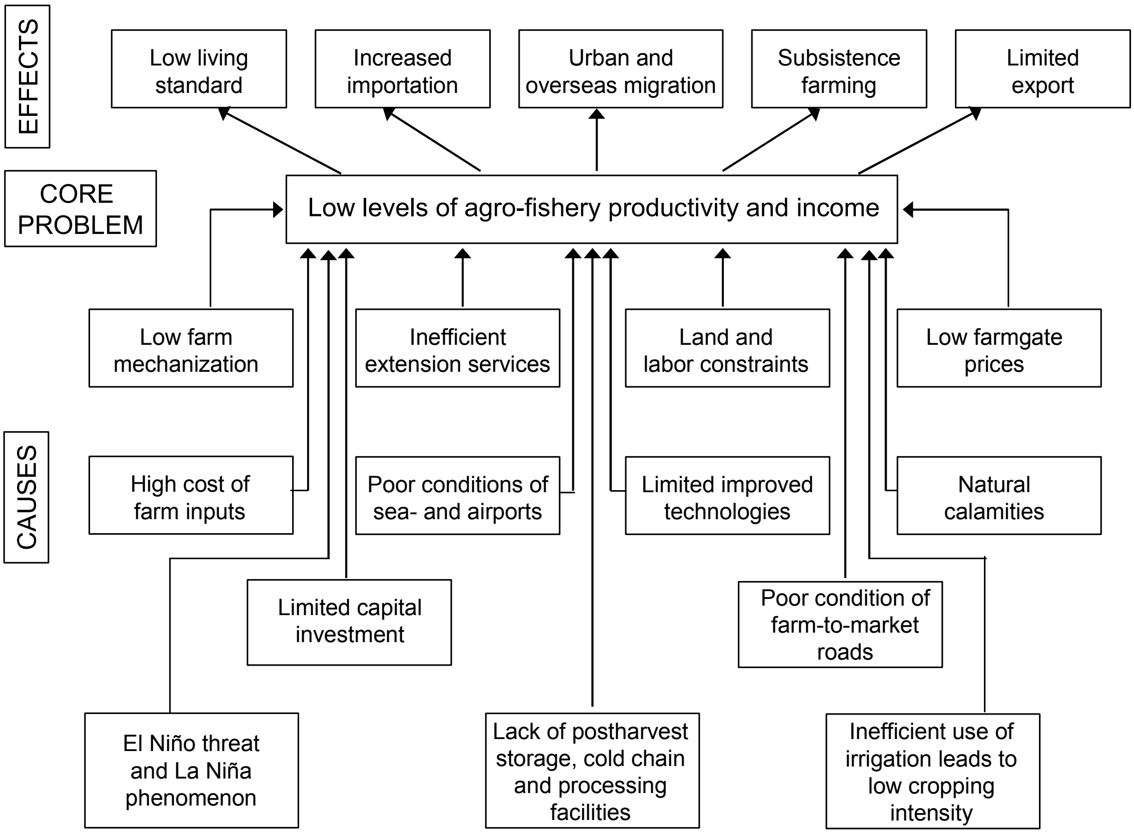

Figure 3. Constraint analysis for Ilocos Norte province (Source: PGIN, 1999).

international airport located in Laoag City, as well as a seaport (in the municipality of Currimao, 23 km south-west of Laoag City), which when upgraded and rehabilitated could contribute to improved export-import trade and agro-industrial development. Moreover, there has been increased financial support and assistance as a result of inclusion of the province in a special infrastructure and development programme, as well as higher levels of remittances from overseas contract workers and migrants from Ilocos Norte.

The planning process

The National Economic Development Authority (NEDA) is the central economic and social development planning agency in the Philippines. There are 15 administrative regions and the Regional Development Council (RDC) in each region is attached to the NEDA for planning and policy coordination. One of the functions of the RDC is to translate the national economic goals into more specific regional objectives and incorporate these into the regional plans. Local governments (provinces, municipalities, cities) have local planning and development officers. Coordination of planning among provincial agencies is done through the Provincial Development Council (PDC). One of the functions of the PDC is to develop a provincial development plan based on the guidelines issued by the RDC and at the same time, integration of the different municipal development plans. Similarly, the Municipality/City Development Council (MDC) is in charge of the preparation and coordination of the municipal/city development plans (Lawas, 1983).

Figure 4 shows the hierarchy and linkages of the different land use, development, and investment plans formulated for the different scales – national down to municipal/city scales.

The National Physical Framework Plan (NPFP) provides a national land use policy agenda to achieve national development goals. This serves as a guide for planners, policy makers and technical officers in the allocation, management and development of land resources. The Provincial Physical Framework Plan (PPFP) considers both the NPFP and the Regional Physical Framework Plan (RPFP) and translates the provincial policies and development goals into a general land use plan that provides direction for the next 10 years. The PPFP gives an indication of the extent of urban expansion of the

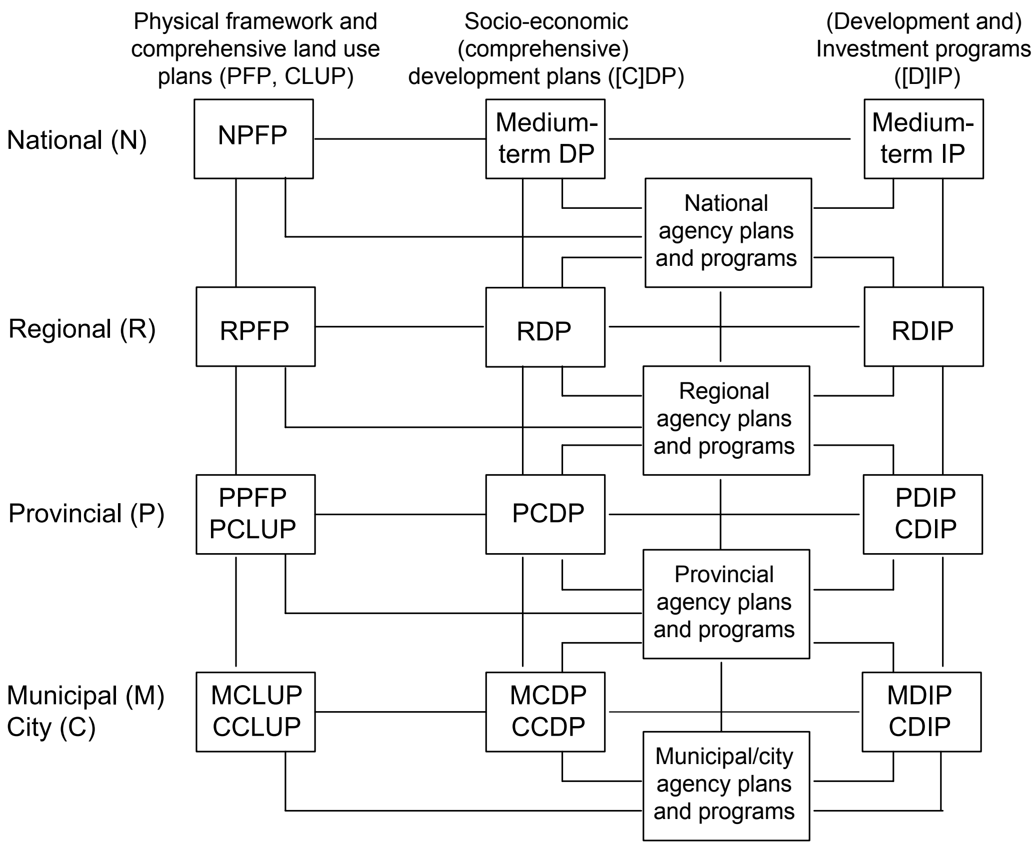

Figure 4. Hierarchy and linkages of plans from national to municipal/city levels (Source: PDC, 1997).

municipalities and component cities in the province, the location of major infrastructure projects and all major land development proposals of provincial, regional or national significance. The draft PPFP is endorsed by the PDC for public hearing. During this public hearing, comments and suggestions are taken from different government agencies, the private sector and other stakeholders. The PPFP will be refined and then endorsed by the PDC to the *Sangguniang Panlalawigan*[2] (SP) for adoption. The PPFP will be endorsed by the SP to the RDC/Regional Land Use Committee (RLUC) for review and it will then endorse the PPFP to the Housing and Land Use Regulatory Board (HLURB) for review and ratification (Figure 5; PDC, 1997). The process from formulation, refinement and ratification takes quite some time and in many instances the plan has been implemented already a couple of years before it is finally approved. The PPFP serves as a guide for the municipality/city in the preparation of land use plans for the locality. The physical framework plan provides the over-all framework in the preparation of development plans.

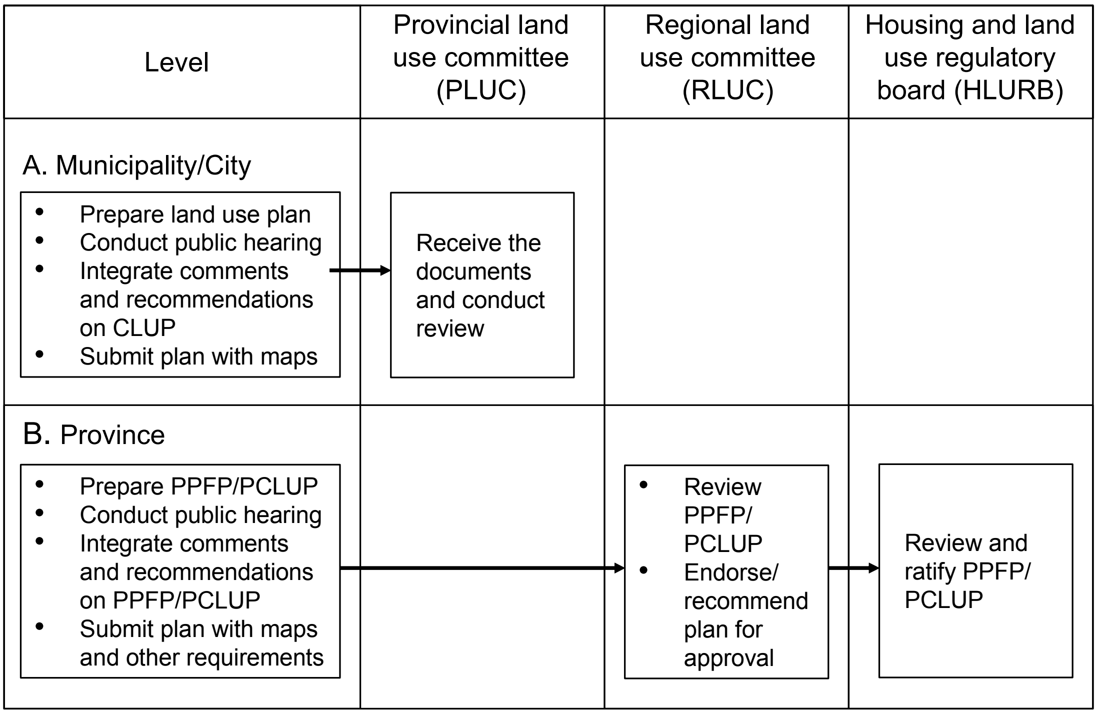

Figure 5. Process flow chart on review, approval and ratification of land use plans (Source: PDC, 1997). Note: PPFP = Provincial Physical Framework Plan; [P]CLUP = [Provincial] Comprehensive Land Use Plan.

[2] The *Sangguniang Panlalawigan* (Provincial Board) is the legislative branch of the province and consists of elected officials with the Vice-Governor as the presiding officer.

The provincial plan may not be exactly complementary to the municipal plans, because the former also takes into account the regional and the national targets. Generally, the provincial plan strictly follows the regional plan, particularly for crops such as rice and corn. The provincial office takes into account the population and available resources in the province when defining production targets. However, in some municipalities, targets are not always met (Libed, Office of the Provincial Agriculturist, Ilocos Norte, personal communication).

To meet production targets, the provincial and municipal agriculture offices conduct programmes and extension work, such as the introduction of technological innovations through techno-demonstrations[3], seed exchange or distribution programmes[4], revival of cooperatives, and distribution of shallow tubewells and construction of small farm reservoirs through cooperatives.

Objectives of the study

This study aims at developing and applying a model-based multi-scale approach that can support joint-learning, policy discussions and decision-making with respect to agricultural land use. This approach enables analysis of the effect of competing objectives at different hierarchical scales, and allows *ex-ante* analysis of agricultural and natural resource use policies, including assessment of the potentials of new agro-technologies.

The specific objectives of the study are:

1. To characterize the biophysical, socio-economic and policy environment, and identify possible conflicts in land use objectives at three decision levels: farm, municipality (sub-region) and province (region);
2. To develop an operational link between regional land use optimization and farm household modelling to analyse land use options that takes into account goals of the stakeholders at the different decision levels;
3. To evaluate the effectiveness of alternative technologies and policies in achieving economic, social and environmental objectives of stakeholders at different scales.

The methodology is operationalized for the province of Ilocos Norte, Philippines in consultation with stakeholders in the region.

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[3] In techno-demonstrations, farmer cooperators (for both techno-demo and non techno-demo farms) are selected. Certified seeds and inputs are provided to the cooperators and a techno-demo coordinator monitors their activities.

[4] This programme has taken two forms and is applied to rice: (1) the agricultural office gives seeds to farmers and at harvest time, the farmers will return twice the amount of seeds loaned to them, (2) the agriculture office sells seeds to farmers at half the price, but farmers have to pay upon getting the seeds. The latter seems more successful.

Outline of the thesis

Chapter 2 presents the empirical base of the models presented in subsequent chapters and describes the views of stakeholders at the farm, municipal and provincial scales.

The methodologies used for multi-scale analysis are presented in Chapters 3, 4, 5 and 6. Chapter 3 discusses the farm household model and its application in the adoption of alternative technologies and Chapter 4 describes the provincial model. Chapter 5 discusses the multi-scale analysis, including the municipal models and Chapter 6 gives the mathematical description of the models at different scales.

An application of the multi-scale framework in assessing agricultural policies is exemplified in Chapter 7.

Finally, Chapter 8 presents a general discussion and the prospects of model-based analysis in participatory policy-making.

CHAPTER 2

Empirical base of the models[1]

[1] The section on current and alternative production activities is partly based on:
Ponsioen, T.C., **Laborte, A.G.**, Roetter, R.P., Hengsdijk, H., Wolf, J., 2003. TechnoGIN-3, a technical coefficient generator for cropping Systems in East and Southeast Asia. Quantative Approaches in Systems Analysis No. 26., Wageningen, The Netherlands, 69 p.; and
Ponsioen, T.C., Hengsdijk, H., Wolf, J., Van Ittersum, M.K., Roetter, R.P., Son, T.T., **Laborte, A.G.**, 2006. TechnoGIN, a tool for exploring and evaluating resource use efficiency of cropping systems in East and Southeast Asia. Agricultural Systems 87, 80-100.

Introduction

This chapter describes the empirical bases of the models presented and discussed in subsequent chapters. The next section describes the views and perceptions of stakeholders in Ilocos Norte. The succeeding section discusses the results from the farm household surveys that were used as basis for the farm typology and quantification of input-output of production activities in Ilocos Norte. Finally, details about the current and alternative production activities used in the models are presented.

Views and perceptions of stakeholders

Frequent interactions with stakeholders in Ilocos Norte were held from 1997 to 2004 to identify the problem issues and the differences in interest among stakeholders at the provincial, municipal and farm scales, co-develop the models and elicit comments on preliminary model results (see Appendices).

Interactions with stakeholders started as part of the SysNet project[2], in which government planners, provincial and municipal agricultural officers, and scientists from institutions in the province, such as Mariano Marcos State University (MMSU), were involved in a series of so-called stakeholder-scientist meetings. In these meetings, stakeholders were involved at the beginning and the end of week-long workshops, to provide information on objectives and constraints to agricultural development at farm, municipal, provincial or national scale. They also provided data, and reviewed results of scenario analyses (Roetter and Laborte, 2000).

The goals for the province, identified jointly by the planners and agricultural officers from the province and different municipalities during these interactions include: (a) expand rice production, (b) increase cash crop production, (c) increase employment in agriculture, (d) increase input use efficiency, and (e) increase farmers' income (Roetter et al., 2005). Just by looking at this list, conflicts among the goals specified are obvious. Expansion of rice production and increasing area under cash crops are clearly conflicting goals. In addition, increasing gainful employment in agriculture may also conflict with increasing farmers' income as the former will require hiring in of more labour which may mean higher cost of production for farmers.

When presented with the model details and assumptions, stakeholders expressed demands for model extension with other production activities (other crops and livestock). Similarly, the necessity for multi-level analyses surfaced from the request by stakeholders at the municipal level for similar analyses for their own municipalities

[2] Systems Research Network for Ecoregional Land Use Planning in Tropical Asia (SysNet) was launched in 1996 and developed and evaluated a methodology for land use analysis in four case study regions including Ilocos Norte province, Philippines.

instead of just presenting results for the province. Also, questions such as how to induce farmers to adopt better farm practices were raised, particularly by the municipal agriculturists. The provincial model developed at that time, could not answer all the questions raised. The question on technology adoption, for instance, can only be answered if farm-level decision-making is incorporated in the provincial model.

In the course of the study presented in this thesis, interaction with stakeholders began in June-July 2001 with an intensive farm survey in Batac. Subsequently, other stakeholders in Batac and in the provincial government offices in Ilocos Norte were interviewed, and focused group discussions were conducted to determine their perceptions on the problems and opportunities for agricultural development in their area, and to present preliminary model results. Interviews were conducted in 2002 (June and October), and in April 2003 a scientist-stakeholder workshop was conducted in the framework of the IRMLA project[3]. Further interviews and field visits were conducted in the second half of 2003 (August and October), when technical coefficients for the different alternative technologies and model assumptions were discussed and preliminary outputs were presented (in separate meetings) to the agricultural technicians in Batac and scientists at MMSU involved in the IRMLA project. Another IRMLA scientist-stakeholder workshop was held in March 2004. Based on these many consultations, farm and municipal models were adapted.

Table 1 lists some stakeholders and their interests relating to land and resource use. In reality, there are more people with a stake in resource use in the province, but the interviews were limited to the stakeholders identified here. Their vision for the province/municipality/community and their favoured direction for development are summarized in Table 2. Commonly specified by stakeholders at different levels is the aspiration of generating higher revenues for the province/municipality/farm and the alleviation of problems associated with production and marketing (e.g., mechanization, improvement of irrigation facilities and roads). Stakeholders, particularly at the provincial level, specifically mentioned food security/self-sufficiency and improved environmental conditions (e.g., forest rehabilitation).

Common issues raised by most stakeholders when asked about the main problems relating to agricultural production and natural resource management, pertain to lack of irrigation facilities, insufficiency of water for irrigation particularly during the dry season, marketing of produce, and high cost of production inputs (Table 3). *Perceptions* of stakeholders, however, *varied* on land conversion and environmental issues. Some stakeholders asserted that conversion of agricultural land to other uses has been happening at a small scale, whereas others considered it a serious problem.

[3] The Systems Research for Integrated Resource Management and Land Use Analysis in East and Southeast Asia (IRMLA) includes four study regions including Ilocos Norte province, Philippines.

Table 1. Interests of stakeholders at different levels on land and resource use.

Stakeholder group	Interests at stake
Province	
Governor	Formulation of plans and policies for the province Achievement of development targets
Provincial Planning and Development Office (PPDO)	Integration of development plans for different sectors Studies/investigations necessary to develop plans People participation in development planning Coordination with government agencies and NGOs
Provincial development council (PDC) [a]	Development of long-term, medium-term and annual plans and policies for the province Prioritization of development projects Preparation of budget for development projects Coordinate, monitor and evaluate implementation of development programmes
Office of the Provincial Agriculturist (OPAG)	Development of plans and strategies for the agricultural sector in the province Definition of production targets for the province Extension and on-site research Transfer of appropriate technologies
National Irrigation Administration (NIA-Provincial office)	Survey, planning and implementation of communal irrigation projects Rehabilitation and improvement of existing irrigation systems Organization and training of irrigators' association
Provincial Environment and Natural Resources Office (PENRO)	Strategies relating to environmental and natural resources protection and conservation Water, soil resource utilization and conservation projects
Municipality	
Mayor	Formulation of plans and policies for the municipality Achievement of development targets
Municipal Planning and Development Office (MPDO)	Integration of development plans for different sectors Studies/researches necessary to develop plans People participation in development planning Coordination with government agencies and NGOs

Table 1. Continued.

Stakeholder group	Interests at stake
Municipal Development Council (MDC) [b]	Development of long-term, medium-term and annual plans and policies for the municipality
	Prioritization of development projects
	Preparation of budget for development projects
	Coordinate, monitor and evaluate implementation of development programmes
Municipal Agriculture Office (MAO)	Development of plans and strategies for the agricultural sector of the municipality
	Identification of production targets for the municipality
	Transfer of appropriate technologies
Municipal Agriculture and Fisheries Council (MAFC) [c]	Participation of agricultural and fisheries sectors in development of plans, programmes and policies.
Farm	
Farmers	Knowledge about alternative production techniques
	Choice of crop and production technique
	Information about collective results of individual choices
Other	
Mariano Marcos State University (MMSU)	Development of appropriate technologies
	Extension

[a] The Provincial Development Council is headed by the governor and consists of mayors of the municipalities and component cities under the province, the chairperson of the committee on appropriations in the Provincial Board (*Sangguniang Panlalawigan*), the congressman or his representative, and representatives of non-government organizations operating in the province. The secretariat of this council is headed by the Provincial Planning and Development Office.

[b] The Municipal Development Council is headed by the mayor and includes the heads of villages under the municipality, the chairperson of the committee on appropriations in the Provincial Board or Municipal Council (*Sangguniang Panlalawigan* or *Sangguniang Bayan*), the congressman or his representative, and representatives of non-governmental organizations operating in the municipality (including MAFC). The secretariat of this council is headed by the Municipal Planning and Development Office.

[c] The Municipal Agriculture and Fisheries Council is headed by a representative from a non-governmental organization and the vice chairman is from the Municipal Agriculture Office. The chairman of the MAFC is a member of the MDC.

Table 2. Vision for the province/municipality/community of different stakeholders.

Stakeholders[a]	Vision for the province/municipality/community (10 years from now)	Favoured direction of growth		
		Agriculture based	Agro-industrial based	Others
Province				
PPDO	Agriculturally self-sufficient		x	
	Tourism boosted			
	Bare lands planted with trees to avoid floods			
OPAG	Food secure province		x	
	Market connections with Korea, Japan, Hongkong, Taiwan (where off-season coincides with harvest time in Ilocos)			
NIA	Increased yields of rice and other crops	x		
	High income			
	Irrigators associations are viable			
	Adequate operation of irrigation systems			
DENR	Food secure province			Ecotourism
	Forests rehabilitated			
Municipality (Batac)				
Mayor	Batac will be the centre for agriculture, education, health and wellness in the region	x		
	Batac will be the biggest market centre catering also for nearby municipalities			
	Improved lives of constituents, particularly farmers			
	Abreast with latest trends in agriculture			
MPDO	Improved economic situation of residents	x		
MAO	Fully mechanized agriculture (not only in land preparation but also in harvesting)	x		
ATs	Abundant water supply		x	
	Fully constructed irrigation systems			
	Fully mechanized farming/modern agriculture			
	Marketing of produce no longer a problem			
	Presence of various processing plants for agricultural commodities			
	Good farm to market roads and bridges			
	NIT (newly industrialized town)			
Farm				
Sitio 2, Brgy. Baay (irrigated)	No water shortage		x	
	Higher income			
	Improved standard of living of residents			
	Availability of complete sets of farm implements			
Sitio Dutdut, Brgy. Colo (rainfed)	Higher income	x		
	Availability of complete sets of farm implements			
	Improved roads			
	Irrigation system in place			
	Learned new/improved production techniques			
Other				
MMSU (IRMLA)	No more problems with marketing of produce – with linkage to institutional buyers and international markets		x	

[a] See Table 1 for acronyms.

With respect to environmental issues, different stakeholders, even at the same scale, appeared to have different perceptions. Some were of the opinion that environmental problems were hardly an issue, whereas others mentioned issues such as flooding, nitrate pollution, salinization, siltation, and soil erosion as major problems in Ilocos Norte. The two farmer groups, however, did not raise any environmental issues when asked about their main problems.

In separate focused group discussions, farmers and agricultural technicians were asked to identify existing practices and production technologies and the reasons they are adopted or not-adopted by farmers in Batac. A common reason for adoption is perceived advantage derived from the practice (Table 4). On the other hand, high labour requirements and an inherent resistance to change ('not used to it') seem to deter adoption of new practices.

Among the model assumptions that were revised during discussions with stakeholders in Ilocos Norte were specific coefficients on input use in some alternative technologies, resource availability (provincial and municipal models), and constraints on areas allotted to off-season vegetables (farm model). The different models, the results of which are presented in succeeding chapters of this thesis, have been substantially improved since the last version presented to stakeholders and we plan to present scenario analyses to stakeholders in Ilocos Norte again, possibly at the second half of 2006.

Farm surveys

Land use models were developed to examine resource use options at the provincial, municipal and farm household scales. In developing these models, data from two farm surveys were used: an extensive survey conducted in the whole province of Ilocos Norte and an intensive survey in Batac municipality.

The extensive farm survey was conducted in 1999 (SysNet, unpublished data). In this survey, purposive sampling was used to obtain input-output information for the dominant crops planted in the different municipalities during the 1998-99 crop year. A total of 1,957 fields in the wet season and 2,284 fields in the dry season in the province were surveyed. Information collected included farm size, crops grown, yields, material inputs (e.g., fertilizer, pesticide), labour use, and other costs. This dataset, however, does not include information required in developing a farm household model. For that purpose, the intensive survey was used.

Table 3. Perceptions of stakeholders on the main problems relating to agricultural development and natural resource management in Ilocos Norte.

Stakeholder	Perceptions of main problem:					
	Resource availability	Farm inputs	Marketing and accessibility	Conversion of agricultural land	Environmental issues	Others
Province						
Provincial Planning and Development Office (PPDO)	Insufficient irrigation water during the dry season Too much water during the wet season	Dependence on inorganic fertilizer	Marketing of products a big problem	Not a problem	Flooding associated with typhoons, Erosion, Soil degradation due to heavy use of inorganic fertilizers	Pests (snails)
Office of the Provincial Agriculturist (OPAG)	Limited irrigation infrastructure		Poor farm to market roads	Big problem	Not so much of a problem	
National Irrigation Administration (NIA)	Limited irrigation infrastructure					Natural calamities damage irrigation facilities
Provincial Environment and Natural Resources Office (PENRO)					Siltation of rivers, Logging	
Municipality (Batac)						
Mayor	Insufficient irrigation water Limited irrigation infrastructure		Small market	Not much conversion of agricultural land in Batac	Siltation (due to indiscriminate cutting of trees for the tobacco industry), Not much other environmental problems due to stringent policies	
Municipal Planning and Development Office (MPDO)	Land fragmentation			Small scale conversion	Flooding associated with typhoons, Siltation	

Table 3. Continued.

Stakeholder	Perceptions of main problem:					
	Resource availability	Farm inputs	Marketing and accessibility	Conversion of agricultural land	Environmental issues	Others
Municipal Agriculture Officer (MAO)	Limited irrigation infrastructure, Limited capital	High cost of farm inputs	Lack of market outlets		Not too much environmental problems	
Agricultural Technicians (AT)	Limited irrigation infrastructure, Insufficient irrigation water	High cost of farm inputs	Lack of market outlets, Poor farm to market roads		Soil erosion due to logging and slash and burn	
Farm						
4 farmers from Sitio 2, Brgy. Baay (with surface irrigation)	Insufficient irrigation water, Lack of capital	High cost of fertilizers and pesticides	Low price of produce			Pest and diseases (tungro, snail), Lack of farm implements
4 farmers from Sitio Dutdut, Brgy. Colo (no surface irrigation)	Too much water during typhoons Insufficient rain during El Nino Lack of capital	High cost of fertilizers and pesticides	Low price of produce due to over-production			Natural calamities
Other						
MMSU (IRMLA)		High cost of inorganic fertilizers		A problem due to urbanization of Batac	Nitrate pollution from intensive cropping systems, Lowering of water table due to heavy pumping of water, Salinization, Soil erosion not so serious	Build-up of pests

Table 4. Crop production practices and technologies introduced in Batac and reasons for adoption/non-adoption by farmers.

Practice/ technology	Responses of farmers		Responses of agricultural technicians	
	Reasons for adoption	Reasons for non-adoption	Reasons for adoption	Reasons for non-adoption
Use of certified seeds and hybrids	Observed good results (higher yield)		Farmers observed high yields	
Balanced fertilization strategy (BFS)	Avoided wastage	Not used to it Requires too much time (application of organic fertilizers)	Better productivity Less cost	Farmers do not see immediate results
Integrated pest management (IPM)	Proper timing of spraying is more effective against pests	Not effective for tobacco (worms will eat their crops) Lack of supply of needed biological control	Reduced cost	
Straight row planting for rice		Not used to it Requires too much time and effort		Too laborious
Planting of off-season crops			High profit	Used to growing in-season crops

The intensive farm survey was conducted in 2001 in rural villages in the municipality of Batac. Of the 43 villages (*barangays*) in Batac, 29 are classified as rural. From a total of 6,665 farming households, a stratified random sample of 150 was taken from rural villages in Batac[4] with the sampling size in each village proportional to the number of farming households. On average, 2.25% of the farming households in each village were interviewed, resulting in a mix of farmers with irrigated, rainfed lowland and upland land holdings. The Batac survey included questions about household characteristics, their land use objectives and agricultural problems, characteristics of their farm holdings (size, fertility, topography, ownership, estimated value, distance from abode and market), and other sources of income, in addition to input-output information for crop activities during the 2000-01 crop year. In the subsequent subsections, results refer to the farm survey in Batac, except for the information on input-output relations, for which results from the two surveys were presented.

The data from the extensive survey were used in the provincial model, whereas data from the intensive survey were used for the municipal and farm household models.

[4] Although there are 29 rural villages, only 28 were sampled. During the farm survey, a strong typhoon hit the province. One village, Baoa East, remained inaccessible, hence was dropped from the list. Samples from neighbouring villages were increased to compensate for the farm households in this village.

Characteristics of farm households

Average family size in the sample is 5.1. Farming accounts for 44% of total income, on average, and 75% of the farm households derive income from off-farm (agricultural labourer) and/or non-farm sources. Non-farm sources of income include construction/carpentry, public transport (mostly as tricycle driver), salaried services and trading.

Farm households attach high priority to food production, as reflected in the weights given to different objectives. Those relating to food security (maximize food production and attainment of food self-sufficiency) got the highest accumulated weights, followed by the economic (minimize use of external (paid) inputs and maximize cash income) and employment objectives (Figure 1).

In response to the question about their farming-related problems, that of low product prices had the highest accumulated weight, followed by lack of capital. Other problems identified (in order of decreasing accumulated weights) were water shortage, high fertilizer and fuel prices, market inaccessibility and lack of knowledge on more advanced production techniques, labour shortage and poor soil (Figure 2).

Farms were grouped on the basis of a cluster analysis of the 150 farm households surveyed (Bi and Pradel, 2003). Farm size, quality of farmland (presence of surface irrigation, perceived fertility, topography) and ownership, number of economically active household members (labour force) and value of farm assets were used in the classification, resulting in four farm household types (Table 5): (i) poor households with a farm size of 0.85 ha, of which one-third is owned, (ii) average households with 0.95 ha of mostly surface-irrigated land (average-IR), (iii) average households with 0.91 ha of land, mostly without surface irrigation and half in the uplands (average-RF), and (iv) better-off households with a farm size of 2.54 ha and owning almost 1 ha of farmland.

Land holdings

Average farm size in the sample for Batac is 1.1 ha. This is higher than the 0.76 ha derived from the agricultural census for the province (NSO, 2004). Land holdings are fragmented, with farm households cultivating on average 3.7 parcels of 0.4 ha each. Average distance of the farm to the residence is 0.7 km, ranging from 0 (just next to the residence) to 9 km. Average distance of the farm to the market is 4.7 km (range from 0.1 to 15 km). About one-third of the total farm land is owned by the household. Most of the remaining farm land is rented-in and the most common tenancy agreement is 75:25 share tenancy, i.e., the farmer pays for all production costs (including irrigation fees, if the land is surface-irrigated) and at harvest time gives the landlord 25% of the total economic product.

Figure 1. Land use objectives identified by farm households in Batac, Ilocos Norte. The values correspond to the sum of weights assigned by the respondents. Farmers were asked to assign numbers to the different goals depending on relative importance (high numbers mean more important). The sum of weights assigned to the different goals by one farmer is standardized to 1.

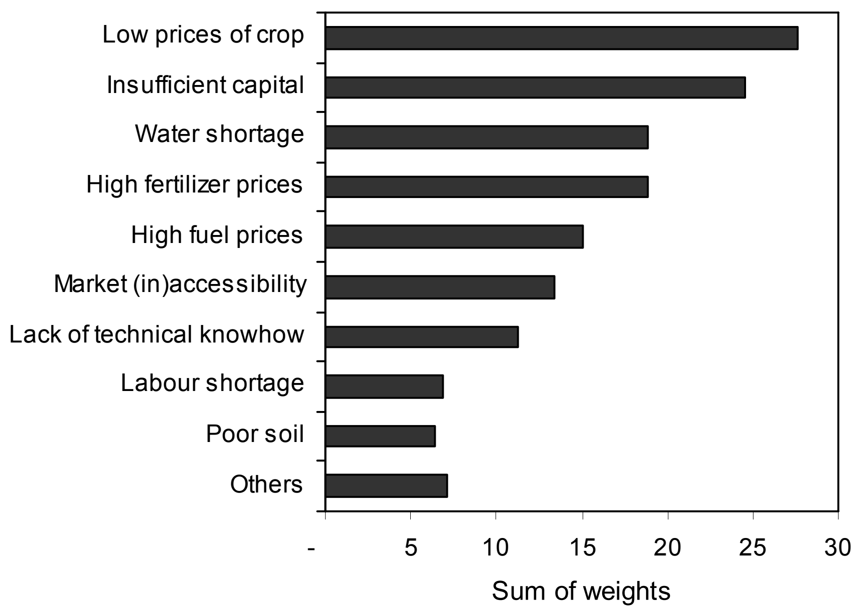

Figure 2. Agricultural problems as perceived by farm households in Batac, Ilocos Norte. The values correspond to the sum of weights assigned by the respondents. Farmers were asked to assign numbers to the different goals depending on relative importance (high numbers mean more important). The sum of weights assigned to the different goals by one farmer is standardized to 1.

Table 5. Characteristics of farm household types in Batac, Ilocos Norte province, Philippines.

Characteristic	Farm household type			
	Poor	Average-IR[h]	Average-RF	Better-off
Family size (persons)	5	5	5	6
Economically active (persons)	3.2	3.4	3.9	4.7
Farm size (ha)	0.85	0.95	0.91	2.54
Owned (% of total)[a]	33	34	41	39
Irrigated (% of total)[b, c]	39	93	4	48
Fertile (% of total)[c]	0	100	100	36
Lowland (% of total)[c]	71	93	51	57
Value of farm assets (10^3 pesos)[d, e]	52	47	52	122
Total income (10^3 pesos)[e, f]	80	90	109	145
No. of farmers surveyed[g]	44	39	55	11

Source: Bi and Pradel (2003).

[a] Proportion of land that is owned by the farm household; the remainder is share-cropped.

[b] With surface irrigation. Includes area irrigated during the wet season only and throughout the year.

[c] Proportion of total cultivated land (owned and rented-in).

[d] Includes the estimated value of draught animals, irrigation pump, tractor, thresher, weeder, sprayer, plough and other farm implements.

[e] US$1 = 51 pesos (2001).

[f] Includes income from crop and livestock activities, wages and remittances.

[g] One respondent was dropped from the list because of extreme values.

[h] Average-IR has mostly surface-irrigated land, whereas Average-RF has mostly land without surface irrigation.

Farmers in Ilocos Norte classify land into four categories depending on topography and drainage characteristics (Lucas et al., 1999). *Bangkag* and *tangkig* are drought-prone fields located in the upper part of the toposequence, whereas, semi-*lungog* and *lungog* fields are located in the lower part. The semi-*lungog* fields are medium-prone to submergence and the *lungog* fields, at the bottom of the toposequence, are generally submergence-prone. Of the sampled fields in the 2001 farm survey, 20% are *lungog*, 31% are semi-*lungog*, 34% are *tangkig* and 15% are *bangkag* fields.

Almost all land is planted to rice in the wet season, except for some upland fields that are planted to corn or vegetables. In the dry season of 2001, about 33% of the total area was planted to tobacco, 20% to corn, 9% to mungbean and 7% to rice. Fifteen percent was planted to different vegetables (tomato, sweet pepper, eggplant). Farmers in Batac are diversifying in terms of crop selection during the dry season: About 16% of the farm parcels were further subdivided and planted with different kinds of vegetables. The criteria cited by respondents for crop selection include soil suitability, profitability, availability of water for irrigation and low input requirements (Table 6).

Farmers were also asked to specify the crops grown on each parcel of land in the last five years. Of the 150 farmers interviewed, 34% changed the cropping system on at least one farm parcel in the last five years. The top two reasons for this change relate to resource availability. Due to labour shortage and insufficient water (in part associated with El Niño), farmers shifted to crops with lower labour and water requirements. In addition, some farmers rotate crops to increase soil fertility (15%) and improve yield (13%), others to increase profit (10%) or in response to changes in market prices of crops (10%). Other reasons given by farmers are listed in Table 7.

Tables 8 and 9 show average yields and input use per crop in the two surveys. Among the dry season crops, tobacco, eggplant and sweet pepper required most labour, and vegetables required high chemical inputs (fertilizers and biocides) in both surveys. Higher average yields for Batac were observed for rice, tomato and sweet pepper. Comparison of the input efficiencies in the two surveys shows that in Batac (2001 survey) farmers used more labour per ton yield in almost all crops and less nutrients per ton yield for vegetables (Table 10). The large differences could be due to imperfect sampling, temporal and spatial differences, differences in resource endowments of farmers and farm management in the different municipalities.

Table 6. Reasons of farmers for crop selection in their fields.

Reasons	% Responding[a]
Suitability of crop to soil	29
High profit	27
Availability of water; low water requirement	16
Low labour requirement	14
Market availability	11
Low capital needed	9
Usual crops planted in the area	8
High selling price for crop	5
Availability of seeds	3
High yield	3
For home consumption	2

[a] Figures will not add up to 100% because of multiple answers of respondents.

Table 7. Reasons of farmers for changing cropping systems in the last 5 years.

Reasons	% Responding[a]
Labour shortage	21
Insufficient water	19
Improve soil fertility	15
Improve yield	13
Change in crop price	10
Increase profit	10
Lack of capital	9
Try other crops	9
Availability of seeds	3
Pests and diseases	3

[a] Figures will not add up to 100% because of multiple answers of respondents.

Table 8. Average yield and input use in farmers' fields in Ilocos Norte province, Philippines[a].

Crop	Number of fields surveyed	Yield ($t\ ha^{-1}$)	Labour use[b] ($d\ ha^{-1}$)	Nutrient use ($kg\ NPK\ ha^{-1}$)	Biocide use ($kg\ a.i.\ ha^{-1}$)
Wet season crop					
Rice	1,957	3.3	76	149	0.1
Dry season crops					
Cotton	13	1.9	26	144	0.7
Eggplant	19	6.7	83	225	1.5
Garlic	324	1.9	66	217	1.4
Mungbean	417	1.1	39	34	0.4
Onion	103	4.4	73	192	1.3
Peanut	163	1.5	39	31	0.1
Rice	309	3.7	72	149	0.1
Sweet pepper	87	5.3	84	276	4.4
Sweet potato	47	6.9	47	70	0.0[c]
Tobacco	188	1.4	90	142	0.5
Tomato	166	17.1	81	277	2.5
Watermelon	31	10.9	42	175	1.6
White corn	40	2.8	35	122	0.2
Yellow corn	377	3.5	36	169	0.2

[a] Results from farm survey conducted in 23 administrative units in Ilocos Norte. Data refer to crop year 1998-99.

[b] Includes family and hired labour.

[c] Less than 0.1 kg a.i. ha^{-1}.

Table 9. Average yield and input use in farmers' fields in Batac, Ilocos Norte province, Philippines[a].

Crop	Number of fields surveyed	Yield ($t\ ha^{-1}$)	Labour use[b] ($d\ ha^{-1}$)	Nutrient use ($kg\ NPK\ ha^{-1}$)	Biocide use ($kg\ a.i.\ ha^{-1}$)
Wet season crop					
Rice	502	4.0	99	165	0.4
Dry season crops					
Cotton	3	1.2	72	264	0.5
Eggplant	8	5.2	148	73	1.5
Garlic	50	1.2	70	115	1.2
Mungbean	59	0.5	42	67	0.1
Onion	0	_	_	_	_
Peanut	0	_	_	_	_
Rice	39	4.3	105	180	0.5
Sweet pepper	17	6.8	113	274	4.3
Sweet potato	0	_	_	_	_
Tobacco	165	1.5	132	79	0.7
Tomato	57	22.3	51	160	1.3
Watermelon	0	_	_	_	_
White corn	74	2.1	68	102	0.1
Yellow corn	41	3.4	64	48	0.1

[a] Based on cropping year 2000-01 from a farm survey conducted in Batac, Ilocos Norte province (28 rural villages). Data are averages of all fields surveyed.

[b] Includes family and hired labour.

Current and alternative production activities in the models

Land units

In all models, farm land was classified in eight land unit classes, based on availability of surface irrigation, soil fertility and topography. Surface irrigation may be available during the wet season only, throughout the year or not at all. Soil fertility (two classes: fertile or poor to average) is based on perceptions of farmer-respondents. For topography, *lungog* and *semi-lungog* fields are classified as lowland, whereas *bangkag* and *tangkig* fields are classified as upland. All farm households own a pump, making water available to all land units during the dry season. Table 11 shows the area per land unit in Ilocos Norte province, Batac municipality and for each of the farm types.

Table 10. Comparison of yield and input use in the two farm surveys.

Crop	Yield ($t\ ha^{-1}$)		Labour use[a] ($d\ t^{-1}$)		Nutrient use ($kg\ NPK\ t^{-1}$)		Biocide use ($kg\ a.i.\ t^{-1}$)	
	Ilocos Norte survey (1999)	Batac survey (2001)	Ilocos Norte survey (1999)	Batac survey (2001)	Ilocos Norte survey (1999)	Batac survey (2001)	Ilocos Norte survey (1999)	Batac survey (2001)
Wet season crop								
Rice	3.3	4.0	23	25	45	41	0.0[b]	0.1
Dry season crops								
Cotton	1.9	1.2	14	60	76	220	0.4	0.4
Eggplant	6.7	5.2	12	28	34	14	0.2	0.3
Garlic	1.9	1.2	35	58	114	96	0.7	1.0
Mungbean	1.1	0.5	35	84	31	134	0.4	0.2
Onion	4.4	_	17	_	44	_	0.3	_
Peanut	1.5	_	26	_	21	_	0.1	_
Rice	3.7	4.3	19	24	40	42	0.0[b]	0.1
Sweet pepper	5.3	6.8	16	17	52	40	0.8	0.6
Sweet potato	6.9	_	7	_	10	_	0.0[b]	_
Tobacco	1.4	1.5	64	88	101	53	0.4	0.5
Tomato	17.1	22.3	5	2	16	7	0.1	0.1
Watermelon	10.9	_	4	_	16	_	0.1	_
White corn	2.8	2.1	13	32	44	49	0.1	0.0[b]
Yellow corn	3.5	3.4	10	19	48	14	0.1	0.0[b]

[a] Includes family and hired labour.

[b] Less than 0.1 kg a.i. t^{-1}.

Land that is surface-irrigated throughout the year can be planted only with rice during both the wet and dry seasons, because of drainage problems. During the dry season, rice is planted in the surface-irrigated areas only, because of its high water requirements and the associated high fuel costs for pumping water. Off-season vegetables (i.e., sweet pepper and tomato grown during the wet season) can only be grown in the uplands, because of the poor drainage conditions in the lowlands.

Crop production activities

The following crops grown in the province were included in the models: rice, white corn, yellow corn, garlic, onion, tomato (contract, non-contract, off-season), sweet

Table 11. Area (ha) per land unit in Ilocos Norte province, Batac municipality and in the different farm types.

Land unit	Surface irrigation	Soil fertility	Topo-graphy	Ilocos Norte	Batac	Farm type[a]			
						Poor	Average-IR	Average-RF	Better-off
IGT	Yes-wet and dry	Good to very good	Lowland	7,414	34	_	0.12	0.04	_
IGW	Yes-wet	Good to very good	Lowland	6,232	221	_	0.76	_	0.37
IPT	Yes-wet and dry	Poor to average	Lowland	7,233	131	0.05	_	_	0.10
IPW	Yes-wet	Poor to average	Lowland	7,150	841	0.28	_	_	0.75
RGL	No	Good to very good	Lowland	15,192	494	_	_	0.42	0.16
RPL	No	Poor to average	Lowland	28,816	1,879	0.27	_	_	0.08
RGU	No	Good to very good	Upland	11,926	1,922	_	0.07	0.45	0.39
RPU	No	Poor to average	Upland	6,886	633	0.25	_	_	0.69
Total				90,849	6,156	0.85	0.95	0.91	2.54

[a] Poor households have a farm size of 0.85 ha, of which one-third is owned, Average-IR are households with 0.95 ha of mostly surface-irrigated land, Average-RF are households with 0.91 ha of land, mostly without surface irrigation and half in the uplands, and Better-off households have a farm size of 2.54 ha and owning almost 1 ha of farm land.

pepper (off-season and dry season), eggplant, mungbean, peanut, sweet potato, watermelon, tobacco and cotton. In contract tomato production, the variety is for making tomato paste and the company (National Food Corporation – NFC) provides seeds, fertilizers and pesticides to farmers, whereas farmers pay other costs. At harvest time, farmers sell their produce at a fixed price of P 2 kg^{-1} to the company. In contrast, the other tomato is a table variety and farmers pay all production costs and sell their produce at P 3.48 kg^{-1} (dry season) or P 16 kg^{-1} (off-season)[5].

Crop production activities have been defined at the level of annual cropping systems of one, two or three crops. Twenty-three feasible combinations of crops were included: three single-crop systems (rice-fallow, sweet pepper-fallow, tomato-fallow), 17 double-crop systems (only two of which are not rice-based, i.e., sweet pepper-

[5] In models with fixed prices, these 2001 prices have been used.

yellow corn, tomato-yellow corn) and three triple-crop systems (rice-garlic-mungbean, rice-yellow corn-mungbean, rice-white corn-mungbean). The cropping calendars and the long-term average rainfall by month and decade are presented in Figure 2 in Chapter 1. During the dry season (November to April), monthly rainfall is very low. Hence, groundwater is heavily used in the dry season to irrigate crops.

Current practice

Inputs (e.g., seed, fertilizer, pesticide, labour, water) and outputs (e.g., yield, nitrogen loss) of crop production activities for current (the average farmers' practice) were quantified for each feasible combination of crop and land unit. Tables 12 and 13 show the yields, input use, and costs and returns for wet season crops on two land units used in the provincial, and municipal and farm models. Off-season vegetables give much higher income than rice but require more inputs.

Among the dry season crops, watermelon, onion and tobacco give the highest net income per hectare in the provincial model (Table 14). On the other hand, onion, watermelon and tomato give the highest net income in the municipal and farm models (Table 15). In general, production costs are higher for vegetables. Benefit cost ratio is highest for watermelon. Tobacco and vegetables both have high labour requirements. Note that all labour use is imputed in the production costs. A large proportion of labour, however, consists of family labour, that does not entail any cash outlay, hence, actual cash expenses may be lower than indicated in the tables.

Defining alternative technologies

Technical coefficient generator In designing alternative innovative production technologies and conducting an *ex-ante* evaluation, the inputs and outputs of production activities need to be quantified. The parameters describing the inputs (e.g., seed, fertilizer, pesticide, labour, water) and outputs (e.g., yield, nutrient emissions) of a land use system are called technical coefficients (TCs). The contribution of each of the production activities to the agronomic, socio-economic, and environmental objectives at field and higher scales (farm or region) is also defined as a TC, hence its impact on realization of each of the objectives can be analysed. With a multitude of possible combinations of production systems and technologies (different crops, different yield levels, and different management strategies), an automated procedure for generating TCs is needed. Technical coefficient generators (TCGs) have been developed in the framework of explorative land use analyses, tailored to the specific production systems and conditions in different regions: Europe (De Koning et al., 1995), West Africa (Hengsdijk et al., 1996), Central America (Bouman et al., 1998; Hengsdijk et al., 1998), and South and Southeast Asia (Bandyopadhyay et al., 2001; Jansen, 2000).

Table 12. Yield, input use, costs and returns of wet season crops grown on fertile lands without surface irrigation, current practice (provincial model).

Crop	Yield ($t\ ha^{-1}$)	Fertilizer ($kg\ NPK\ ha^{-1}$)	Biocide ($kg\ a.i.\ ha^{-1}$)	Labour[a] ($d\ ha^{-1}$)	Irrigation water ($10^3\ m^3\ ha^{-1}$)	Gross returns[b] ($10^3\ P\ ha^{-1}$)	Total cost[c] ($10^3\ P\ ha^{-1}$)	Net income ($10^3\ P\ ha^{-1}$)	Returns to labour[d] ($10^3\ P\ d^{-1}$)	Benefit cost ratio
Lowland (RGL)										
Rice	2.9	149	0.1	72	0	22	18	4	0.2	1.2
Upland (RGU)										
Rice	2.9	131	0.1	72	0	22	18	5	0.3	1.2
Sweet pepper	5.6	229	4.3	85	1.7	115	72	43	0.7	1.6
Tomato	10.5	392	3.1	135	0.7	250	36	214	1.8	6.9

[a] Includes family and hired labour.
[b] Total value of output (yield × price); 1US$ = 51 pesos (2001).
[c] Includes material costs (seeds, fertilizer, pesticide, etc.), machine rental, irrigation and labour costs. Family labour cost is imputed.
[d] Total value of output minus value of purchased inputs divided by total labour use.

Table 13. Yield, input use, costs and returns of wet season crops grown on fertile lands without surface irrigation, current practice (municipal and farm models).

Season/Crop	Yield ($t\ ha^{-1}$)	Fertilizer ($kg\ NPK\ ha^{-1}$)	Biocide ($kg\ a.i.\ ha^{-1}$)	Labour[a] ($d\ ha^{-1}$)	Irrigation water ($10^3\ m^3\ ha^{-1}$)	Gross returns[b] ($10^3\ P\ ha^{-1}$)	Total cost[c] ($10^3\ P\ ha^{-1}$)	Net income ($10^3\ P\ ha^{-1}$)	Returns to labour[d] ($10^3\ P\ d^{-1}$)	Benefit cost ratio
Lowland (RGL)										
Rice	3.9	127	0.4	98	0	30	22	8	0.2	1.4
Upland (RGU)										
Rice	3.6	188	0.4	95	0	28	23	5	0.2	1.2
Sweet pepper	8.9	147	4.5	122	1.9	183	68	115	1.1	2.7
Tomato	10.5	392	3.8	135	0.7	250	37	213	1.7	6.8

[a] Includes family and hired labour.
[b] Total value of output (yield × price); 1US$ = 51 pesos (2001).
[c] Includes material costs (seeds, fertilizer, pesticide, etc.), machine rental, irrigation and labour costs. Family labour cost is imputed.
[d] Total value of output minus value of purchased inputs divided by total labour use.

Table 14. Yield, input use, costs and returns of dry season crops grown on fertile lowlands without surface irrigation (RGL), current practice (provincial model).

Crop	Yield ($t\ ha^{-1}$)	Fertilizer ($kg\ NPK\ ha^{-1}$)	Biocide ($kg\ a.i.\ ha^{-1}$)	Labour[a] ($d\ ha^{-1}$)	Irrigation water ($10^3\ m^3\ ha^{-1}$)	Gross returns[b] ($10^3\ P\ ha^{-1}$)	Total cost[c] ($10^3\ P\ ha^{-1}$)	Net income ($10^3\ P\ ha^{-1}$)	Returns to labour[d] ($10^3\ P\ d^{-1}$)	Benefit cost ratio
Cotton	1.9	143	0.7	26	5.6	33	36	–2	0.1	0.9
Eggplant	6.7	225	1.7	83	3.6	68	79	–11	0.0	0.9
Garlic	1.9	217	1.4	66	3.1	75	40	35	0.7	1.9
Mungbean	1.1	34	0.4	39	1.4	29	19	10	0.4	1.5
Onion	4.4	192	1.4	73	3.3	103	49	54	0.9	2.1
Peanut	1.6	30	0.1	41	2.6	25	13	12	0.4	1.9
Sweet pepper	5.6	275	4.3	85	4.1	59	76	–17	–0.0	0.8
Sweet potato	6.9	71	0.0	47	3.7	38	20	19	0.5	1.9
Tobacco	1.5	142	0.5	95	3.8	67	25	41	0.6	2.7
Tomato (contract)	17	318	3.9	80	3.9	34	15	19	0.4	2.3
Tomato	17	277	2.2	80	3.9	59	52	7	0.2	1.1
Watermelon	10.9	175	1.4	77	2.6	110	21	89	1.3	5.2
White corn	2.4	122	0.2	34	2.7	24	12	12	0.5	2.0
Yellow corn	3.5	169	0.2	36	2.8	27	17	10	0.4	1.6

[a] Includes family and hired labour.

[b] Total value of output (yield × price); 1US$ = 51 pesos (2001).

[c] Includes material costs (fertilizer, pesticide, etc.), machine rental, irrigation and labour costs. Family labour cost is imputed. For tomato (contract), seeds, fertilizers and pesticides are supplied by the tomato company and are not accounted for in the production costs.

[d] Total value of output minus value of purchased inputs divided by total labour use.

Table 15. Yield, input use, costs and returns of dry season crops grown on fertile lowlands without surface irrigation (RGL), current practice (municipal and farm models).

Season/ Crop	Yield ($t\ ha^{-1}$)	Fertilizer ($kg\ NPK\ ha^{-1}$)	Biocide ($kg\ a.i.\ ha^{-1}$)	Labour[b] ($d\ ha^{-1}$)	Irrigation water ($10^3 m^3\ ha^{-1}$)	Gross returns[c] (10^3 peso ha^{-1})	Total cost[d] (10^3 peso ha^{-1})	Net income (10^3 peso ha^{-1})	Returns to labour[e] (10^3 peso d^{-1})	Benefit cost ratio
Cotton	1.1	272	0.5	70	5.3	19	22	–3	0.1	0.9
Eggplant	10.6	91	1.6	226	3.9	107	63	44	0.3	1.7
Garlic	1.5	131	1.1	71	3.1	59	31	28	0.5	1.9
Mungbean	0.5	98	0.0	42	1.4	13	11	2	0.2	1.2
Onion[a]	6.0	249	2.2	84	3.3	140	52	89	1.2	2.7
Peanut[a]	1.6	30	0.1	41	2.6	25	13	12	0.4	1.9
Sweet pepper	5.8	175	4.4	109	4.2	61	65	–3	0.1	0.9
Sweet potato[a]	4.3	0	0.0	65	3.7	24	18	6	0.2	1.3
Tobacco	1.6	81	0.7	132	3.9	71	30	41	0.5	2.4
Tomato (contract)	28.0	318	4.9	104	4.2	56	17	39	0.5	3.3
Tomato	25.3	146	1.4	116	4.2	88	32	56	0.7	2.8
Watermelon[a]	10.9	175	1.7	77	2.6	110	21	88	1.3	5.2
White corn	2.2	109	0.1	68	2.7	22	13	9	0.3	1.7
Yellow corn	3.6	45	0.1	65	2.7	28	14	14	0.4	2.0

[a] No data for these crops were included in the 2001 survey, data included here were calculated as the average of the 1998-99 survey for fields located in Batac.

[b] Includes family and hired labour.

[c] Total value of output (yield × price); 1U$ = 51 pesos (2001).

[d] Includes material costs (fertilizer, pesticide, etc.), machine rental, irrigation and labour costs. Family labour cost is imputed. For tomato (contract), seeds, fertilizers and pesticides are supplied by the tomato company and are not accounted for in the production costs.

[e] Total value of output minus value of purchased inputs divided by total labour use.

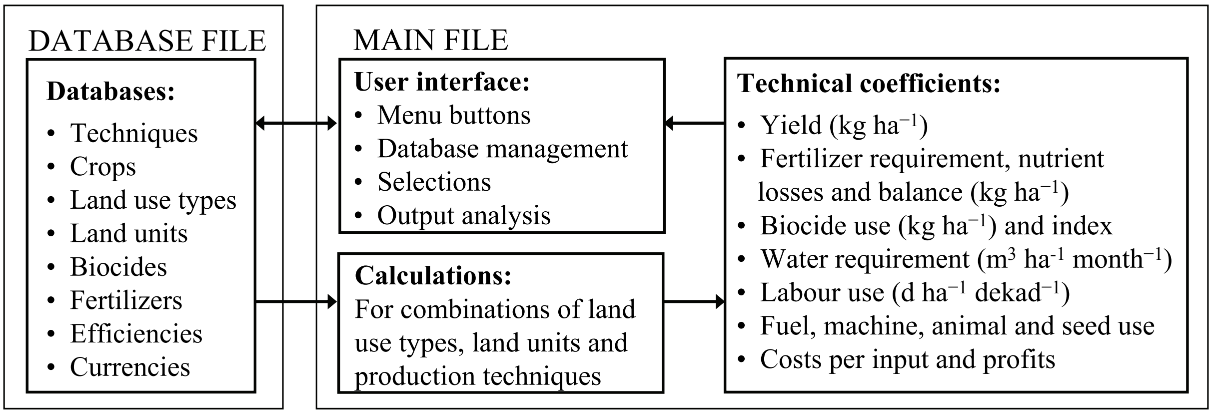

Figure 3. Schematic representation of the structure of TechnoGIN. The arrows represent flows of data. (Source: Ponsioen et al., 2006).

These TCGs integrate process-based knowledge, empirical data, and expert knowledge to generate TCs as inputs in land use models. TechnoGIN is an example of a TCG that employs the target-oriented approach (Van Ittersum and Rabbinge, 1997). At an exogenously supplied target yield level, inputs such as fertilizers, pesticides, labour and water, required to realize that target yield are calculated. Other 'outputs', such as crop residue production and sustainability indicators associated with each production activity are also calculated. Among the environmental indicators calculated by TechnoGIN are nutrient losses and balance, biocide use and residue index[6].

In TechnoGIN, technical coefficients for different production techniques are quantified by defining efficiencies in terms of labour, fertilizer and other input use (Ponsioen et al., 2003; 2006). TechnoGIN may be used as a stand-alone tool to evaluate different production systems and technologies and to explore options at the field scale or as input to optimization models at farm or regional scale. A schematic representation of the structure of TechnoGIN and the list of data requirements are given in Figure 3 and Table 16, respectively.

Alternative technologies Four alternative production technologies were defined: hybrid rice production (HYR), balanced fertilization strategy for rice and corn (BFS), site-specific nutrient management (SSNM) and integrated pest management (IPM). HYR, BFS and IPM are actively promoted by the national government throughout the Philippines. HYR is being promoted as the major technological option to increase land productivity and attain self-sufficiency in rice (DA, 2002). A presidential proclamation issued in 1997 provides a legal and institutional basis for the promotion of BFS, which

[6] Biocide use (expressed in active ingredients) is used in Chapters 3 and 5 in comparing different scenarios. Other chapters use biocide residue index, which is a better indicator because it accounts for toxicity and persistence of chemicals used.

Table 16. Data requirements per data sheet in TechnoGIN[a].

Data sheet	Data requirements
Production techniques	Relative nutrient use (R), biocide use (R) and water use efficiencies (R) compared with those for current techniques, labour (R), fuel (R), machine (R) and animal use (R) proportionally to those under current techniques, prices of labour, fuel, machinery, draft animal and irrigation water (S)
Crops	Maximum yield (S or F), dry matter content (F), harvest index (F), minimum and maximum N,P and K concentrations (F) in harvested products and crop residues, crop duration (S), crop coefficients (S), labour requirements per task (S), number of dekads needed for land preparation and harvesting (F), seed amount (F), fuel (S), machinery use (S), draft animal use (S), investments (S), recovery correction factor (F), anaerobic/aerobic (F), biocide use (S), farm gate price (S), seed price (S), current fertilizer rates for each land unit (S)
Land use types	Crop rotation in one year (S), fraction of crop residues used as fodder, burnt or mulched (S), low and high target yields per crop type and land unit (S)
Land units	Long-term supply of N, P and K (S), maximum soil water holding capacity (F), elevation and slope (S), fractions of sand, silt and clay (S), rainfall (S) and reference evapotranspiration (S) per dekad
Biocides	Active ingredient (S), duration (S), EPA/WHO index (S), and prices (S) for each biocide type
Fertilizers	DM content (S), N, P and K concentrations (S) and prices (S) for each fertilizer type
Efficiencies	Relative nutrient use (R), biocide use (R) and water use efficiencies (R) proportionally to relative yield
Currencies	Conversion rates (S) between different currencies for several years

[a] For each type of data, it is indicated whether its value is generally applicable and can be considered as fixed (F), whether its value should be established specifically (S) for each land use system, or whether its value is a relative fraction (R) which allows rapid analysis of the effects (e.g., fertilizer demand) of relative changes in a factor compared with the standard value for a land use system (e.g., 20% more or less efficient nutrient use). Source: Ponsioen et al., 2006.

aims at sustainable (high) crop yields through the combined use of organic and inorganic fertilizers at the proper grade and doses to meet crop requirements (Concepcion et al., 1999). Similarly, to address environmental concerns, IPM has been established as the national crop protection strategy; and starting in 1993, a nationwide IPM training programme for farmers has been set up (Medina and Callo, 1999). Techno-demonstrations for HYR and season-long farmer field schools on BFS and IPM have been conducted for rice and corn (and lately, also for vegetables) in Ilocos Norte and other provinces. SSNM, on the other hand, is a nutrient management strategy for rice that has been tested extensively in farmers' fields in Asia (Witt et al., 2004), but is not yet applied in Ilocos Norte. The characteristics in terms of yield, nutrient and pest management strategies, and labour use of all technologies considered are given in Table 17.

HYR yields are assumed to be 25% higher than those of the current inbred varieties. Based on a data set consisting of 75 experiments, conducted in 14 years, average standard heterosis was 24.6% at low yield levels (< 5 t ha^{-1}) (Peng et al., 2003). Crop parameters for rice used in TechnoGIN were revised to account for the change in yield potential, target yield, seeding rate (20 kg ha^{-1} for HYR vs 70 kg ha^{-1} for current practice (CP)), price of seeds, additional cost of applying organic materials to the seed-bed, 15% higher nutrient uptake efficiencies and higher labour requirements for land preparation and crop establishment (including seedbed preparation and management).

Table 17. Description of production technologies.

Technology	Yield	Nutrient management	Pest and weed management	Labour use
Current practice (CP)	CP	CP	CP	CP
Hybrid rice (HYR)	25% higher yield for rice	Additional 50 kg of organic materials for the seedbed; 15% higher recovery than CP	Same as CP	More labour for land preparation and crop establishment[a]
Balanced fertilization (BFS) for rice & corn	15% higher yield for rice and corn; same yields for other crops	Use of organic and inorganic fertilizers at specified rates; 15% higher recovery than CP for rice	Same as CP	4-5 more labour days ha^{-1} for hauling and application of organic fertilizer and crop management[a]
Site-specific nutrient management for all crops (SSNM)	15% higher yield for rice; same yields for other crops	As calculated by QUEFTS in TechnoGIN; 15% higher recovery than CP	5% less insecticide and fungicide	15-20% more labour for monitoring and crop management[a]
Integrated pest management (IPM)	Same as CP	Same as CP	70-85% less insecticide; 10-20% less fungicide; 10% (rice) to 90% (vegetables) less herbicide	10 more labour days ha^{-1} for plastic mulching (vegetables); 20% more labour for monitoring and crop management[a]

[a] Labour requirements for harvesting/threshing per hectare are higher because of higher yields. In TechnoGIN, this parameter is expressed per ton of output. Labor use for harvesting/threshing per ton of output is unchanged.

In BFS, rice and corn yields are assumed to be 15% higher and fertilizer applications follow the recommendations for Ilocos Norte, consisting of both organic and inorganic sources (doses per ha):

Wet-season rice:	250 kg (commercial) organic fertilizer, 150 kg urea, 150 kg 'complete', 50 kg ammonium phosphate (total: 103 kg N, 19 kg P, 26 kg K)
Dry-season rice:	300 kg organic fertilizer, 50 kg urea, 150 kg 'complete', 200 kg ammonium sulphate (total: 92 kg N, 15 kg P, 27 kg K)
Corn:	250 kg organic fertilizer, 150 kg urea, 100 kg 'complete', 50 kg ammonium phosphate (total: 96 kg N, 16 kg P, 20 kg K)

Under BFS, less nitrogen per hectare is applied to rice and more of all nutrients (N, P, K) to corn compared with current practices; labour requirements are higher because of hauling and application of organic fertilizers.

SSNM, in contrast to blanket fertilizer recommendations, involves the following principles: balanced fertilization based on crop requirements, crop-specific estimates of nutrient supplies from the soil, need-based fertilizer N management and sustainable P and K management (Witt et al., 2004).

Under SSNM, a 15% higher yield for rice was assumed, and fertilizer requirements were calculated in TechnoGIN using the QUantitative Evaluation of the Fertility of Tropical Soils (QUEFTS; Janssen et al., 1990; Witt et al., 1999) approach. The QUEFTS module in TechnoGIN calculates fertilizer nutrient requirements by subtracting nutrient supply from 'natural sources' (i.e., soil organic matter and atmospheric deposition, also referred to as indigenous supply) from crop uptake and dividing the residual by the nutrient recovery fraction. Indigenous nutrient supply is estimated from soil chemical characteristics and/or from crop yields in unfertilized plots in the lowlands of Ilocos Norte (Sta. Cruz et al., 1995; Pascua et al., 1999). Crop uptake at the target yield is calculated using a linear optimization procedure, with maximum dilution and accumulation of nutrients as constraints (Janssen et al., 1990; Ponsioen et al., 2003, 2006). For rice, a 20% higher labour requirement for monitoring and crop management (including additional fertilizer applications) and a 5% lower insecticide and fungicide use, associated with a more balanced fertilizer application, are assumed.

Although SSNM was developed for rice, we assume that the principle of balancing fertilizer input with indigenous supply and crop nutrient requirement can also be applied to other crops. For other crops, no change in yield, a slightly lower insecticide and fungicide use and a 15% higher labour requirement for crop management and monitoring are assumed.

Under IPM, there is no change in yield for any crop, but biocide use (especially for vegetables) is significantly lower. Additional costs to account for plastic mulch (for vegetables) and biological control agents (for non-rice crops) and additional labour use for monitoring and crop management are added, but there are considerable savings on insecticide (for all crops) and herbicide use (Kogan, 1998).

The input-output coefficients for the alternative production systems were derived from earlier studies, such as Casiwan et al. (2003) for hybrid rice, Concepcion et al. (1999) for BFS, Fairhurst and Witt (2002) and Dobermann et al. (2004) for SSNM, and Medina and Callo (1999) and Palis (1998, 2002) for IPM, and unpublished data from farmer field schools and techno-demonstration farms provided by the Agricultural Training Institute and Mariano Marcos State University, both located in Batac. In addition, information from interviews with farmer-adopters and agricultural technicians in Batac was used.

Tables 18 and 19 show the comparative yield, input use, and costs and returns of crops for different technologies included in the farm and municipal models. For wet season rice, net income and benefit-cost ratio are highest under HYR, but returns to labour are similar under the different technologies. For off-season sweet pepper, net income, returns to labour and benefit-cost ratio are highest for IPM. For off-season tomato, on the other hand, SSNM yields the highest net income and benefit-cost ratio. Dry season crops, vegetables in general, perform best under IPM.

Animal activities

Animals (cattle, pigs and poultry) are mostly kept in backyard farming in the province. They are bought and, after fattening for a certain period (2 months for poultry and 5 months for cattle and pigs) sold. Feed requirements are met by commercial feed and crop residues from the farm and for cattle partly by grazing along roads and pasture areas. Residues may be consumed in the month of harvest and it is assumed that these cannot be stored for future use.

In the model, the contribution from residues of the farm and commercial feeds to cattle feed is assumed to be 25% of the total feed requirement in the wet season and 75% in the dry season, when availability of grass for grazing is limited. For pigs and poultry, 80% of the feed requirements are covered by commercial feeds, that are supplemented by household food residues (usually rice).

The benefit/cost ratio is highest for poultry and lowest for cattle, while the capital requirements are highest for cattle (7,107 peso animal^{-1}). Returns to labour, on the other hand, are eight times higher for cattle than for poultry (Table 20). Animal activities in the model comprise only current technologies.

Table 18. Yield, input use, and costs and returns of wet season crops under different production technologies (municipal and farm models).

Land unit/ Crop	Technology [a]	Yield ($t\ ha^{-1}$)	Fertilizer (kg nutrient ha^{-1}) N	P	K	Biocide (kg a.i. ha^{-1})	Labour [b] ($d\ ha^{-1}$)	Gross returns [c] (10^3 peso ha^{-1})	Total cost [d] (10^3 peso ha^{-1})	Net income (10^3 peso ha^{-1})	Returns to labour [e] (10^3 peso d^{-1})	Benefit cost ratio
Lowland (RGL)												
Rice	CP	3.9	110	15	2	0.4	98	30	22	8	0.2	1.4
	HYR	4.9	110	15	2	0.4	112	38	24	13	0.3	1.6
	BFS	4.5	103	19	26	0.5	108	35	24	11	0.2	1.5
	SSNM	4.5	137	26	76	0.4	107	35	25	10	0.2	1.4
	IPM	3.9	110	15	2	0.3	101	30	22	8	0.2	1.4
Upland (RGU)												
Rice	CP	3.6	136	21	31	0.4	95	28	23	5	0.2	1.2
	HYR	4.5	136	21	31	0.4	108	35	25	10	0.2	1.4
	BFS	4.1	103	19	26	0.4	105	32	24	8	0.2	1.3
	SSNM	4.1	101	22	50	0.4	103	32	24	8	0.2	1.3
	IPM	3.6	136	21	31	0.3	97	28	23	5	0.2	1.2
Sweet	CP	8.9	116	12	19	4.5	122	183	68	115	1.1	2.7
pepper	SSNM	8.9	193	39	152	4.3	127	183	71	112	1.0	2.6
	IPM	8.9	116	12	19	2.8	139	183	44	139	1.2	4.2
Tomato	CP	10.5	310	30	52	3.8	135	250	37	213	1.7	6.8
	SSNM	10.5	43	9	50	3.6	143	250	33	218	1.7	7.6
	IPM	10.5	310	30	52	2.5	156	250	42	208	1.5	6.0

[a] See Table 17 for description of production technologies
[b] Includes family and hired labour.
[c] Total value of output (yield × price); 1US$ = 51 pesos (2001).
[d] Includes material costs (fertilizer, pesticide, etc.), machine rental, irrigation and labour costs. Family labour cost is imputed. For tomato (contract), seeds, fertilizers and pesticides are supplied by the tomato company and are not accounted for in the production costs.
[e] Total value of output minus value of purchased inputs divided by total labour use.

Table 19. Yield, input use, and costs and returns of dry season crops on fertile lowlands without surface irrigation (RGL) under different production technologies (municipal and farm models).

Land unit/ Crop	Technology [a]	Yield ($t\ ha^{-1}$)	Fertilizer (kg nutrient ha^{-1}) N	P	K	Biocide (kg a.i. ha^{-1})	Labour [b] ($d\ ha^{-1}$)	Gross returns [c] (10^3 peso ha^{-1})	Total cost [d] (10^3 peso ha^{-1})	Net income (10^3 peso ha^{-1})	Returns to labour [e] (10^3 peso d^{-1})	Benefit cost ratio
Cotton	CP	1.1	185	30	57	0.5	70	19	22	–3	0.1	0.9
	SSNM	1.1	0	5	0	0.5	72	19	18	2	0.2	1.1
	IPM	1.1	185	30	57	0.2	79	19	22	–3	0.1	0.9
Eggplant	CP	10.6	51	12	28	1.6	226	107	63	44	0.3	1.7
	SSNM	10.6	6	12	0	1.6	230	107	62	45	0.3	1.7
	IPM	10.6	51	12	28	0.2	246	107	55	52	0.4	1.9
Garlic	CP	1.5	76	19	36	1.1	71	59	31	28	0.5	1.9
	SSNM	1.5	0	0	0	1.0	75	59	29	30	0.5	2.0
	IPM	1.5	76	19	36	0.7	82	59	24	35	0.6	2.5
Mungbean	CP	0.5	84	5	9	0.0	42	13	11	2	0.2	1.2
	SSNM	0.5	0	0	0	0.0	43	13	8	5	0.3	1.6
	IPM	0.5	84	5	9	0.0	45	13	12	2	0.2	1.1
Onion	CP	6.0	197	18	34	2.2	84	140	52	89	1.2	2.7
	SSNM	6.0	91	41	0	2.2	88	140	49	91	1.2	2.9
	IPM	6.0	197	18	34	1.4	97	140	31	109	1.3	4.5
Peanut	CP	1.6	19	4	7	0.1	41	25	13	12	0.4	1.9
	SSNM	1.6	0	13	9	0.1	41	25	13	12	0.4	1.9
	IPM	1.6	19	4	7	0.0	43	25	14	11	0.4	1.8
Sweet pepper	CP	5.8	135	14	26	4.4	109	61	65	–3	0.1	0.9
	SSNM	5.8	88	17	41	4.2	114	61	63	–2	0.1	1.0
	IPM	5.8	135	14	26	2.5	125	61	42	19	0.3	1.5
Sweet potato	CP	4.3	0	0	0	0.0	65	24	18	6	0.2	1.3
	SSNM	4.3	0	0	0	0.0	68	24	19	5	0.2	1.3
	IPM	4.3	0	0	0	0.0	73	24	20	4	0.2	1.2

Table 19. Continued.

Land unit/ Crop	Technology [a]	Yield ($t\ ha^{-1}$)	Fertilizer (kg nutrient ha^{-1}) N	P	K	Biocide (kg a.i. ha^{-1})	Labour [b] ($d\ ha^{-1}$)	Gross returns [c] (10^3 peso ha^{-1})	Total cost [d] (10^3 peso ha^{-1})	Net income (10^3 peso ha^{-1})	Returns to labour [e] (10^3 peso d^{-1})	Benefit cost ratio
Tobacco	CP	1.6	39	14	28	0.7	132	71	30	41	0.5	2.4
	SSNM	1.6	114	18	44	0.7	133	71	33	39	0.4	2.2
	IPM	1.6	39	14	28	0.2	135	71	31	40	0.5	2.3
Tomato (contract)	CP	28.0	150	30	138	4.9	110	56	17	39	0.5	3.3
	SSNM	28.0	124	23	95	4.6	113	56	18	38	0.5	3.1
	IPM	28.0	150	30	138	3.9	122	56	19	37	0.5	2.9
Tomato	CP	25.3	106	4	36	1.4	104	88	32	56	0.7	2.8
	SSNM	25.3	96	19	67	1.3	107	88	33	55	0.7	2.7
	IPM	25.3	106	4	36	0.9	116	88	32	57	0.6	2.8
Watermelon	CP	10.9	122	20	33	1.7	77	110	21	88	1.3	5.2
	SSNM	10.9	49	0	0	1.6	78	110	19	91	1.3	5.8
	IPM	10.9	122	20	33	1.0	80	110	21	88	1.2	5.2
White corn	CP	2.2	81	11	17	0.1	68	22	14	8	0.3	1.6
	BFS	2.5	96	16	20	0.1	75	25	16	10	0.3	1.6
	SSNM	2.2	22	17	0	0.1	72	22	14	8	0.3	1.6
	IPM	2.2	81	11	17	0.0	79	22	16	6	0.2	1.4
Yellow corn	CP	3.6	30	5	10	0.1	65	28	13	14	0.4	2.2
	BFS	4.1	96	16	20	0.1	73	32	16	15	0.4	2.0
	SSNM	3.6	105	39	0	0.1	67	28	16	12	0.3	1.8
	IPM	3.6	30	5	10	0.1	71	28	14	14	0.4	2.0

[a] See Table 17 for description of production technologies
[b] Includes family and hired labour.
[c] Total value of output (yield × price); 1US$ = 51 pesos (2001).
[d] Includes material costs (fertilizer, pesticide, etc.), machine rental, irrigation and labour costs. Family labour cost is imputed. For tomato (contract), seeds, fertilizers and pesticides are supplied by the tomato company and are not accounted for in the production costs.
[e] Total value of output minus value of purchased inputs divided by total labour use.

Table 20. Yield and input use of animal activities.

Characteristic	Unit	Animal activity		
		Cattle	Pigs	Poultry
Yield	kg animal^{-1}	300	90	1.3
Purchase price[a]	Peso animal^{-1}	7,107	583	25
Costs, excluding feeds	Peso animal^{-1}	0	750	3
Feed requirements				
Metabolizable energy	MJ animal^{-1}	8,455	3.7	0.02
Digestible crude protein	kg animal^{-1}	104	45.5	1.2
Labour requirements	d animal^{-1}	9.4	18.8	0.6
Residence time on the farm	Months	5	5	2
Survival rate	Fraction	1.0	1.0	0.9
Gross returns[b]	Peso animal^{-1}	14,214	5,250	113
Production costs[c]	Peso animal^{-1}	7,147	1,372	29
Net income	Peso animal^{-1}	7,067	3,878	84
Returns to labour[d]	Peso d^{-1}	1,512	279	188
Benefit/cost ratio	Unitless	2.0	3.8	3.9

[a] 1 US$ = 51 pesos (2001).

[b] Total value of output (production × price).

[c] Excludes labour costs.

[d] Total value of output minus value of purchased inputs divided by total labour use.

CHAPTER 3

Adoption of new technologies and its consequences on farmers' welfare and the environment: A model-based case study from the northern Philippines*

A.G. Laborte[1,2], M.M. van den Berg[2,3], M.K. van Ittersum[2], R.A. Schipper[3], A.G. Prins[2] and M. Hossain[1]

[1] International Rice Research Institute (IRRI), DAPO Box 7777, Metro Manila, Philippines

[2] Plant Production Systems, Wageningen University, P.O. Box 430, 6700 AK Wageningen, The Netherlands

[3] Development Economics, Wageningen University, P.O. Box 8130, 6700 EW Wageningen, The Netherlands

Abstract

The policy objectives of attaining food self-sufficiency and improving the well-being of subsistence farmers, while protecting the environment, have stimulated the development of many improved agricultural production technologies. Adoption of these new technologies by farmers, however, has not always met the expectations of scientists. With a choice of technologies, farm household production decisions are governed not only by productivity and profitability considerations but also by other factors, such as available resources and their quality, family consumption preferences and prevailing policies. It is therefore necessary to analyse the adoption of technologies from a whole-farm perspective, rather than concentrating on costs and benefits of specific technologies.

In this paper, a farm household model is used to evaluate technology adoption behaviour of farmers in Ilocos Norte province, Philippines. Four alternative technologies are evaluated: hybrid rice production, balanced fertilization strategy, site-specific nutrient management and integrated pest management (IPM). In addition, the possible impacts of price policies and infrastructure improvements on technology adoption are assessed. Results of simulations show differential degrees of adoption for poor, average and better-off households. Simulations show the highest rates of adoption for IPM and hybrid rice production, with IPM giving the highest increase in income. The availability of low-cost credit and a reduction in transaction costs are important determinants of farmer welfare but have varying effects on technology adoption among different farm types.

We argue that the methodology and results presented can contribute to *ex-ante* assessments of policies targeted at stimulating technology adoption by farmers.

Keywords: Farm household modelling; Cropping systems; Integrated nutrient management; IPM; Hybrid rice; Philippines

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Introduction

In most countries, growth in cereal production in the previous decades has kept pace with the increasing demand as a result of advances in plant breeding, increased use of inputs such as fertilizers and biocides, and improved access to irrigation water. With the continuing rise in population, economic growth and rapid urbanization, the demand for food will increase further and this has to be met using less land, less water and less labour (IRRI, 1998). As farmers resort to intensification through increased use of chemical inputs, concern is growing about the negative effects of such practices on human health and the environment. Therefore, crop management practices need to be improved such that productivity gains are achieved with minimum adverse effects on the quality of the natural resource base.

In the Philippines, where arable land per person is already less than one-tenth of a hectare and the population continues to grow at an annual rate of over 2.3%, the government is actively promoting such crop management. These production technologies include hybrid rice production (HYR), a balanced fertilization strategy (BFS) and integrated pest management (IPM). In spite of their active promotion, these technologies have not been widely adopted (PGIN, 1999; Casiwan et al., 2003).

With a choice of technologies, farm household production decisions are governed not only by profitability considerations but also by other factors, such as the quantity and quality of resources farm households have access to, family consumption preferences, compatibility with current activities, perceived benefits from the technology and prevailing policies (Pandey, 1999; Dawe et al., 2004). Assessment of the suitability for small-scale farmers of new and existing technologies is therefore required, whereas for policymakers knowledge of the best-bet options that will enhance the adoption of new technologies is essential.

Analysis of costs and benefits is a useful method to assess the profitability of a production activity, which is a necessary condition for adoption. It does not, however, guarantee adoption, which may depend on many economic, social and cultural factors, including access to resources, not only at single activity, but also at farm scale. In addition to cost-benefit analysis, statistical methods can be used to identify characteristics that influence adoption (David and Otsuka, 1994; Floyd et al., 1999; Lapar and Pandey, 1999), but such methods do not allow comparison of current and potential technologies. Therefore, for *ex-ante* evaluation of new technologies, whole-farm modelling and simulation approaches are needed (Ruben et al., 1998).

The farm household modelling (FHM) approach (Singh et al., 1986) has been extensively used to model decision-making behaviour of farmers and to assess likely effects of policy measures on land-use decisions and farmer welfare. The approach explicitly models the farm household's objectives, available resources and activities, and its other biophysical and socioeconomic circumstances. It has been applied in various studies to assess the impact of new technologies and of policy instruments such as price stabilization, taxation, reduction of transaction costs and increases in credit availability on farm households' welfare and sustainability indicators (Barlow et al., 1983; Kruseman et al., 1995; Van Rheenen, 1995; Schipper, 1996; Kruseman and Bade, 1998; Roebeling et al., 2000; Shiferaw et al., 2001).

In this chapter, a farm household model is used to evaluate the suitability of four production technologies: HYR, BFS, IPM, and site-specific nutrient management (SSNM) – a nutrient management strategy that has been tested extensively in farmers' fields in Asia (Witt et al., 2004), for local farmers in the northernmost province of the Philippines, Ilocos Norte. Specifically, this chapter aims at

- identifying the factors that constrain the adoption of new technologies,
- analysing the consequences of new technologies on farmers' welfare, food production and the environment, and
- assessing the impacts of changes in relative prices on technology choice.

The case study area

The province of Ilocos Norte is situated in the northwestern part of the Philippines, and comprises 23 administrative units: 22 municipalities and 1 city. Batac, the most populous municipality in the province, has a total land area of 16,101 ha, of which 67% is used as agricultural land. Farmers in Ilocos Norte classify their land into four categories on the basis of topography and drainage characteristics: *lungog*, *semi-lungog*, *bangkag* and *tangkig* (Lucas et al., 1999). *Lungog* and *semi-lungog* fields are located in the lower part of the toposequence (lowlands) and are submergence-prone, whereas *bangkag* and *tangkig* are drought-prone fields located in the upper part of the toposequence (highlands). These classes form the basis for defining the land units in the study (see Section Production activities and technology levels).

The climate in Batac is characterized by two distinct seasons: the wet (May to October) and dry (November to April) seasons. Average annual rainfall is 2,000 mm, more than 90% of which falls during the wet season.

The staple food rice is grown in both the wet season and dry season in areas with surface irrigation. Crop options during the wet season are limited, particularly in the lowlands, where only rice can be grown because of rainfall intensity and soil drainage characteristics. In the uplands, however, farmers have started to grow off-season vegetables (e.g., sweet pepper and tomato) on part of their land. In the dry season, on the other hand, a variety of crops such as corn, tobacco, garlic, onion, eggplant, tomato and other vegetables are grown, using groundwater for supplemental irrigation (Lucas et al., 1999). In some cases, a short-duration crop, such as mungbean, is grown as a third crop.

The local government of Ilocos Norte aims at encouraging the adoption of farm management systems that enhance productivity and employ sustainable practices (PGIN, 1999). Food self-sufficiency remains the principal strategy of the national government for ensuring food availability and accessibility. In line with this objective, hybrid rice production (HYR) is being promoted as the major technology option to increase productivity and attain self-sufficiency in rice (DA, 2002). Similarly, farm management practices that increase productivity and make efficient use of inputs, such as the balanced fertilization strategy (BFS), are being promoted throughout the country. A presidential proclamation, issued in 1997, provides a legal and institutional basis for the promotion of BFS, which aims at sustainable (high) crop yields through the combined use of organic and inorganic fertilizers at the proper grade and doses to meet crop requirements (Concepcion et al., 1999). To address environmental concerns, integrated pest management (IPM) has been established as the national crop protection policy; a nationwide IPM training program for farmers started in 1993 (Medina and Callo, 1999). Techno-demonstrations for hybrid rice production and season-long farmer field schools on BFS and IPM have been conducted for rice and corn (and lately, also for vegetables) in Ilocos Norte and other provinces. BFS and IPM reduce dependence on purchased inputs (fertilizers and pesticides), hence reducing both monetary production costs and environmental impact.

The farm household model

To evaluate the suitability of different technologies at the farm level, we developed a farm household model that incorporates the essential characteristics of the study area. Three market imperfections are accounted for. First, transaction costs cause a price band between farm-gate prices and consumer prices (retail prices). This results in a tendency to produce for home consumption (De Janvry et al., 1991). Second, wage employment in both the farm and non-farm sector is limited. Hence, for households with a high labour/land ratio, the shadow price of labour may be below the market wage rate. Third, availability of credit is often a constraint, which could make input-intensive technologies infeasible. These market imperfections result in non-separability of production and consumption decisions (Singh et al., 1986).

Adoption patterns may vary among farm households, because of differences in biophysical and socioeconomic circumstances. To increase understanding of adoption behaviour of different farm households, simulations were performed for an average household in different farm household groups, characterized on the basis of a cluster analysis of 150 farm households surveyed in 28 rural villages in the municipality of

Batac in 2001 (Bi and Pradel, 2003). Farm size, quality of farmland and ownership, number of economically active household members (labour force) and value of farm assets were used in the classification, resulting in four farm household types: (i) poor households with a farm size of 0.85 ha, of which one-third is owned, (ii) average households with 0.95 ha of mostly surface-irrigated land (average-IR), (iii) average households with 0.91 ha of land, mostly without surface irrigation and half in the uplands (average-RF), and (iv) better-off households with a farm size of 2.54 ha and owning almost 1 ha of farmland. Technological change and policy simulations were analysed for these four farm household groups.

Model structure

Figure 1 gives a simple conceptual representation of the model. A detailed mathematical description is given in Chapter 6. Households maximize utility, subject to resource endowments, potential activities and the socioeconomic and biophysical environment. Utility is represented by discretionary income, that is, income available for spending after the essentials have been taken care of (Castaño, 2001). This relatively simple linear function enables accounting for home consumption resulting from differences between farm-gate and consumer prices. Risk is explicitly included, following Low's safety first approach (Low, 1974). In this approach, income should be enough to meet fixed costs, credit repayments and living costs in 'every state of nature' (Hazell and Norton, 1986). Only risk in prices is included in the model. Although yields also vary from year to year due to differences in rainfall, most of the farmers own pumps, so the effect of climatic conditions on yields can be less. On the other hand, farm prices, particularly of vegetables, fluctuate heavily causing a large effect on farmers' income.

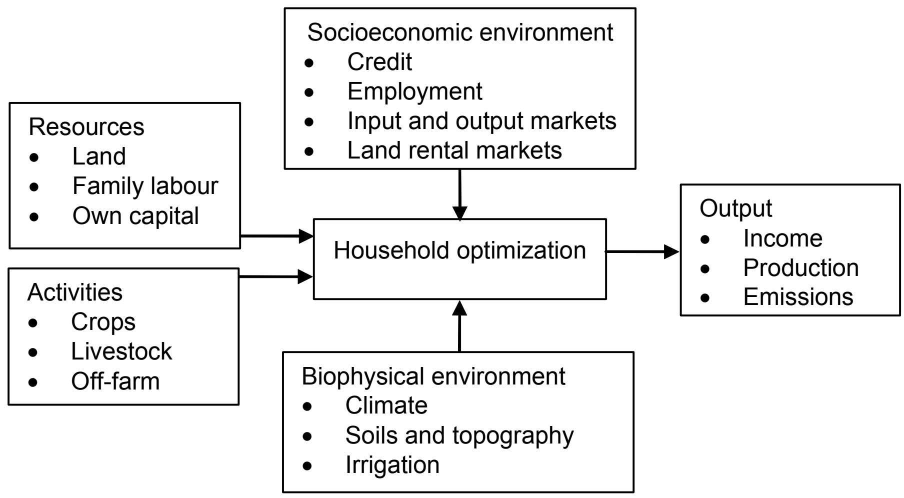

Figure 1. Basic structure of the farm household model.

A cluster analysis was performed on farm prices from 1985 to 2004 of 7 price-variable crops (eggplant, garlic, onion, sweet pepper, tobacco, tomato, watermelon). Based on the grouping of years, farm and retail price averages for each grouping were calculated for each crop. For each price combination, the constraint on minimum attainable income is imposed.

The decision variables in the model are land allocation by cropping system and rental of land for crop activities; selling and buying of crop products and livestock; allocation of family labour to crop and animal production activities, as well as to work outside the farm; hiring of labour for crop production activities; and credit. The constraints in the model are the resource endowments of the household (available land by quality, family labour, water, capital), subsistence consumption needs, opportunities for off-farm and non-farm work, number of animals and their feed requirements, and monthly capital and loans for on-farm activities.

Capital is a major constraint for farming. To capture the seasonality in availability of capital, cash balances are calculated by month. Starting capital for crop production expenses at the beginning of the wet season is assumed to be 25% of total income for the better-off households and 4% for the poor and average farm types, derived from the farm survey (NSO, 1997). This can be used for purchasing inputs or hiring labour for crop production activities. Credit can be obtained from informal sources at a rate of 10% per month and loans plus interest must be repaid at the end of the cropping season. Although it is possible for farmers to borrow money from formal sources at much lower interest rates, farmers rarely do so, because they do not have the needed collateral, there is too much paperwork and loans are not immediately released.

Material inputs, such as fertilizers and pesticides, are assumed to be purchased at the start of the growing season, whereas hiring of labour and costs for pumping water are accounted for in the month that the input is required. Irrigation fees (for surface-irrigated areas) and post-harvest expenses for tobacco processing are paid in the month of harvest.

Production activities and technology levels

Farmland in Batac was classified into eight land unit classes based on availability of surface irrigation, soil fertility and topography. Surface irrigation may be available during the wet season only, throughout the year or not at all. Land that is surface-irrigated throughout the year can be planted only with rice because of drainage problems. All farm households own a pump, thus making water available to all land units during the dry season.

Production activities have been defined at the level of annual cropping systems of one, two or three crops. Fifteen crops grown in the municipality were included in the model, with average yields from farmers' fields (Table 1). Twenty-three feasible combinations of crops were included as cropping systems: three single-crop systems (rice-fallow, sweet pepper-fallow, tomato-fallow), 17 double-crop systems (only two of which are not rice-based: sweet pepper-yellow corn, tomato-yellow corn) and three triple-crop systems (rice-garlic-mungbean, rice-yellow corn-mungbean, rice-white corn-mungbean).

Estimates of the inputs (e.g., seed, fertilizer, pesticide, labour, water) and outputs (e.g., yield) of production activities for the average practice were derived from a farm household survey conducted in Batac in 2001. For the alternative production

Table 1. Yield from experimental stations and techno-demonstration farms, and average farmers' yield and input use for land types with good soil quality and located in the lowland, Ilocos Norte province, Philippines[a].

Crop	Yield from experimental stations and techno-demonstration farms[c] (t ha^{-1})	Farmers' fields					
		Yield (t ha^{-1})	Nutrient application (kg ha^{-1})			Biocide use (kg a.i.[d] ha^{-1})	Labour use (d ha^{-1})
			N	P	K		
Rice (wet-irrigated)		4.2	126	16	20	0.45	101
Rice (dry-irrigated)	7.0-10.0	4.1	126	16	20	0.49	103
Rice (wet-rainfed)		3.9	110	15	2	0.44	98
White corn	5.0-7.0	2.2	81	11	17	0.13	68
Yellow corn		3.6	30	5	10	0.13	65
Garlic	5.0-10.0	1.5	76	19	36	1.06	71
Onion[b]	20.0-55.0	6.0	197	18	34	2.24	84
Tomato (contract)	-	28.0	150	30	138	4.87	104
Tomato	20.0-45.0	25.3	106	4	36	1.38	104
Sweet pepper	-	5.8	135	14	26	4.37	109
Eggplant	16.0-25.0	10.6	51	12	28	1.60	226
Mungbean	1.0-1.8	0.5	84	5	9	0.04	42
Peanut[b]	1.8-2.8	1.6	19	4	7	0.05	41
Sweet potato[b]	14.0-23.0	4.3	0	0	0	0.00	65
Watermelon[b]	-	10.9	122	20	33	1.66	77
Tobacco	-	1.6	39	14	28	0.73	132
Cotton	-	1.1	185	30	57	0.51	70

[a] Based on cropping year 2000-01 from a farm survey conducted in Batac, Ilocos Norte province (28 rural villages).

[b] None of the farmers surveyed planted this crop during the dry season of 2000-01. Values here were taken from the farm survey conducted in Ilocos Norte for the crop year 1998-99. Data refer to averages for surveyed fields in Batac only.

[c] Source of data: PGIN (1999). [d] a.i. is active ingredient.

technologies, on the other hand, input-output data were calculated following the target-oriented approach (Van Ittersum and Rabbinge, 1997). Combinations of inputs required to realize predefined target yield levels were quantified using TechnoGIN, a technical coefficient generator that integrates empirical data with production-ecological and expert knowledge in defining efficiencies in input use (Ponsioen et al., 2003, 2006).

Current farmers' practices Average yields are low and variability among farmers' fields is high. Similarly, big gaps exist between farmers' yields and yields obtained at experiment stations and techno-demonstration farms (Table 1). The yields and associated inputs for the land type with no surface irrigation, with good soil quality and located in the lowland are also given in Table 1.

Various studies in Ilocos Norte have shown that farmers usually apply excessive fertilizers to dry-season crops, particularly vegetables (Shrestha and Ladha, 1998; Lucas et al., 1999). In these high-input rice-vegetable systems, however, losses of up to 550 kg N ha^{-1} have been observed (Tripathi, 1995; Tripathi et al., 1997). Such systems may not be sustainable in the long run because of on-site and off-site adverse effects, such as groundwater pollution (Gumtang et al., 1999; Lucas et al., 1999).

Herbicide use, particularly for rice, is low (on more than half of the rice fields surveyed no herbicides were used). The majority of the vegetable farmers, however, spray large doses of herbicides and insecticides. Insecticides to control pests are sprayed once a week and sometimes even two to three times (Lutap and Atis, 2002; Roguel et al., 2002).

Alternative production technologies The four alternative production technologies were evaluated against current farmers' practices (CP). Characteristics of the alternative production technologies, in terms of yield, nutrient and pest management strategies, and labour use are given in Table 2.

HYR yields are assumed to be 25% higher than those of the current inbred varieties[a]. Crop parameters for rice used in TechnoGIN were revised to account for the change in yield potential, target yield, seeding rate (20 kg ha^{-1} for HYR *vs* 70 kg ha^{-1} for CP), price of seeds, additional cost of applying organic materials to the seedbed, 15% higher nutrient uptake efficiencies and higher labour requirements for land preparation and crop establishment (including seedbed preparation and management).

In BFS, rice and corn yields are assumed to be 15% higher and fertilizer

[a] Based on a data set consisting of 75 experiments conducted in 14 years, average standard heterosis was 24.6% at low yield levels (<5 t ha^{-1}) (Peng et al., 2003).

Table 2. Description of production technologies.

Technology	Yield	Nutrient management	Pest and weed management	Labour use
Current practice (CP)	CP	CP	CP	CP
Hybrid rice (HYR)	25% higher yield for rice	Additional 50 kg of organic materials for the seedbed; 15% higher recovery than CP	Same as CP	More labour for land preparation and crop establishment[a]
Balanced fertilization (BFS) for rice & corn	15% higher yield for rice and corn; same yields for other crops	Use of organic and inorganic fertilizers at specified rates; 15% higher recovery than CP for rice	Same as CP	4-5 more labour days ha^{-1} for hauling and application of organic fertilizer and crop care[a]
Site-specific nutrient management for rice (SSNMr)	15% higher yield for rice; same yields for other crops	As calculated by QUEFTS in TechnoGIN; 15% higher recovery than CP for rice	5% less insecticide and fungicide (rice only)	20% more labour for monitoring and crop care[a]
Site-specific nutrient management for all crops (SSNMa)	15% higher yield for rice; same yields for other crops	As calculated by QUEFTS in TechnoGIN; 15% higher recovery than CP	5% less insecticide and fungicide	15-20% more labour for monitoring and crop care[a]
Integrated pest management (IPM)	Same as CP	Same as CP	70-85% less insecticide; 10-20% less fungicide; 10% (rice) to 90% (vegetables) less herbicide	10 more labour days ha^{-1} for plastic mulching (vegetables); 20% more labour for monitoring and crop care[a]

[a] Labour requirements for harvesting/threshing per hectare are higher because of higher yields. In TechnoGIN, this parameter is expressed per ton of output. Labour use for harvesting/threshing per ton of output is unchanged.

applications follow the recommendations for Ilocos Norte, consisting of both organic and inorganic sources (application per ha):

Wet-season rice:	250 kg (commercial) organic fertilizer, 150 kg urea, 150 kg ‘complete’, 50 kg ammonium phosphate (total: 103 kg N, 19 kg P, 26 kg K)
Dry-season rice:	300 kg organic fertilizer, 50 kg urea, 150 kg ‘complete’, 200 kg ammonium sulphate (total: 92 kg N, 15 kg P, 27 kg K)
Corn:	250 kg organic fertilizer, 150 kg urea, 100 kg ‘complete’, 50 kg ammonium phosphate (total: 96 kg N, 16 kg P, 20 kg K).

Under BFS, less nitrogen and more potassium per hectare is applied to rice and more of all nutrients (N, P, K) to corn compared with current practices; labour for hauling and application of organic fertilizers is accounted for in higher labour requirements.

SSNM, in contrast to blanket fertilizer recommendations, involves the following principles: balanced fertilization based on crop requirements, crop-specific estimates of nutrient supplies from the soil, need-based fertilizer N management and sustainable P and K management (Witt et al., 2004).

Under SSNMr, a 15% higher yield for rice was assumed, and fertilizer requirements were calculated in TechnoGIN using the QUantitative Evaluation of the Fertility of Tropical Soils (QUEFTS; Janssen et al., 1990; Witt et al., 1999) approach. The QUEFTS module in TechnoGIN calculates fertilizer requirements by subtracting nutrient supply from ‘natural sources’ (i.e., soil organic matter and atmospheric deposition, also referred to as indigenous supply) from crop uptake and dividing the residual by the nutrient recovery fraction. Indigenous nutrient supply is estimated from soil chemical characteristics and existing studies involving crop yields in unfertilized plots in the lowlands of Ilocos Norte (Sta. Cruz et al., 1995; Pascua et al., 1999). Crop uptake at the target yield is calculated using a linear optimization procedure, with maximum dilution and accumulation of nutrients as constraints (Ponsioen et al., 2003). Under SSNMr, a 20% higher labour requirement for monitoring and crop care (including additional fertilizer applications) and a 5% lower insecticide and fungicide use, associated with a more balanced fertilizer application, are assumed.

Although SSNM was developed for rice, we assume that the principle of balancing fertilizer input with indigenous supply and crop nutrient requirement can also be applied to other crops (SSNMa). Under SSNMa, all assumptions under SSNMr hold for rice. For other crops, no change in yield, a slightly lower insecticide and fungicide use and a 15% higher labour requirement for crop care and monitoring are assumed.

Under IPM, there is no change in yield for any crop, but biocide use (especially for vegetables) is significantly lower. Additional costs to account for plastic mulch (for vegetables) and biological control agents (for non-rice crops) and additional labour use for monitoring and crop care are added, but there are considerable savings on insecticide (for all crops) and herbicide use (Kogan, 1998).

The input-output coefficients for the alternative production systems were derived from earlier studies, such as Casiwan et al. (2003) for hybrid rice, Concepcion et al. (1999) for BFS, Fairhurst and Witt (2002) and Dobermann et al. (2004) for SSNM, and Medina and Callo (1999) and Palis (1998, 2002) for IPM, and unpublished data from farmer field schools and techno-demonstration farms provided by the Agricultural Training Institute and Mariano Marcos State University, both located in Batac. In addition, information from interviews with farmer-adopters and agricultural technicians in Batac was used.

Results

The base run

Net income from the base run simulations, in which only current farmers' practices have been included (Table 3), is higher than that from the farm survey. The discrepancies could partly be explained by the inclusion in the model of off-season vegetables, which are a relatively new and highly profitable commodity. Their adoption was still low at the time the farm survey was conducted.

Comparison of actual land allocation by farmers during crop year 2000-01 with the results of the base run (Figure 2) shows a higher tobacco area under the base run simulation. Tobacco cultivation provides very high returns in spite of high labour requirements, particularly for post-harvest processing (sorting and flue-curing). Despite small differences for areas under vegetables and other crops for some farm types, the model adequately simulates actual land-use decisions of the different farm types in Ilocos Norte.

Poor and average households show similar capital intensities, whereas capital intensity for better-off households is slightly higher and credit intensity less than half of that for the other farm household types (Table 3). Labour intensity is highest for average-IR which grows more than 1 ha of rice, a labour-intensive crop.

Average annual biocide use of the different farm types ranges from 1.0 to 1.6 kg active ingredient (a.i.) ha^{-1} and fertilizer use is between 204 and 233 kg NPK ha^{-1}. Both, the level of chemical inputs and N loss show considerable scope for improving environmental efficiencies of current crop production practices of farmers in Ilocos Norte.

Table 3. Simulated indicator values for the base run for farm households in Ilocos Norte, Philippines.

Indicator	Unit	Farm type			
		Poor	Average-IR[g]	Average- RF	Better-off
Net income	10^3 pesos[e]	114	127	146	300
Discretionary income	10^3 pesos	98	110	130	281
Cultivated land[a]	ha	0.85	0.95	0.91	2.44
Rice area[b]	ha	0.80	1.04	0.77	1.99
Vegetable area	ha	0.11	0.04	0.19	0.45
Rice production	ton	3.0	4.4	2.9	7.7
Family labour	d yr^{-1}	133	149	144	319
Hired labour	d yr^{-1}	9	18	5	79
Labour intensity[c]	d ha^{-1} yr^{-1}	103	108	105	105
Capital intensity[d]	10^3 pesos ha^{-1} yr^{-1}	12	11	14	17
Credit intensity	10^3 pesos ha^{-1} yr^{-1}	7	6	8	3
Biocide use	kg a.i.[f] ha^{-1} yr^{-1}	1.4	1.0	1.6	1.6
Fertilizer use	kg NPK ha^{-1} yr^{-1}	233	228	204	229
N loss	kg N ha^{-1} yr^{-1}	43	34	37	41

[a] Includes own and rented land. [b] Area allocated to rice for all seasons; double rice is counted twice.

[c] Includes family and hired labour for crop production.

[d] Refers to cash outlay for variable inputs and labour. [e] In 2001, US$1 = 51 pesos.

[f] a.i. is active ingredient.

[g] Average-IR: average households with mostly surface-irrigated land; Average-RF: average households with land mostly without surface irrigation.

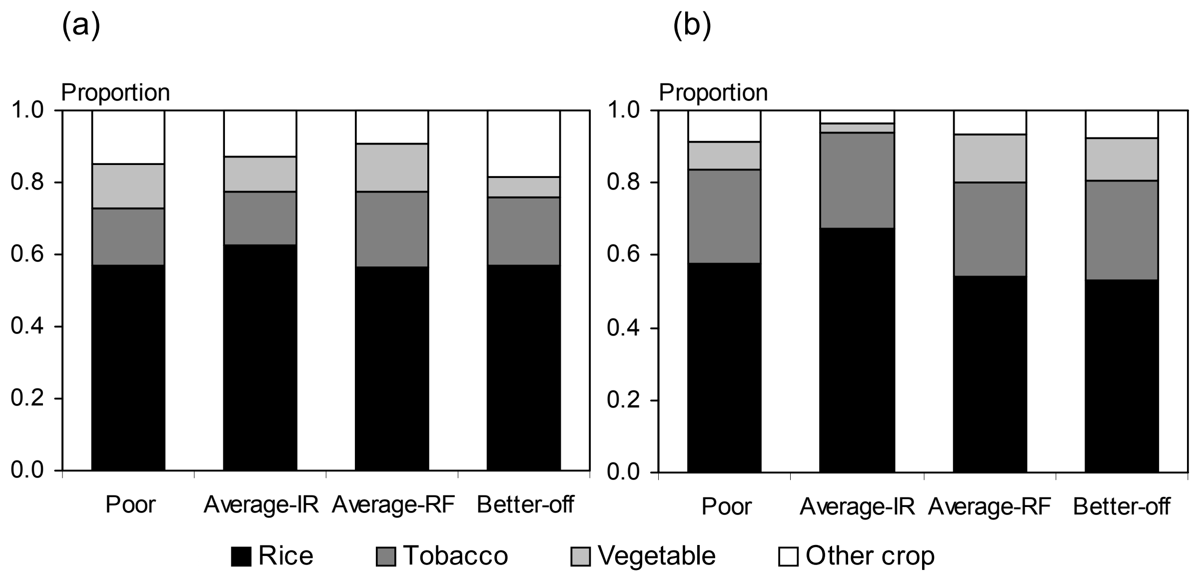

Figure 2. Actual land allocation by farmers in the crop year 2000-01 (a) and results from the base run (b) for different farm types in Batac, Ilocos Norte, Philippines.

Technological change simulations

The effects of introducing alternative technologies are shown in the results of the technology simulations (Tables 4 and 5). In the discussion of the results, comparisons refer to differences with the base run (Table 3).

HYR In the HYR simulations, farm households allocate at least 80% of their farmland to this technology. Adoption is highest for average households with mostly surface-irrigated land (average-IR) that allocate 97%. Average-IR has limited crop options compared with other households that have greater opportunities to grow off-season vegetables, providing a much higher income than hybrid rice. The simulation results in an increase in rice production by at least 25%. Labour, capital and credit intensities for crop activities, however, increase as a result of adoption of HYR.

BFS The BFS simulations show moderate to high adoption rates. Poor, average-RF and better-off households allocate from 44% to 67% of their cultivated land to BFS, whereas average-IR households allocate 97%. There is an increase in rice production resulting from the adoption of BFS, but very little or no change in discretionary

Table 4. Simulated response of farm households to alternative technologies in terms of the absolute (ha) and relative (%) areas used under the alternative technology.

Farm household	Technology simulation[a]					
	HYR	BFS	SSNMr	SSNMa	IPM	All technologies
Poor	0.75	0.57	0.75	0.57	0.82	0.85
	(88)	(67)	(88)	(67)	(96)	(100)
Average-IR[b]	0.92	0.92	0.42	0.31	0.93	0.95
	(97)	(97)	(44)	(33)	(98)	(100)
Average-RF	0.73	0.50	0.50	0.45	0.88	0.91
	(80)	(55)	(54)	(50)	(96)	(100)
Better-off	2.09	1.12	1.69	1.45	2.48	2.54
	(82)	(44)	(67)	(57)	(98)	(100)

[a] Numbers refer to cultivated land (in hectares) where farmers adopt the technology. Values in parentheses refer to proportion of total cultivated land (own and rented land that is left fallow is excluded). HYR hybrid rice production, BFS balanced fertilization strategy (for rice and corn), SSNMr site-specific nutrient management (for rice), SSNMa site-specific nutrient management (for all crops), IPM integrated pest management. For each technology run, only current practice and the corresponding technology are included. For the last column, current practice and all alternative technologies are included in the simulations.

[b] Average-IR: average households with 0.95 ha of mostly surface-irrigated land; Average-RF: average households with 0.91 ha, most of which are without surface irrigation.

Table 5. Simulated impact of adoption of new technologies on farm households' welfare, food production and the environment (% change over base run).

Indicator	Farm household type	Technology simulation[a]					
		HYR	BFS	SSNMr	SSNMa	IPM	All technologies
Discretionary income	Poor	2	1	2	2	5	7
	Average-IR[b]	3	1	1	1	2	4
	Average-RF	2	0	1	1	6	8
	Better-off	2	0	1	1	5	7
Rice production	Poor	25	12	15	11	0	22
	Average-IR	25	15	8	6	0	25
	Average-RF	25	10	10	9	0	22
	Better-off	38	19	24	22	11	36
Capital intensity	Poor	11	7	7	0	−16	−8
	Average-IR	16	14	7	6	−6	12
	Average-RF	9	6	4	2	−25	−17
	Better-off	12	6	5	4	−10	−1
Credit intensity	Poor	19	12	12	3	−29	−12
	Average-IR	32	27	14	11	−12	22
	Average-RF	17	9	8	6	−45	−31
	Better-off	73	37	35	31	−56	1
Labour intensity (crop activities)	Poor	8	5	5	3	4	8
	Average-IR	9	7	3	2	3	9
	Average-RF	7	4	3	3	5	9
	Better-off	7	3	4	3	4	8
Biocide use	Poor	−2	−1	−1	−1	−45	−15
	Average-IR	1	1	−2	1	−49	−5
	Average-RF	0	1	0	−1	−42	−20
	Better-off	−1	−1	−1	−2	−44	−19
N loss	Poor	−13	−20	−4	−12	0	−21
	Average-IR	−14	−29	7	0	0	−15
	Average-RF	−10	−16	−2	−11	0	−18
	Better-off	−9	−13	−1	−9	2	−16

[a] HYR hybrid rice production, BFS balanced fertilization strategy (for rice and corn), SSNMr site-specific nutrient management (for rice), SSNMa site-specific nutrient management (for all crops), IPM integrated pest management. For each technology run, only current practice and the corresponding technology are included. For the last column, current practice and all alternative technologies are included in the simulations.

[b] Average-IR: average households with 0.95 ha of mostly surface-irrigated land; Average-RF: average households with 0.91 ha, most of which are without surface irrigation.

income. N loss, however, is lower for BFS adopters, because of the more balanced application of fertilizers for rice and corn. Application of organic fertilizers, an important component of BFS, improves soil quality and may have long-term beneficial effects that, however, are not currently accounted for in the model.

SSNM All households allocate a significant portion of their cultivated land to SSNMr and SSNMa. In both technology simulations, poor households allocate the highest proportion (88% for SSNMr and 67% for SSNMa). The adoption of SSNM results in an increase in rice production. As a result of a more balanced fertilizer regime and higher nutrient recoveries, N loss is lower.

IPM The IPM simulations show very high adoption rates (> 96%), resulting in higher discretionary income for all farm types, accompanied by a substantial reduction in biocide use (> 42%). Labour intensities, however, are higher, due to the higher labour requirements for monitoring and crop care. Capital and credit intensities are lower because of the large reduction in biocide costs, particularly for vegetables.

All technologies The simulations including current and *all* alternative technologies show the comparative attractiveness of the alternative technologies considered. All four farm types adopt all the alternative technologies, albeit at different rates (Table 6). HYR is the most attractive among the alternatives considered. Adoption rate varies from 53 (average-RF) to 92% (average-IR). BFS, on the other hand, appears the least attractive with adoption rate only at 1% for all farm types.

The simulations including all alternative technologies show the highest increase in

Table 6. Land allocation (% of total area) for simulations including current and all alternative technologies for different farm types in Batac, Ilocos Norte, Philippines.

Farm household type	Technology[a]					
	CP	HYR	BFS	SSNMr	SSNMa	IPM
Poor	0	60	1	10	17	12
Average-IR[b]	0	92	1	1	2	3
Average-RF	0	53	1	11	15	20
Better-off	0	63	1	6	14	17

[a] CP current practice, HYR hybrid rice production, BFS balanced fertilization strategy (for rice and corn), SSNMr site-specific nutrient management (for rice), SSNMa site-specific nutrient management (for all crops), IPM integrated pest management.

[b] Average-IR: average households with 0.95 ha of mostly surface-irrigated land; Average-RF: average households with 0.91 ha, most of which are without surface irrigation.

discretionary income, despite the highest labour intensities (Table 5). In addition, the selected technologies result in lower biocide use and N loss, and hence in reduced environmental impact.

Policy simulations

The base run and technology simulations reflect the prevailing economic conditions. To further enhance adoption of alternative production technologies, policies may be formulated that provide incentives for farmers. To assess the effect of policy measures on the adoption of alternative technologies, the policy simulations were compared with the technology simulations. The policy instruments evaluated in this study are (1) input price policies (subsidy on fertilizers and taxation on fertilizers and biocides), (2) improvements in infrastructure, reflected in reduced transaction costs[b], and (3) availability of low-cost credit. The possible impacts of these policy measures on the adoption of alternative technologies and farmer welfare are shown in Tables 7 and 8, respectively.

Input price policies A 10% reduction in fertilizer prices frees some capital and may serve as an incentive (or disincentive) for adopting new technologies. At the same time, fertilizer and biocide only account for a small portion of the production expenses in rice. This explains why, generally, changes in fertilizer and biocide prices do have little effect on adoption of alternative technologies for rice (HYR and SSNMr). The only significant effects occur with BFS: better-off households increase the area under BFS by 22% if the fertilizer prices drops; a 10% increase in fertilizer prices results in a 54% reduction in adoption of BFS by average-IR households.

Under SSNMa, higher fertilizer inputs are required (particularly P and K). Hence a reduction in fertilizer price leads to expansion of area under this alternative technology.

The price simulations have little or no effect on discretionary income (Table 8).

Infrastructure improvements A reduction in transaction costs implies a narrower price band between the buying and selling price of farm products. It is assumed that, when transaction costs decrease, farm-gate prices increase, retail price decrease and costs incurred when family members engage in off-farm and non-farm work are lower.

A reduction of 10% in transaction costs results in an increase in discretionary income by at least 9% for all farm types and across all technologies considered. The effect on technology adoption, however, is variable. For poor households, there is no significant change in the adoption of alternative technologies. Other farm types

[b] Here transaction cost is defined as the price band between farm and retail prices.

Table 7. Simulated farm household response to policy instruments: change in area under technology (% change over technology simulations as presented in Table 4).

Technology[a]	Farm type	Policy instrument: Fertilizer price −10%	Fertilizer price +10%	Biocide price +10%	Transaction cost −10%	Credit rate (3%)
HYR	Poor	0	0	0	−1	0
	Average-IR[b]	0	0	0	0	0
	Average-RF	0	0	0	−1	0
	Better-off	0	0	0	−1	0
BFS	Poor	0	0	0	−1	32
	Average-IR	0	−54	0	0	0
	Average-RF	0	−1	0	−1	0
	Better-off	22	0	0	19	65
SSNMr	Poor	0	0	0	−1	0
	Average-IR	0	0	0	0	119
	Average-RF	0	0	0	−1	46
	Better-off	0	0	0	−1	24
SSNMa	Poor	16	0	0	0	32
	Average-IR	70	−2	0	81	82
	Average-RF	16	0	0	6	16
	Better-off	25	0	2	25	28
IPM	Poor	0	0	0	0	0
	Average-IR	0	0	0	0	0
	Average-RF	0	0	0	0	0
	Better-off	0	0	0	−2	0

[a] HYR hybrid rice production, BFS balanced fertilization strategy (for rice and corn), SSNMr site-specific nutrient management (for rice), SSNMa site-specific nutrient management (for all crops), IPM integrated pest management.

[b] Average-IR: average households with 0.95 ha of mostly surface-irrigated land; Average-RF: average households with 0.91 ha, most of which are without surface irrigation.

increase the area under SSNMa up to as much as 81% (average-IR). Better-off households expand the area under BFS by 19% and SSNMa by 25% in separate technology simulations. For these farm types with changes in adoption, there is an expansion of areas devoted to vegetables and watermelon – crops which require high inputs and have high transaction costs.

Table 8. Simulated farm household response to policy instruments: change in discretionary income (% change over technology simulations as presented in Table 5).

Technology[a]	Farm type	Policy instrument				
		Fertilizer price −10%	Fertilizer price +10%	Biocide price +10%	Transaction cost −10%	Credit rate (3%)
HYR	Poor	1	−1	−1	11	4
	Average-IR[b]	1	−1	0	10	2
	Average-RF	0	0	−1	10	3
	Better-off	1	−1	−1	9	1
BFS	Poor	1	−1	−1	11	4
	Average-IR	1	−1	0	10	2
	Average-RF	0	0	−1	10	3
	Better-off	1	−1	−1	9	1
SSNMr	Poor	1	−1	−1	11	4
	Average-IR	1	−1	0	10	2
	Average-RF	0	0	−1	10	3
	Better-off	1	−1	−1	9	1
SSNMa	Poor	1	−1	−1	11	3
	Average-IR	1	−1	0	10	2
	Average-RF	0	0	−1	10	3
	Better-off	1	−1	−1	9	1
IPM	Poor	1	−1	0	10	2
	Average-IR	1	−1	0	10	2
	Average-RF	0	0	0	9	1
	Better-off	0	0	0	9	0

[a] HYR hybrid rice production, BFS balanced fertilization strategy (for rice and corn), SSNMr site-specific nutrient management (for rice), SSNMa site-specific nutrient management (for all crops), IPM integrated pest management.

[b] Average-IR: average households with 0.95 ha of mostly surface-irrigated land; Average-RF: average households with 0.91 ha, most of which are without surface irrigation.

Credit Making low-cost credit available results in expansion of the areas under SSNMa for all households, and under SSNMr for average and better-off households. There is no change in adoption for poor households which are already adopting SSNMr on 88% of their land in the technology simulation. For poor and better-off households, the areas under BFS also increase. Availability of low-cost credit relaxes the capital constraint and allows farm households to increase borrowing. Discretionary income increases for all farm household types, with the highest net effect for poor households.

Discussion and conclusions

Current crop production systems in Ilocos Norte are characterized by low yields and inefficient use of fertilizers and biocides. These systems could be improved by introducing production technologies that lead to higher crop yields and make more efficient use of inputs. A farm household modelling approach is used in this study to simulate farmers' behaviour towards the adoption of alternative production technologies: HYR, BFS, SSNM and IPM. Because the model takes into account the resource endowments of farm households and the various activities, in addition to crop production, they are engaged in, farmers' adoption of new technologies can be simulated from a system's perspective.

The base run results show large differences in discretionary income for the different households, resulting from different access to resources. Also, because of differences in resource endowments and circumstances, farm households' adoption rates of alternative technologies and their impacts vary considerably. In all technology simulations, relative profitability, labour and capital requirements and availabilities are the decisive factors for the adoption of alternative technologies. Production activities that are too labour-intensive or require high investments at the start of the growing season cannot be widely adopted because of household resource limitations.

For labour requirements, it is important to note that family members are also engaged in other activities in addition to crop production (e.g., livestock and off-farm work). Introduction of labour-intensive technologies will result in higher costs for hiring agricultural workers to perform additional tasks. In the model presented here, hiring of labour is indirectly limited by available capital. In reality, when labour needs of all households are pooled, there may not be enough labour for hire for labour-intensive tasks.

Moreover, labour for monitoring and decision-making in knowledge-intensive technologies, such as SSNM and IPM, may not always be available. If decisions are highly farm-specific, then the costs associated with acquiring the required knowledge can be high, and therefore be a major factor preventing adoption (Pingali et al., 1998). Pandey (1999) also asserts that a necessary condition for the adoption of knowledge-intensive technologies is that savings should be higher than the costs of their acquisition and use. These additional decision costs, however, are not accounted for in the model, so the actual adoption of SSNM and IPM could be lower than suggested by the results of the simulations presented here.

Results show that all alternative technologies are promising in terms of adoption by farmers. HYR can contribute to increased food production. In terms of effect on the environment, BFS and SSNM lead to large reductions in N loss, whereas IPM leads to a strong reduction in biocide use. IPM shows the highest rate of adoption (in separate technology simulations) and increase in discretionary income. The model, however, does not account for risk in yield involved in adopting IPM, particularly for vegetables. The risk accounted for in the model is that of risk in prices only.

Policy simulations show that fertilizer and biocide price changes do not strongly affect adoption, except for SSNMa. The lack of response to increased biocide prices is consistent with the findings of Binamira (1991) that biocide price changes have no quantifiable effect on adoption preference for IPM of irrigated rice farmers in the Philippines.

The reduction in transaction costs and the availability of low-cost credit show the largest effect on improvement in farmer welfare for all farm types, but have varying effects on the adoption of alternative technologies. These policy instruments have the largest effect on poor households and the smallest on better-off households.

The model presented here adequately simulates the current situation and the decision-making behaviour of farmers. The methodology also allows evaluation of the impacts of policy measures on inducing farmers to adopt alternative production technologies. Such results can therefore contribute to policy discussions on the most appropriate policy instruments for stimulating adoption by farmers of more resource-use-efficient and sustainable practices.

CHAPTER 4

Integration of Systems Network (SysNet) tools for regional land use scenario analysis in Asia: A case study for Ilocos Norte province, Philippines*

Abstract

This chapter introduces the approach of the Systems research Network (SysNet) for land use planning in tropical Asia with a focus on its main scientific-technical output: the development of the land use planning and analysis system (LUPAS) and its component models. These include crop simulation models, expert systems, GIS, and multiple goal linear programming (MGLP) models for land evaluation and optimization. LUPAS is aimed at exploration of potential and alternative land use options at regional (e.g., provincial) scale. LUPAS was designed as a decision support system (DSS) for strategic land use planning. Integration of LUPAS components in four case studies was performed in a network with national research teams and local stakeholders. This network allowed iterative evaluation and refinement of LUPAS for scenario analysis on technical and policy changes. Several interactive sessions with stakeholders led to more detail in scenarios (goals and constraints), model features and databases. In interactive sessions, goal restrictions are tightened to quantify trade-offs between conflicting goals. Choice and degree of tightening reflect the specific priorities for sustainable land use. The development of LUPAS is exemplified for one case study, the province of Ilocos Norte, Philippines. Weak points of the system include inadequate spatial differentiation of socio-economic characteristics, scarce database for quantifying perennials and mixed cropping systems, and insufficient consideration of long-term effects of production technologies on resource quality. However, a promising perspective for effective policy support lies in the possible link of the regional LUPAS approach with farm household models.

Keywords: Land use planning; Regional modelling; Systems research; Scenario analysis; Simulation models; Information technology; Rice-based production systems; South and South-east Asia

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* Adapted from Roetter, R.P., Hoanh, C.T., **Laborte, A.G.**, Van Keulen, H., Van Ittersum, M.K., Dreiser, C., Van Diepen, C.A., De Ridder, N., Van Laar, H.H., 2005. Integration of Systems Network (SysNet) tools for regional land use scenario analysis in Asia. Environmental Modelling and Software 20, 291-307.

Introduction

The need for new tools for land use scenario analysis

Growing populations, expanding economies and increasing urbanization characterize the situation in South and South-east Asia. Agricultural systems 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 (El Swaify, 1998; Walker, 2002; Lu et al., 2004). In such situations, effective systems analysis tools are required (Van Ittersum et al., 1998) to:

- quantify conflicts in rural development goals, land use objectives and resource use;
- support identification of technically feasible, environmentally sound and economically viable production systems that best meet a well-defined set of rural development goals; and
- widen perspectives of stakeholders through learning about possibilities and limitations within the (agricultural) land use system, thus contributing to a more transparent policy-making process.

For this purpose, the 'Systems Research Network for Ecoregional Land Use Planning in Tropical Asia' (SysNet), launched in late 1996, developed the land use planning and analysis system (LUPAS), that was evaluated in four case study regions (Roetter and Hoanh, 1998; Roetter et al., 1998). Until then, methodologies for exploratory land use analysis had been developed for different regions (Veeneklaas et al., 1991; Stoorvogel et al., 1995); however, these studies had been conducted independent of specific demands and questions of local stakeholders and with their limited involvement in the research process.

Since the mid 1980s, new quantitative approaches for agricultural policy support at (sub-) regional level have been developed, resulting in a range of complementary analytical frameworks and operational tools (Stoorvogel and Antle, 2001). Following Van Ittersum et al. (1998), these tools may be sub-divided on the basis of their objectives into explorative, projective and predictive.

For example, in the explorative land use study focussing on the biophysical and socio-economic perspectives for southern Mali, bio-economic modelling has been applied (Kuyvenhoven et al., 1998), implemented in the form of a multiple goal linear programming (MGLP) model for regional analysis (Bakker et al., 1998; Sissoko, 1998). A regional MGLP model also forms the core of LUPAS.

An example of a projective tool is the CLUE model (De Koning et al., 1999), that projects land use changes based on statistical relationships among various drivers.

A different type of tool is required to analyse the scope for land use changes in the short term as a result of agricultural policies and technologies ('predictive' analysis). In the trade-off analysis model (Stoorvogel et al., 2001) an econometric process simulation model approach is applied to quantify trade-offs among different ecological and economic indicators of agricultural systems. This trade-off analysis is based on a stochastic simulation framework that combines site-specific data with an econometric representation of the production technology. The multi-agent/cellular automata approach, which takes social and spatial interaction explicitly into account, has been applied to better understand resource use change and diffusion of innovation (Berger, 2001).

In a major effort to document progress in and outline prospects for the emerging discipline of integrated assessment and modelling (IAM) of ecosystems and environmental processes, Parker et al. (2002) underline the importance of incorporating human components and joint learning for solving future environmental problems. Communication among scientists and with stakeholders is identified as the central issue. Examples of IAM for catchment management have been presented by Jakeman and Letcher (2003).

SysNet project and its overall research approach

Stimulated by the United Nations Earth Summit on 'Environment and Development' (UNCED, 1992), new concepts in land use planning were introduced (FAO, 1993, 1995) and 'Ecoregional Initiatives' were established world-wide (Bouma et al., 1995), to promote sustainable agriculture and integrated rural development. SysNet, operating during 1996–2000, was a methodology development project under the umbrella of IRRI's Ecoregional Initiative (ECOR(I)) for the humid and subhumid tropics and sub-tropics of Asia. ECOR(I) was established in 1995 with the aim to improve natural resource management (NRM), determine research priorities and required policy changes in the major rice-growing environments in Asia (Teng et al., 1997; IRRI, 1998).

SysNet was expected to contribute to the design, exploration and evaluation of land use options at higher (i.e., regional) integration levels, such as province and state. Specifically, its objectives were to develop methodologies and tools for exploratory land use analysis, and to evaluate these for generating options for policy and technical changes. SysNet's strategy was to develop an operational methodology and corresponding system for quantitative land use planning at the regional level, and to elaborate and evaluate the methodology in close interaction with stakeholders in four representative regions.

The expected outputs of SysNet were:

- a general methodology for land use planning, models and expert systems for estimating yield at the sub-national level;
- various options for agricultural land use, explored at four representative domains; and
- teams of trained scientists capable of applying systems analysis techniques at the regional level, to identify development potentials, opportunities and constraints.

The SysNet approach can be regarded as a further step in the development of exploratory land use studies. These studies combine quantitative land evaluation with linear programming, production ecological principles and economics and are based on the conceptual work of Spronk and Veeneklaas (1983) and De Wit et al. (1988). During the last decade several research projects (Veeneklaas et al., 1991; Bouman et al., 2000a) have contributed individual building blocks to this methodology.

Conflicts in decisions on land use need to be analysed in the local context, i.e., in specific biophysical and socioeconomic settings. In SysNet, provinces/states were selected as target regions, since these represent an important decision level for policy formulation and implementation of land use plans. The four regions selected at sub-national scale, on basis of data availability and research management aspects, were Haryana state (India), Kedah-Perlis region (Malaysia), Ilocos Norte province (Philippines) and Cantho province (Vietnam) (Aggarwal et al., 1998; Tawang et al., 1998; Lansigan et al., 1998; Lai et al., 1998).

Partners in SysNet

SysNet was structured around five main partners: the national agricultural research and education systems (NARES) of India, Malaysia, Philippines and Vietnam and the International Rice Research Institute. In addition, several institutes of Wageningen University and Research centre (Wageningen UR) substantially supported the network through conducting and coordinating scientific work. Moreover, networks of stake-holders from different levels (village, municipality, district, provincial/state government) were established (Roetter et al., 2000a, b).

Land use issues in the case study regions

Common to all case study regions is, that they are expected to produce food far above local demand, to feed the increasing urban population. Currently, agricultural production in the study regions is being (further) intensified and diversified. At the same time, analysis of issues related to land use, resource availability and quality indicates that the sustainability of the prevailing agricultural systems is – at least – partially at stake. For instance, Haryana state (India) and Cantho province (Vietnam), that greatly benefited from the green revolution, are now struggling with undesired ecological side-effects of intensification, such as declining water tables (Haryana) or long-term decline in the productive capacity of the soil (Aggarwal et al., 2001; Dobermann et al., 2000). Moreover, prices for rice and wheat remain low (Dawe, 2002) and the gap between farmers' income and that of the urban population widens. Diversification and intensification of agricultural production may lead to higher incomes, but presumably at the expense of reduced availability and quality of scarce soil and water resources.

Differences in ecological conditions, economic situations and problem perceptions lead to different sets of questions for which decision support is required (Hoanh et al., 1998; Van Ittersum et al., 2004). Table 1 provides an overview of the characteristics of the various case study regions.

Objectives of this chapter

In this chapter, the LUPAS modelling framework is described together with its underlying methodology, model components and their development and integration into a modelling system, and the evaluation of that system in a network consisting of scientists and local stakeholders.

In the next section, the basic methodology elements and a number of system development aspects are addressed. Model results to support land use planning, exemplified for one study region, Ilocos Norte, are presented and discussed. Finally, research challenges and future steps in operationalizing the decision support system LUPAS for multi-scale analysis of land use scenarios will be identified in the last section.

Table 1. Main characteristics of the four case study areas.

Items	Haryana (India)	Kedah-Perlis (Malaysia)	Ilocos Norte (Philippines)	Cantho (Vietnam)
Total area (million ha)	4.42	1.01	0.36	0.30
Agricultural land area (million ha)	3.72	0.53	0.09	0.25
Population (million persons)	16.5	1.64	0.50	1.89
Agricultural labour (million persons)	2.76	0.28	0.12	0.93
Agro-ecological units	87	19	8	18
Administrative units	16	11	23	7
Major agricultural land use types	14	18	23	19

LUPAS: approach, components and their integration

Basic approach and methodology elements

Land use planning is defined as the systematic assessment of land and water potential, alternatives for land use, and economic and social conditions in order to select and adopt the best land use options (FAO, 1993). While over the years public concern has been expressed with respect to a large number of land use issues, specific to rural or peri-urban areas, the core issues remain:

- conflicts in land use objectives by different interest groups;
- uncertainty about future land use objectives, land resources and technological options.

To tackle these, we advocate a systems research approach in which systems simulation and scenario analysis are applied as a means of gaining understanding of system behaviour when various factors change (Forrester, 1971). As such, these techniques can support decision-making under multiple objectives and uncertainty (Rehman and Romero, 1993; Hayashi, 2000).

LUPAS (Figure 1), developed with the aim to improve the scientific basis for land use planning, is a decision support system (DSS) for strategic planning, based on the interactive multiple goal linear programming (IMGLP) technique (Nijkamp and Spronk, 1980; De Wit et al., 1988). Agricultural systems are characterized and analysed through:

- databases on biophysical and socio-economic resources and development targets;
- input-output models for all promising production activities and technologies;
- multiple criteria decision method (IMGLP models);
- sets of goal variables (representing specific objectives and constraints).

Three major methodology elements can be distinguished in LUPAS (Van Ittersum et al., 2004): (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.

Operationalizing the methodology requires:

- survey data, models and expert systems for assessing resource availability and quality and describing input-output relations for all relevant production activities;
- active stakeholders that translate and prioritize policy views into specific objectives and targets; and
- IMGLP models to optimize land use under different sets of objectives and constraints.

LUPAS was developed, adapted and evaluated in various cycles in close collaboration with local stakeholders (Roetter et al., 2000a, b). The way multi-stakeholder interaction has been facilitated is reported by Roetter et al. (2001). A detailed account of the concepts and steps applied in developing LUPAS methodology is given by (Van Ittersum et al., 2004). The specific roles of scientists and other stakeholders in the SysNet research process and its impact are treated by (Roetter et al., 2000b) and in the subsequent discussion.

Characterization of main components

In the operational structure of LUPAS, illustrated in Figure 1, four modelling components and three databases can be distinguished (Hoanh et al., 1998):

Components:

(C1) Resource balance and land evaluation

(C2) Yield estimation

(C3) Input-output estimation

(C4) Interactive multiple goal linear programming

Databases:

(D1) Biophysical resources

(D2) Socio-economic resources

(D3) Policy views and development plans

For each of these components, the main functions, techniques and tools applied are summarized in Table 2.

For a given development scenario, results from C1, C2 and C3 are integrated, in combination with value-driven information contributed by various interest groups in C4. The resultant IMGLP model run generates land use options in the form of goal achievements, land use allocations and associated resource requirements for a given set of objectives and constraints. Results are automatically transferred and inserted in tables, graphics and maps for immediate presentation, following a fixed format.

Resource balance and land evaluation (C1)

Characterization of regional resources is of critical importance, because these resources dictate the potential of the land for food production and present the major constraints to attaining these potentials. Such characterization consists of a description of the spatial and temporal availability of both the natural and other biophysical resources and the various socio-economic resources (Kalra et al., 2001). Characterization of resource supply and demand is closely linked to the relevant questions formulated in the regional development scenarios (land use objectives and constraints).

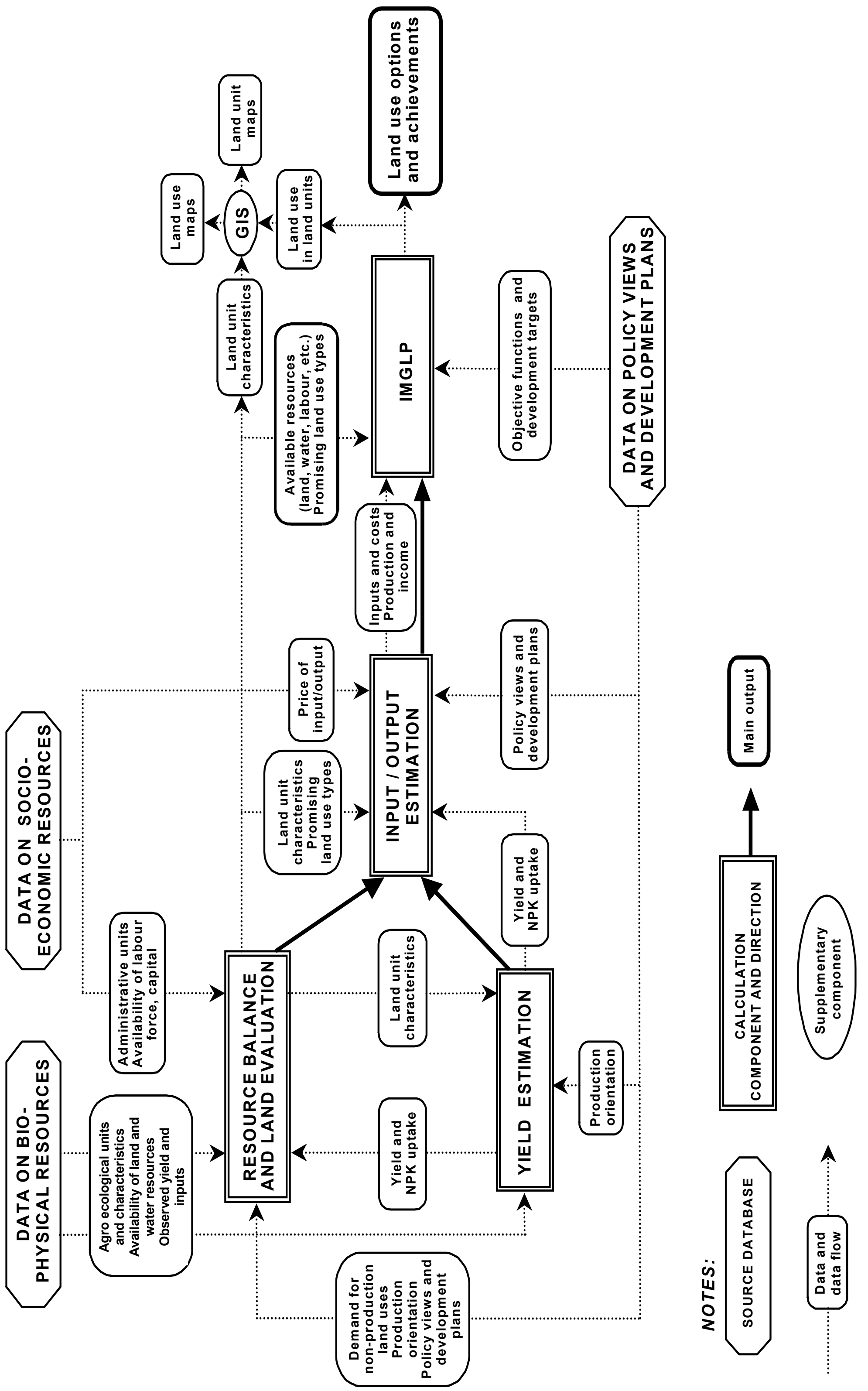

Figure 1. Operational structure of LUPAS modeling framework.

Table 2. Characterization of LUPAS components and techniques applied.

Component	Main functions	Tools and techniques
Resource balance and land evaluation	To identify land units and their characteristics based on agro-ecological units and administrative units.	Overlay technique in GIS
	To estimate available resources (land, water, labour) for production-oriented land use (agriculture, fisheries, and production forestry).	Statistical analysis for population and labour projection Referring to policy reports and sectoral development plans Balance between supply of resources and demands for other than production-oriented land use (settlements, infrastructure, industry) GIS to identify resources available for agricultural land use in each land unit
	To identify promising land use types and possible technology levels applied in each land unit.	Statistical analysis of experimental and farm survey data; literature review, comparison by transfer and experimental research Consultation with national and international experts, including stakeholders and farmers Qualitative land evaluation including crop simulation modelling
	To formulate objective functions for various land use scenarios.	Referring to policy reports and sectoral development plans Consultation with stakeholders
	To identify demand for products (type and amount) and potential changes.	Projection of local demand Statistical analysis of market potential
Yield estimation	To estimate actual, potential and future attainable yield of main products and by-products from promising land use types at well-defined technology levels in each land unit.	Crop modelling, including complex models and simple parametric models Statistical analysis of farming survey data; consultation with national and international experts (including local farmers); interpolation or aggregation of environmental variables by GIS
	To estimate side-effects, in particular environmental impact promising land use types in each land unit.	Thematic modelling (as soil erosion model, methane emission model; leaching models) and links to GIS: statistical analysis of experimental and survey data Consultation with national and international experts
	To analyse spatial and temporal variations of yield and side-effects	GIS and statistical analysis
Input/output estimation	To estimate input-output relations for the various production activities.	Crop modelling Statistical analysis of experimental and survey data Using technical coefficient generators Expert judgement
	To estimate variations of input-output values due in dependence of selected land use options	Expert judgement Analysis of elasticities of supply and demand (not formalized in SysNet case studies) Multi-temporal analysis (not formalized)
	To analyse spatial and temporal variations of input-output	GIS and statistical analysis
Multiple goal linear programming	To generate land use options for each scenario by optimizing selected objective functions under explicit goal constraints.	Linear programming using commercial software packages
	To identify and analysis conflicts in land use objectives and land resources	Scenario analysis by using interactive multiple goal linear programming (IMGLP) technique
	To identify the effects of government policy	Sensitivity analysis of government policy parameters
	To analyse the risks associated with selected land use options	Statistical analysis of relevant factors of physical and economic environment Sensitivity analysis in IMGLP of relevant factors
	To analyse spatial and temporal distribution of resources to land use types	GIS and statistical analysis

In LUPAS, this component comprises the following activities:

- formulating objective functions (and constraints);
- delineating land units;
- assessing land suitability for promising land use types and agricultural activities;
- assessing available land, water and labour resources;
- estimating demand for agricultural products.

In SysNet's case studies, different resource characteristics, aggregation levels and methods for assessing current and future resource availabilities have been selected, depending on the land use scenarios of interest, data availability and the specific biophysical and socioeconomic settings (Ismail et al., 2000; Kalra et al., 2001).

A land unit (LU) is defined as an area of land with specific land characteristics and land qualities that can be mapped (FAO, 1993). In LUPAS, an LU is a unique combination of an agro-ecological unit with a (socio-economic or administrative) sub-region, and as such the smallest calculation unit for which input-output relations for agricultural activities are quantified. Characteristics (agro-climatic, topographic, pedological, hydrological, irrigation schemes) considered for establishing and delineating agro-ecological units (AEUs) for each region, are given in Table 3.

Table 3. Biophysical characteristics considered in delineating AEUs in the various case study areas.

Characteristics	Haryana	Kedah-Perlis	Ilocos Norte	Cantho
1. Average annual rainfall	x	-	-	-
2. Temperature zones	x	-	-	-
3. Agro-ecological Zone (AEZ)	-	x	-	-
4. Slope/elevation	-	x	x	-
5. Flooding depth	-	-	-	x
6. Flooding duration	-	-	-	x
7. Soil classification	-	-	x	x
8. Parent material	-	x	-	-
9. Soil texture	x	x	-	-
10. Soil organic carbon	x	-	-	-
11. Salinity	x	x	-	-
12. Sodicity	x	-	-	-
13. Laterite occurrence	-	x	-	-
14. Irrigated areas	x	x	x	x

GIS overlays of the various characteristics (data surfaces or attribute vectors) resulted in different numbers of AEUs per study area. These were then overlaid with administrative sub-regions (municipalities in Ilocos Norte; districts in Haryana and Cantho, districts and development authority boundaries in Kedah-Perlis). For this purpose, minimal map generalization was performed by combining very similar units (whereby homogeneity was based on outcome of IMGLP runs with higher differentiation of land attributes) or assigning very small units to the most similar larger units.

The selection of characteristics, their weights and class boundaries were, in first instance based on expert knowledge, on correlation between individual characteristics and qualities, and in relation to the current and (anticipated) future land use activities. Generally, this procedure was not restricted by data availability – with the exception of certain socio-economic data that could not be disaggregated.

For evaluating land suitability for (identified) agricultural production activities, different techniques were applied:

- determination of areas not suitable for agriculture from satellite data or digital elevation (slope) maps, in combination with land use maps;
- defining promising agricultural activities using crop zone maps or expert systems for assessing land suitability and yield expectation in combination with expert judgement from local stakeholder meetings;
- establishing cropping calendars using rainfall distribution and flooding maps in combination with expert knowledge.

Resource availability was also assessed in different ways in the four case studies:

- land availability (land use statistics; detailed land use maps);
- water availability (water balance based on rainfall, potential evaporation, crop water and irrigation requirements; ground and surface water availability per district/municipality; irrigation facilities);
- labour availability (based on population statistics per district/municipality);
- future (year 2010) resource availability (trend projections, taking into account development plans).

Demands and targets for agricultural products were estimated in each case study. The minimum requirements (local demands) for products were derived from (projected) per capita consumption multiplied by (projected) population, while the production targets were based on agricultural policy and action plans.

Yield estimation (C2)

Information on the resource base from C1 needs to be related to the biophysical potentials and limitations of land units to producing economic yields of different crops and livestock. This requires consideration of current farming systems and those likely to gain importance in the future ('promising' land use types).

For estimating yields, various growth-defining, -limiting and -reducing factors can be distinguished according to the concepts of production ecology (Van Ittersum and Rabbinge, 1997). During the last three decades these concepts have been translated into a multitude of crop simulation models (Bouman et al., 1996). In these models the production potential of a specific crop cultivar in a given environment is determined by the interactive effects of atmospheric CO_2 content, radiation and temperature conditions on crop growth and development. Realization of this production potential, in any specific situation, can be limited by shortage of water, nutrients, or by other edaphic factors. Insects, weeds and diseases can further reduce yields. The difference between potential and actual yield represents the magnitude of technology improvement that is possible within a given environment. These production levels (and, thus yield gaps) may vary considerably in the different AEUs.

For many, but not for all, annual field crops, crop growth simulation models of the SUCROS and DSSAT model families (Bouman et al., 1996), such as WOFOST (Boogaard et al., 1998) and CERES-Rice (Singh et al., 1993), were applied to estimate potential yields, as well as yields limited by water and nutrients. Farm surveys and yield statistics were used to estimate actual yields (Roetter et al., 1998). Under the SysNet project, particular attention was paid to further develop the functionality of crop simulation model WOFOST and its crop database for the purpose of the regional optimization studies. A user interface (WOFOST Control Center, WCC) was developed, to allow easier handling of input data, compilation of model runs and extraction of results. Furthermore, calibration and validation exercises, including some important annual crops, were performed (Roetter et al., 1998). This eventually resulted in model version 7.1 (Boogaard et al., 1998) of the generic crop growth simulation model WOFOST.

Input-output estimation (C3)

In LUPAS, input-output estimation describes the main 'choice elements' of agro-ecosystems (production activities) in a quantitative manner. In production ecology, a crop production activity is defined as 'the cultivation of a crop or crop rotation in a particular physical environment completely specified by its inputs and outputs' (Van Ittersum and Rabbinge, 1997). Similarly, a livestock activity is defined as the keeping of an animal or herd in a particular environment completely specified by its inputs and outputs. In this approach, the inputs and outputs are characterized in so-called 'technical coefficients'. They quantify agricultural outputs and the required amounts (time-specific) of various (mixtures of) inputs such as labour, water, fertilizer, and feed that can also be expressed by their monetary values. In addition to marketable products and crop residues, undesirable outputs, or 'externalities' of the production process that affect the resource base, such as soil nutrient depletion and/or pollution of the environment (such as methane emissions to the air or nitrate leaching to the groundwater) are considered. Different technology levels, characterized by different sets of technical coefficients, can be applied for a crop/livestock activity in a given physical environment. In LUPAS, technical coefficients are used to characterize 'all' relevant current and possible future (alternative) production activities for a target region, sub-divided in homogeneous land units.

A technical coefficient generator (TCG) is a tool for creating an input-output matrix for different combinations of land units, crop/livestock activities and technology levels. In recent years, several TCGs have been developed for the purpose of exploratory land use studies (Hengsdijk, 2001). In SysNet, three different TCGs were developed:

- TechnoGIN, developed for Ilocos Norte, calculates technical coefficients using a target-yield approach (Ponsioen et al., 2003; 2006);
- AGROTEC for Cantho (Jansen, 2000); and
- CASS for Haryana (Bandyopadhyay et al., 2001; Pathak et al., 2001).

While these TCGs differ in terms of options, data requirements and program structure, they follow a common target-yield-oriented approach, in which the inputs required to realize a given target yield are calculated on the basis of knowledge of the physical, chemical, physiological and ecological processes involved in crop growth and livestock production (Van Ittersum and Rabbinge, 1997).

In terms of database handling, adaptability/flexibility for extensions, TechnoGIN is the most advanced. It is programmed in MS Excel with macro programming in Visual Basic. The prototype of TechnoGIN has been arranged in one Excel file including three major components: (1) user forms for data selection and handling, (2) databases, and (3) a macro (incl. solver models) for calculating technical coefficients (Figure 2).

For given combinations of land use type, land (management) unit, and target yield, data worksheets (identified by 'water', 'nutrient', etc.) are generated in the macro to calculate sets of technical coefficients. Solver modules are used for calculation of optimal balance of required fertilizer (following the QUEFTS approach (Janssen et al., 1990) and of associated fertilizer costs. Based on comments of users, TechnoGIN has been further developed to permit variation of resource use efficiencies, and calculation of nutrient balances at different levels of detail. Training modules have been added to facilitate learning about the various calculation procedures. For details on the current capability of TechnoGIN, its structure and algorithms reference is made to the most recent user's guide (Ponsioen et al., 2003, 2006).

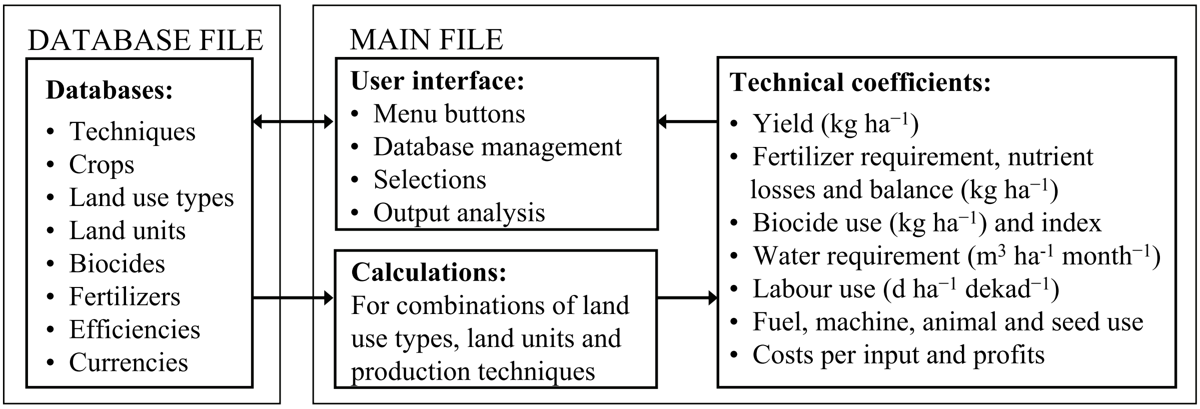

Figure 2. Simplified representation of TechnoGIN (the arrows represent flows of data) (Source: Ponsioen et al., 2006).

Interactive multiple goal linear programming (IMGLP) (C4)

At the core of LUPAS is an optimization model, called interactive multiple goal linear programming (IMGLP) model (Nijkamp and Spronk, 1980). It 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). Interactive refers to the consultation with different stakeholders in identifying agricultural objectives and constraints under different development scenarios, combining multiple objectives. Furthermore, in various iterations, guided by discussions among stakeholders, different goal restrictions can be tightened, to quantify trade-offs between conflicting goals, which may lead to further discussions on alternative scenarios or negotiation of the most acceptable solution (Ten Berge et al., 2000).

Models, programmed in XPRESS-MP (Dash Associates Ltd., 1997), along with the data used in the optimization have been developed for the four case studies. The IMGLP technique is illustrated with an example, presented in the next section. In a very simplistic form the underlying linear programming model can be mathematically described by:

Maximize (or Minimize) $W = \sum cx$

Subject to the constraints: $Ax \le b$ and $x \ge 0$

in which c is a vector containing the coefficients of the production activities contributing to the objective function, A is a matrix containing the coefficients of the production activities relating their contribution to the constraints, and b is a vector containing the boundary values for the constraints.

Link between components (C1–C4) and databases (D1–D3)

All data on available resources (from C1), yields (from C2) and associated input–output relations for land use activities (from C3) are linked to an IMGLP model (C4) developed in the mathematical programming software XPRESS-MP (Dash Associates Ltd., 1997). As indicated in Figure 1, the four components draw basic information from three databases (D1-D3) to generate input as required by the IMGLP model. Details on data and IMGLP model structure and complete sets of databases for each case study are provided by Laborte et al. (2001) (CD ROM SysNet Tools, version 1.1). Output data are aggregated to different spatial levels (land unit, municipality and district).

GIS is used as a supporting tool in the mapping of model input and results of land use optimizations.

The model will optimize, based on the selections, and generate output (goal achievements, land use allocation).

SysNet set the following criteria for integration of tools (TCG, IMGLP models, GIS), data and information from and with local stakeholders in a common modelling framework (LUPAS) for the purpose of land use scenario analysis:

- tailor-made system in response to stakeholders' questions and information needs;
- development of tools and databases tailored to the specifics of the regional problems;
- efficient links of tools and data for generating the required information;
- a system, designed for facilitating communication and negotiation between scientists and stakeholders and for making the data pool accessible to stakeholders.

With the realization of the IMGLP user interface for interactive land use scenario analysis, also the latter two criteria were met. All LUPAS components have been made available on CD-ROM, including a technical description of the user interface (Laborte et al., 2001).

The process of multiple goal analysis comprises three steps: (i) pre-optimization, (ii) optimization, and (iii) post-optimization. In step 1, stakeholders are requested to answer a number of questions (Table 4) that help to shape up and tailor all analytical components of LUPAS to a given regional case study. Based on the answers to these questions, the database structure is formulated, and data to be used in the optimization step are collected or estimated. In the post-optimization step, land use scenarios are analysed and presented to stakeholders. Following an iterative process of thorough formulation of relevant questions, building of comprehensive databases, scenario formulation and examination of results, addition of a user interface can add value to the system by transforming it into a vehicle for informed communication between participants of (established) discussion platforms.

Table 4. Main questions to be answered in scenario construction (pre-optimization analysis).

Analytical step (LUPAS component)	Question
Resource balance and land evaluation	• What is the spatial extent of the study region? (whole region or certain sub-region(s))? • What is the target year of the scenario? • What are the objectives of agricultural land use in the target year? • What are the demands for each agricultural product in the target year, including local consumption, national requirement and potential markets? • How much land resource is available for agriculture in the target year after satisfying the claims on land by prioritized land use such as infrastructure, industry and settlements? • How much water resources, including rain, surface and groundwater are available for agriculture in that target year taking into account the development in water supply and water use? • How much labour-force is available for agriculture in the target year considering development and migration to urban and industrial regions? • How much capital is available for agricultural land use in the target year? • What are the relevant agricultural land use types and technology levels currently applied in the region? • What might be promising land use types and technology levels for the regions in the target year?
Yield estimation	• What are current yield levels and corresponding technology? • What are target yield levels in the target year? • What are biophysical conditions/quality of the natural resource base (climate, soil, water) in each land unit in the target year? • What are current and alternative production technologies and inputs (labour, fertilizer, pesticides, etc.) required to achieve alternative target yield levels? • What are by-products or side effects from each land use type?
Input/output estimation	• What is the production orientation (maximizing production, environmental protection)? • Which technologies are promising to achieve target yields in the target year? • What are the effects of supply/demand of certain products on price of inputs and outputs?
IMGLP	• What is the main objective of agricultural land use to be optimized? • What are the other objectives to be optimized? • How are or will the resources (land, water, labour, capital) be shared among land units? • What are local demand, regional and national targets, and market ceiling for each commodity in the target year?

An example: Model development and scenario analysis for Ilocos Norte province, Philippines

Land use issues

Rice-based production systems prevail in Ilocos Norte. Rice is grown in the wet season (June–October), whereas diversified cropping (tobacco, garlic, onion, maize, sweet pepper and tomato) is practised 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). Meetings with the Ilocano stakeholders between 1997 and 2000 revealed that the major issue for the province was the assessment of trade-offs between food security and farmers' income (Roetter et al., 2000b). Environmental issues, such as injudicious use of agro-chemicals and groundwater contamination, needed to be addressed as well (Chapter 2).

Database for the IMGLP model

Farm lands were classified into eight land unit classes based on availability of surface irrigation, soil fertility and topography. Surface irrigation may be available during the wet season only, throughout the year or not at all. Soil fertility (two classes: fertile or poor to average) is based on perceptions of farmer-respondents. For topography, there are two classes: lowland and upland fields. The land use types (LUTs) included in this study comprise: (i) single cropping of rice or off-season vegetables (sweet pepper, tomato) followed by fallow; (ii) double cropping: two rice crops, rice in rotation with (yellow or white) corn, garlic, onion, eggplant, sweet pepper, tomato (contract and non-contract), mungbean, peanut, sweet potato, watermelon, cotton, tobacco, and off-season vegetables in rotation with yellow corn; and (iii) triple cropping: rice in rotation with garlic and mungbean, and with (white or yellow) corn and mungbean.

In addition to crop activities, three animal production activities are included: cattle, pig and poultry-raising.

The available resources for agriculture such as land, labour force and irrigation water were quantified per land unit. In addition, labour force was quantified by dekad and for each municipality and irrigation water by month. The area of land (ha) available for agriculture was determined using statistics and maps. Available labour force for agriculture was estimated as a proportion of population based on statistics.

Scenario construction

Three major goals were identified by stakeholders: Maximizing rice production, income and employment from agriculture. The specific 'what-if questions' we present in this example are: (1) What are the trade-offs in prioritizing different goals (income, rice production and employment)? (2) How does attainment of these goals and resource use change and what are the likely environmental implications, if under given resource availability and a set of available production activities, the technologies change? Availability of land, labour and water are assumed to remain at present levels (2001).

Six crop production technologies were considered: (1) current farmers' practice, (2) hybrid rice technology, (3) balanced fertilization strategy for rice and corn, (4) site-specific nutrient management for rice, (5) site-specific nutrient management for all crops, (6) integrated pest management (IPM). In the baseline scenario and in the comparison of different goals, only the current technology is included. In the technological change scenario, all six technologies are included in the model and the model selects the combination of cropping systems and technologies that give the highest value for the objective function (Chapters 2, 3).

The relevant input-output coefficients were derived from an extensive farm survey conducted in the province in 1999. For the current farmers' practice, average values for these farms were applied. Assumptions on technology change and the associated changes in farm management are based on earlier studies and unpublished data from farmer field schools and techno-demonstration farms in Ilocos Norte, and interviews with farmer-adopters and agricultural technicians in Batac. Details, as well as a comparison of the different technologies in terms of yield, nutrient and pest management, and labour use, are given in Chapter 2.

For animal production activities, only the current practice is included (Chapter 2).

Model results

The trade-offs in prioritizing goals on income, food production and employment are shown in Figure 3. Income is lowest when rice production is maximized (74%[1] lower than maximum income). There is also a large reduction in income when employment is maximized (38% lower than maximum income). However, there is no difference in rice production with the objective of maximizing rice production and employment. When income is optimized, however, rice production is 25% lower than the maximum value. Producing a lot of rice would mean allocating resources to rice instead of the more profitable crops like tobacco, vegetables and watermelon. This analysis gives us an idea about the outer limits of possibilities and trade-offs in income, food production and employment. Each individual model run, may not be acceptable considering the multiple goals of stakeholders. A reasonable combination that gives acceptable values for all three goals may be arrived at by subsequently tightening the constraints for each

[1] When rice production is maximized, most areas are left fallow during the dry season because growing non-rice crops during the dry season does not add any value to the objective function. Only irrigated areas can be grown with rice in the dry season. This partly explains the big difference.

goal until reasonable values are arrived at. This can be done in cooperation with stakeholders.

In looking at the effect of technological change, we maximized income and compared two scenarios: the baseline scenario, which includes only current farmers' practice and the technological change scenario, which includes current and six alternative production technologies. Results show that with technological change (Figure 4b), income would not be significantly higher than with only current farmers' practice (Figure 4a). The increase in net income is only 3% in spite of use of hybrid rice on 15% of total land allocated, 14% and 33% for site-specific nutrient management for rice and all crops, respectively, and 39% for IPM. The relatively low increase in net income is due to the higher labour costs that these new technologies require.

There are, however, increases in other goals: rice production and employment (labour use) increase by 16% and 11%, respectively as a result of technological change. Likewise, environmental indicators improve: N loss decreases by 16% and biocide residue index decreases by 12% as a result of adoption of better nutrient and

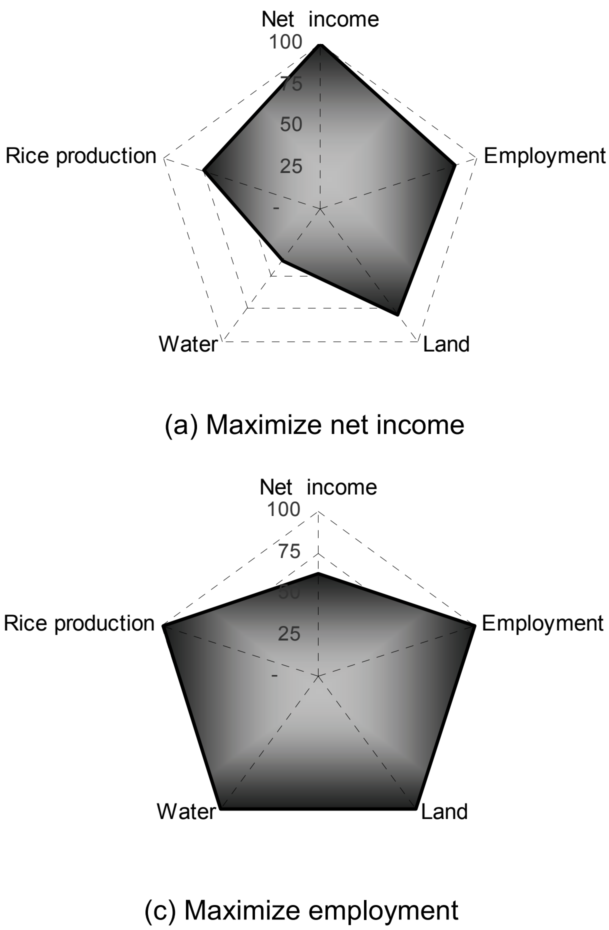

Figure 3. Trade-offs in prioritizing different goals: (a) net income, (b) rice production, and (c) employment. The radar plot values are expressed as a proportion of the maximum value for each characteristic.

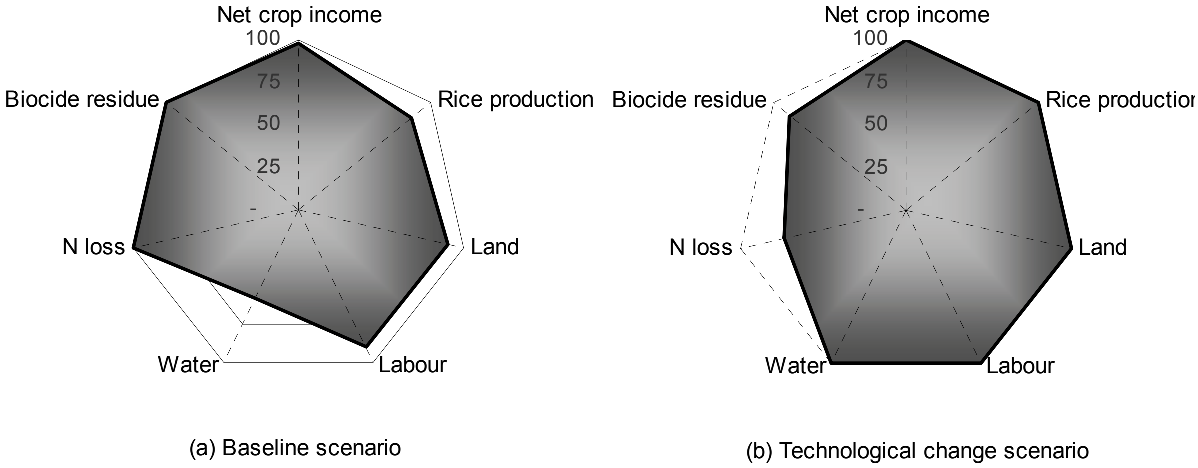

Figure 4. Implications of technological change: trade-off among income, rice production, resource use and environmental indicators. The radar plot values are expressed as a proportion of the maximum value for each characteristic obtained in the two scenarios.

pest management practices. Aggregate water use for irrigation, however, increases by 72% as a result (in part) of higher cropping intensity (more cropping system with double crops). In addition to alternative technologies included, those involving improved water-use efficiency are needed to mitigate future water scarcity.

In both scenarios, total rice production exceeds the current self-sufficiency requirements. Hence, improved nutrient and pest management practices could lead to reduced environmental costs and slightly higher income, while still satisfying local demand for the main food crop: a clear win-win situation. To realize this situation, however, extra costs are involved in terms of increasing farmers' knowledge and skills to attain the assumed input use-efficiency gains. Considerable investments in extension and dissemination activities would be needed. Also, policy interventions that provide incentives to farmers to adopt the new (nutrient) management practices will be a prerequisite.

Discussion and perspectives

Since the mid-1980s, new quantitative approaches for agricultural policy support at (sub-)regional level have been developed, resulting in a range of complementary analytical frameworks and operational tools (Stoorvogel and Antle, 2001; Parker et al., 2002).

All these different tools and underlying techniques have their advantages and disadvantages and their role to play in addressing different questions. However, most of these tools are rather region-specific and cannot easily be applied to other cases. This restriction applies more to statistical models than for simulation and MGLP models. Given the set-up of SysNet project, comprising four different case study regions, the LUPAS methodology was designed as a generic framework for land use explorations at the regional scale. In the operationalization of LUPAS, some of its component models contain more region-specific elements than others (Roetter et al., 2000a).

In the following, the strong and weak points of the system, as well as opportunities for its improvement are discussed.

Strengths

When applying the criteria provided by Walker (2002), LUPAS has evolved into a true decision support system (DSS) for strategic agricultural planning and resource management. Designed for and tailored to the specific questions of planners and policymakers in a given region (province/state), it offers improved accessibility of information in support of:

- trade-off analysis of multiple goals (such as production, income, employment) in complex decisions situations;
- fine-tuning of resource management systems;
- comparison of resource use intensity and environmental costs of alternative production activities.

In comparison to other approaches (and DSSs) that have been developed for regional land use analysis, such as the trade-off analysis model (Stoorvogel et al., 2001) or SOLUS (Bouman et al., 2000a), LUPAS is characterized by two major innovations:

- full involvement of stakeholders in its design and evaluation;
- use of information technology to fully operationalize the interactive part of the IMGLP technique for land use analysis under multiple goals.

SysNet, through its modelling framework LUPAS, jointly developed and evaluated by scientists and policymakers, addresses the questions ‘what would be possible, and what would have to be changed’. This is the first step in resolving land use conflicts at the (sub-) regional level. At the level of provinces/states, LUPAS model results provide quantitative information on trade-offs between different land use objectives – objectives that were jointly defined/prioritized by policymakers, planners and scientists. Through discussions and extended scenario analyses, one or more feasible options can be identified, given the specific biophysical, economic and socio-cultural conditions of a region.

Weaknesses and opportunities for improvement

Overall, further development of LUPAS is required to address several weak points.

Spatial analysis

The LUPAS methodology operates at the regional level, and resource availability and quality are defined at that level, i.e., the total area of land of a certain quality, total available irrigation water, the total labour force, etc. However, the spatial distribution of these resources has a major impact on the way in which they are being, and can be used. This holds for both the physical characteristics (i.e., the spatial distribution of the water resources determines to what extent they can be used for various purposes) and the socio-economic characteristics (such as the distance to markets, in absolute terms, or in terms of transport possibilities, which determine whether production of a certain commodity is economically attractive). For some commodities, such as fresh milk or vegetables, distance may even be a prohibitive constraint. Various attempts to introduce the spatial dimension in models for land use analysis have been made, but these still face serious difficulties, in particular incorporating the spatial dimension of socioeconomic characteristics. Especially for effective targeting of policy measures, lack of adequate spatial differentiation is a serious drawback. In the SysNet case studies this problem relates to water resources (Haryana, Ilocos Norte), and, in general, to socioeconomic characteristics.

Description of production technologies

For alternative production techniques that are not currently practised in a region, technical coefficients can, in principle, be generated by applying simulation models (with modules for crop growth, water balance, nutrient cycling, erosion processes). Such models have been developed for various (major) crops, but, for many of the minor crops, for which subsistence and market-oriented systems in developing countries can be of critical importance, such tools are not available. This also holds for most of the perennial crops that often represent an important component in agricultural production systems in tropical countries. It appears that, in agricultural research, development of such tools does currently not have a high priority. In many low-external-input farming systems, mixed cropping, i.e., the simultaneous growth of a mixture of crop species and/or varieties is a common technology, to reduce risks, to profit from the spatial heterogeneity of the resource base or to make use of synergistic effects. Also, for these types of crop systems, adequate simulation models are not available. This lack of quantitative tools for generating accurate technical coefficients of alternative production technologies hampers their inclusion in land use analysis.

One other aspect that may not be overlooked is that many production techniques and technologies selected for inclusion in LUPAS case studies, may negatively affect resource quality over time. This 'sustainability aspect' was not dealt with in the MGLPs, as the models lack the relevant time dimension and only generate static end pictures. New approaches are being developed, such as that by Hengsdijk (2001) for identifying management strategies that simultaneously realize multiple goals including a minimum soil N-stock. Such approaches should be considered in future model development.

Land use optimization

The regional land use analysis can illustrate the (bio) physical potentials of the natural resources, but cannot identify the major socio-economic constraints to modifying land use at the farm household level. For that purpose, the regional analysis has to be integrated with the farm household analysis that incorporates farmers' behaviour.

Given its interdisciplinary approach and consideration of economic, technical, ecological and social aspects of land use and the agricultural production process, the LUPAS methodology is in full compliance with the principles of sustainable agricultural development. Yet, despite these considerable advancements in land use analysis methodology, LUPAS does not – *and was not intended to* – provide information on 'how negotiated options for policy and technical change' can be best implemented. To identify the most effective policy measures and production systems for pursuing the various development goals and targets, different approaches need to be followed. Policy measures that best support the adoption of new technologies for sustainable agricultural development in a given region can only be identified by considering farmers' decision behaviour, as governed by their goals and aspirations and their risk perceptions, in the analysis. In a follow-up study to SysNet (the IRMLA project; see, www.irmla.alterra.nl), it is intended to operationalize a multi-scale approach by combining the LUPAS regional land use modelling approach with farm household modelling, taking into account farmers' decision behaviour and risk perceptions in identifying sustainable land use options (Chapter 3).

Interaction with stakeholders

The biggest challenge in the LUPAS methodology is probably its implementation in practice. This means, in first instance, evaluation of LUPAS under real conditions of regional land use planning. One of the challenges is to select from a multitude of possible questions, those most relevant to the sustainable development of a region. That requires close cooperation with the various stakeholders. The relevant questions can only be addressed and translated into meaningful scenarios, if both the system and the scientists involved are sufficiently flexible/competent for demonstrating the scope for extension and limitations of the system. Another related challenge is, how to institutionalize this dialogue. Based on their experience of the merits of this new land use planning approach, national SysNet teams are looking for opportunities for its institutionalization.

CHAPTER 5

Multi-scale analysis of agricultural development: A modelling approach for Ilocos Norte, Philippines*

Alice G. Laborte[1,2], Martin K. van Ittersum[1], Marrit M. van den Berg[1,3]

[1] Plant Production Systems, Wageningen University, P.O. Box 430, 6700 AK Wageningen, The Netherlands

[2] International Rice Research Institute (IRRI), DAPO Box 7777, Metro Manila, Philippines

[3] Development Economics, Wageningen University, P.O. Box 8130, 6700 EW Wageningen, The Netherlands

Abstract

Decisions and policies that have implications on allocation of resources are made at different levels. Goals at different scales may be conflicting and decisions at one scale have consequences for those at other scales. Performing analyses at more than one scale is, therefore necessary in analysing future options for resource use. This chapter illustrates the use of a multi-scale method enabling assessment of multi-purpose natural resource management options. Three examples of analyses that it allows are presented for Ilocos Norte province in the Philippines, at the farm household, municipal (Batac municipality) and provincial levels. Results show that: (1) Differences in resource endowments of farm households strongly affect the potential adoption rates of five well-defined alternative technologies. (2) Limited markets, inadequate infrastructure and resource endowments of farm households have large effects on resource use and goal achievement in the municipality. Not including these factors in a resource use analysis results in a so-called aggregation bias. As these are significant, ignoring them may result in misleading simulation results and policy conclusions. The aggregation bias resulting from assuming spatially fixed input and output prices is significant for Batac, which has poor farm-to-market roads. This suggests large potential benefits from improving infrastructure. The factors investigated suggest that aggregate income in the municipality is most strongly affected by the size of the market for some vegetables. (3) The differences in resource allocations resulting from prioritizing objectives at different levels reveal potential conflicts. The municipal income was highest with crops which pose more risk to farmers; our farm household analysis shows that farmers tend not to select too much of these crops. Similarly, the provincial income is highest when resources in the province are allocated such that more of the staple crop rice and less of the highly profitable cash crops are cultivated in Batac, resulting in lower income for the municipality.

It is anticipated that the presented multi-scale approach will provide valuable information for joint-learning, policy discussions and decision-making regarding agricultural land use.

Keywords: Multi-scale analysis; Linear programming; Natural resource use; Farm household model; Policy analysis

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* Accepted Agricultural Systems.

Introduction

There is increasing awareness that environmental, economic and social problems and challenges associated with agricultural and rural development and natural resource management are tightly interrelated. This is one of the reasons for the increasing attention for the concept of multi-functional natural resource management and agriculture, though under various labels in different parts of the world, e.g. roles of agriculture and ecosystem services.

In parallel to the growing awareness of the importance of multiple roles of agriculture, it is increasingly realized that natural resource management and decision making is shaped at multiple scales (Kuiper et al., 2001; López-Ridaura et al., 2005). Farm households decide which crops to grow and the associated use of resources such as land, labour, water and capital. Governments, on the other hand, develop policies (e.g., subsidies, taxation, infrastructural developments) that are targeted at influencing decision making at farm scale to realize aggregated changes, deemed desirable at municipal, provincial or national scale. At national scale, over-all policies and decisions are formulated on sectoral allocations of resources and economic activities. Strategies, policies and programs for sectoral development are included in the sector plans. At sub-national level, potentials, constraints and objectives (targets) for agricultural development are identified. In this multi-level planning approach, the plans at different levels have to be consistent and interlinked. The national plan provides the framework and direction for developing plans at the lower levels (top-down). The plans at the lower levels reflect the needs and aspirations of the relevant stakeholders and are used also as inputs in developing plans at the higher levels (bottom-up). This two-way process in planning may result in conflicts because of different priorities of decision-makers at different levels (Dantwala, 1983).

Stakeholders at different spatial scales take important decisions/policies that have implications for decisions on allocation of resources. Goals at different scales may be conflicting and decisions at one scale have consequences for those at other scales. The interrelationships among different goals across the various scales may be extremely complex and may hinder transparent discussions and policy-making processes. Science has a role to play here via revealing relationships and trade-offs among scales and objectives. Performing analyses at more than one scale is necessary in analysing future options for resource use.

Methodologies proposed by literature are, almost without exception, partial in terms of issues dealt with, scales being addressed and disciplines involved. Land use studies have been conducted for farm (Kruseman et al., 1995; Rossing et al., 1997; Shiferaw et al., 2001), watershed (Barbier and Bergeron, 1999), regional (Veeneklaas et al., 1991; Schipper et al., 1995; Lu, 2000) and national (Deybe, 1998) levels. Bouman et al.

(2000) presented models for land use analysis at different scales for Costa Rica, without, however, presenting a consistent analysis across all three scales. Multi-scale (or bi-scale when two scales are involved) models have been proposed by Goreux, 1973; Candler et al., 1981; Hazell and Norton, 1986; López-Ridaura et al., 2005), but such models are very complicated and practical applications are scarce. To date, methodologies with comprehensive multi-scale capabilities in terms of assessing alternative land uses, new technologies and policies across a range of relevant scales (field, farm, municipality, province, ...) and that can deal with multiple issues that are relevant for natural resource use are still very limited.

Schipper (1996), in discussing natural resource use modelling at the regional (or higher) scales, recognizes three aggregation issues that may arise: (1) aggregation bias may result from omitting relevant farm types, i.e., all farms within the region are assumed to have equal access to the same amount of resources and hence the objective function is overestimated, (2) the nature of some variables may change at the regional level, i.e., variables that are exogenous at the farm level may become endogenous at the regional level, (3) the difficulty in analysing decision-making at more than one level simultaneously.

Jansen and Stoorvogel (1998) addressed aggregation bias resulting from the first two issues: inclusion of farm types and their interdependencies, as well as the assumption of uniform price vectors independent of geographical location. They also quantified the bias resulting from ignoring labour-market interdependencies among farm types. Their study, however, did not include analysis of the effect of variable product prices that are exogenous at the farm scale, but may need to be endogenized at higher aggregation scales (Hazell and Norton, 1986). Although all three aggregation issues are important, we are not aware of studies that have addressed all and analysed their implications for resource use in one particular area.

This chapter presents results of application of a multi-scale methodology in Ilocos Norte, the Philippines, in terms of multiple objectives. The methodology allows assessment of alternative rice-based production systems and policies to stimulate sustainable development at farm, municipal and provincial scale, as well as aggregation bias in such analysis. Three examples are presented, illustrating how (1) differences across farm types affect technology adoption behavior and thus farm households' welfare, food production and the environment, (2) farm structure, infrastructure and markets for agricultural goods affect natural resource use options at municipal scale, and (3) achievement of objectives at different scales is interrelated and conflicting. These analyses can provide valuable information to stakeholders at the municipal and provincial scales for joint learning, policy discussions and decision-making regarding agricultural land use.

The study area – Ilocos Norte

The province of Ilocos Norte, situated in the north-western part of the Philippines has a total land area of 0.36 million ha. Administratively, it forms the Ilocos region, with the provinces of Ilocos Sur, La Union, and Pangasinan, and is sub-divided in 23 administrative units: 22 municipalities and 1 city. Its total population is more than half a million with an average annual growth rate of 1.37%. This is below that of the country as a whole, due to out-migration. Batac, the most populous municipality, has a total land area of 16,101 ha, of which 67% is in use as agricultural land, occupied mostly by rice-based cropping systems. Rice is usually planted in the wet season (June to October), while in the dry season a diversity of crops is grown, e.g., tomato, garlic, onion, sweet pepper, tobacco and mungbean. The province is classified as a key area for rice production and is a major supplier of rice for the whole Ilocos Region. In addition to rice, provincial production exceeds consumption for corn, vegetables, legumes and fruits (Cosio et al., 1998).

The agricultural and natural resource use issues in the province and Batac municipality have been identified through interactions with policy makers and other stakeholders at local (farmers), municipal and provincial scale, including scientist-stakeholder workshops held in the period 1999–2004. Key problems are related to low productivity and income. Causes identified include insufficient water for irrigation, high costs of farm inputs and low farm gate prices – indicative of poorly functioning markets and high transaction costs, limited capital availability, low level of farm mechanization, lack of post-harvest and storage facilities, and limited access to improved technologies (PGIN, 1999).

In the Philippines, planning is done at the national and sub-national levels. The National Economic and Development Authority (NEDA) is the central planning agency that coordinates the formulation and implementation of national policies. The country is subdivided into 16 administrative regions. In each region, a Regional Development Council is established and is tasked to translate the national economic goals in line with specific regional objectives. Development councils at the provincial and municipal levels are tasked to formulate land use plans. In formulating the land use plan for the province, the plans of the city and municipalities are integrated with the national and regional policies. The development councils at each level are tasked to do the planning, programming and budgeting which involve the preparation of the physical framework and comprehensive land use plans, socio-economic development plans, as well as investment plans.

Goals at the farm level differ from those of decision-makers at the higher scales (Table 1). Risk reduction is an important consideration in the choice of crops and extent of cultivation of farm households, but is not an important consideration at the

Table 1. Some characteristics of various decision levels at the provincial, municipal and farm.

Level	Decision-makers	Goals	Decision areas
Province (Ilocos Norte)	Governor Provincial Development Council Provincial Planning and Development Office Provincial Agriculture Office	Food security Economic growth Employment Environmental protection	Provincial development plan Subsidies Infrastructure Extension
Municipality (Batac)	Mayor Municipal Development Council Municipal Planning and Development Office Municipal Agriculture Office	Food security Economic growth Employment Environmental protection	Municipal development plan Subsidies Infrastructure Extension
Farm	Farm household	Subsistence Cash income Risk reduction	Resource allocation Production plan Investment strategies

higher scales. On the other hand, environmental protection is one of the goals at the provincial and municipal scales, but is not a main concern of farm households, who are more concerned with short-term economic viability. Vegetables and tobacco, for instance are very profitable crops. However, injudicious use of agro-chemicals, particularly for vegetables, presents a threat to resource quality and human health. Nitrate contamination of groundwater in the municipality of Batac was observed to be high in some farm locations due to heavy application of fertilizers particularly to dry season crops (Gumtang et al., 1999). Similarly, cutting of trees to provide fuel wood, particularly for tobacco-curing, contributes to erosion, leading to flooding and siltation downstream. So, there is a conflict in goals between long term sustainability and short term economic viability.

Methodology

Three modelling analyses will be presented, based on results of six models, developed for the farm household, municipal and provincial scales (Figure 1):

1. Farm household model for each of four major farm types (Figure 1) in Batac.
2. Municipal model for Batac using representative farms, infrastructure differentiation

and market constraints – Municipal-R (FT+Inf+Mkt).
3. Municipal model for Batac using representative farms and infrastructure differentiation – Municipal-R (FT+Inf).
4. Municipal model for Batac using representative farms – Municipal-R (FT).
5. Aggregated municipal model for Batac – Municipal-A.
6. Aggregated provincial model for Ilocos Norte.

Table 2 presents the details of the models. In all the models an objective is optimized subject to a set of constraints. The constraints in the model refer to resource endowments and consumption requirements. Production activities are defined using TechnoGIN, a technical coefficient generator that integrates empirical data with production-ecological and expert knowledge in defining efficiencies in input use (Ponsioen et al., 2006). This methodological approach of combining linear programming models with technical coefficient generators has been extensively applied to analyse resource use options in various geographical regions, including The Netherlands (Van de Ven, 1996), West Africa (Kruseman and Bade, 1998), Costa Rica (Bouman et al., 1999) and Asia (Roetter et al., 2005).

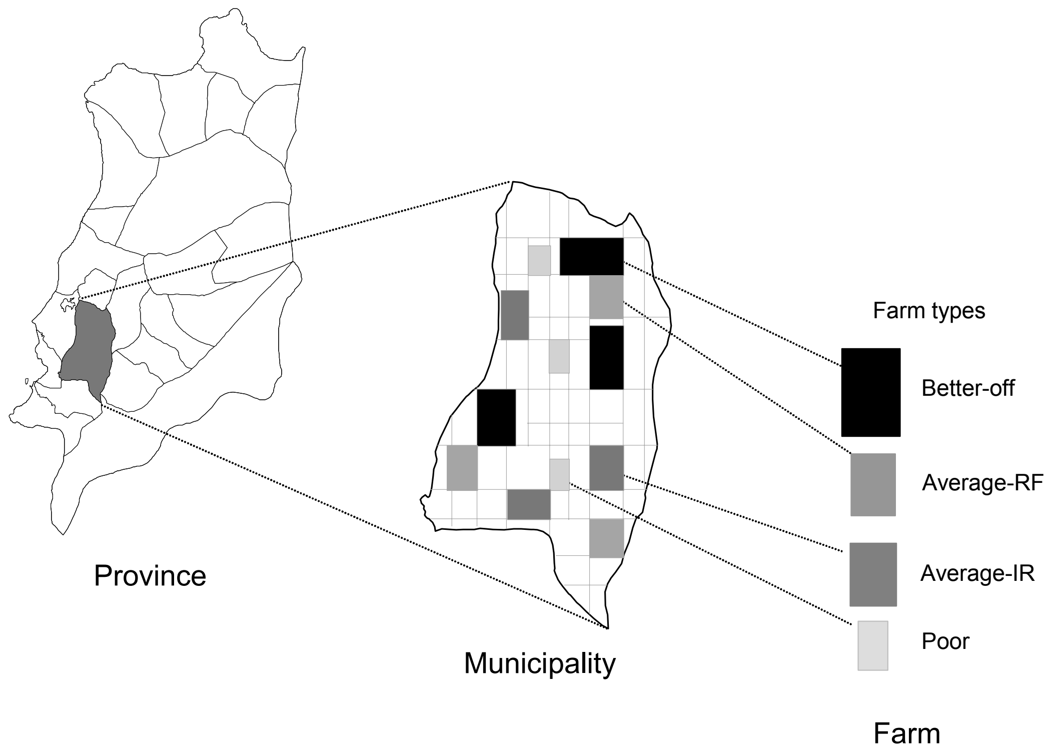

Figure 1. Schematic representation of the different scales of analysis: province, municipality and farm.

Table 2. Summary description of the different models.

Characteristics	Model			
	Farm (model 1)	Municipal-R (models 2–4)	Municipal-A (model 5)	Province (model 6)
Aggregation level	Farm	Municipality	Municipality	Province
Type of model	Farm household model	Representative farms	Aggregate (single farm)	Aggregate (single farm)
Objective function	Discretionary income (individual)	Model 2: Economic surplus; Models 3–4: Discretionary income (collective)	Net income (collective)	Net income (collective)
Farm types	4 farm types (separate models)	4 farm types[b]	None	None
Sub-regions	None	None	None	23 administrative units (1 city and 22 municipalities)
Land types	8 (IGT, IGW, IPT, IPW, RGL, RPL, RGU, RPU)[a]	Same as Farm	Same as Farm	Same as Farm
Crops	15	Same as Farm	Same as Farm	Same as Farm
Animal activities	3 (cattle, pig, poultry)	Same as Farm	Same as Farm	Same as Farm
Maximum number of animals	Set for individual farm types	Set for individual farm types and at municipal level (based on current numbers)	Set at municipal level (based on current numbers)	Set at provincial level (based on current numbers)
Renting of land	Farm types can rent up to the area of land they currently rent per land type	Farm types can rent more of the land type they currently rent	Renting of land not included in the model	Same as Municipal-A
Labour	Only cost for hiring labour included in production costs	Same as Farm	All labour included in production costs	Same as Municipal-A
Consumption	Farm households can satisfy family consumption requirement from own production or from the market	Same as Farm; the municipality should be self-sufficient in rice	The municipality should be self-sufficient in rice	The province should be self-sufficient in rice
Capital and credit	Monthly balance; maximum loan and own capital depend on farm type; interest rate is 10% per month	Same as Farm	Not included	Not included
Sources of income	Crop and livestock production, off-farm and non-farm employment	Same as Farm	Crop and livestock production	Same as Municipal-A

[a] Surface-irrigated throughout the year, good soil quality, lowland (IGT); surface-irrigated during the wet season, good soil quality, lowland (IGW); surface-irrigated throughout the year, poor soil quality, lowland (IPT); surface-irrigated during the wet season, poor soil quality, lowland (IPW); groundwater-irrigated, good soil quality, lowland (RGL); groundwater-irrigated, poor soil quality, lowland (RPL); groundwater-irrigated, good soil quality, upland (RGU); groundwater-irrigated, poor soil quality, upland (RPU).

[b] In models 2 and 3, farm types near and far from the main road are differentiated. Farm types far from the main road incur additional transaction cost for selling and buying products and inputs.

In the farm model (model 1), each farm type is optimizing its own objective function in complete isolation of the other farm types. The decision variables in the model are land allocation by cropping system and rental of land for crop activities; selling and buying of crop products and livestock; allocation of family labour to crop and animal production activities, as well as to work outside the farm; hiring of labour for crop production activities; and credit. The constraints in the model are the resource endowments of the household (available land by quality, family labour, water, capital), subsistence consumption needs, opportunities for off-farm and non-farm work, number of animals and their feed requirements, and monthly capital and loans for on-farm activities. The farm model is described and evaluated in detail in Chapter 3.

Two versions of the municipal model for Batac were set up: (1) representative farms model (Municipal-R), and (2) aggregate municipal model (Municipal-A). In Municipal-R, all farms in the municipality are grouped into farm types (as in model 1) with specific constraints for each farm type, but one over-all objective function. These farm models are aggregated using the number of farms in each group as weights and limits on available resources at the municipal level are also imposed. In Municipal-A, all resources in the municipality are aggregated as if they form a single large farm. In both municipal models, the collective goal is optimized.

The representative farms model has three variants: Model 2 – Municipal-R (FT+Inf+Mkt) – in addition to including farm structures, includes differentiations associated with existing infrastructure and hence transport costs, within the municipality, and constraints that simulate price formation of agricultural products of which the prices are sensitive to the municipal production. Model 3 is similar to model 2 but excludes the price formations. Model 4 has the least constraints and also excludes infrastructure differentiation.

To simulate price formation, market-sensitive crops were identified based on the current proportion of production in the municipality relative to the province and the fluctuations in real farm prices over the years. For these crops (garlic, onion, eggplant, sweet pepper, tomato, watermelon), horizontal demand curves are replaced by downward-sloping ones. Retail prices (P_c^m) are determined endogenously in the model as (Hazell and Norton, 1986): $P_c^m = \alpha_c - \beta_c Q^c$, where Q^c is the sales of crop *c* in Batac as calculated by the model, and the coefficients α_c and β_c are pre-calculated as follows:

$$\beta_c = \frac{-p_c^m}{e_c^r q_c}, \qquad \alpha_c = p_c^m + \beta_c q_c, \qquad e_c^r = e_c^N \frac{1}{K} - \sigma_c \frac{1-K}{K}$$

where p_c^m and q_c are the retail price and total production, respectively, in the base year (2001); e_c^N and e_c^r are the demand elasticities at national scale and for Batac municipality, respectively; σ_c is the supply elasticity in regions other than Batac; and *K* is the ratio of Batac's output to the national output. The national demand elasticities and supply elasticities from other regions were assumed to be the same as those estimated for the Philippines using the IMPACT model (International Model for Policy analysis of Agricultural Commodities and Trade), a global food projection model developed at the International Food Policy Research Institute (IFPRI) (Rosegrant et al., 2002). Subsequently, farm-gate price is derived by subtracting from the derived retail price the difference between the consumer price and farm-gate price in the base year.

The infrastructure differentiations were defined by distinguishing between farm types that are within 5 km from the main road and those that are outside this buffer zone. The main road is of high quality and is well-maintained. This road system connects the different municipalities in the province, as well as the different areas in Batac with the two existing markets in the municipality. The farther from the main road, the poorer is the quality of the roads. Farm types located more than 5 km from the main roads incur additional transaction costs for selling crop and animal products, as well as buying production inputs and products for home consumption. This implies that each of the four farm types is further differentiated in a group within and one beyond 5 km from the main road.

The model for Ilocos Norte province (model 6) is an aggregate model with municipalities as sub-regions. The resources in each sub-region are aggregated as if they form large farms and goals for the entire province are optimized (as in Roetter et al., 2005). The model is a typical explorative land use model, aimed at exploring bio-physical potentials and limitations, rather than at predicting likely developments.

All models can be run with only current crop production activities or with both current and alternative crop production activities (Ponsioen et al., 2006). For livestock activities, only current practice is available. Quantification of current agricultural activities is based on surveys carried out in Ilocos Norte in 1999 (for model 6) and in Batac in 2001 (for models 1–5), and for alternative crop activities on insights in agro-ecological processes summarized in simulation models and expert rules. The alternative technologies considered are (Table 3): hybrid rice production (HYR), balanced fertilization strategy (BFS), site-specific nutrient management (SSNM) and integrated pest management (IPM). In the analyses of technology adoption at the farm scale, the current technology is assessed against each of the alternative technologies in subsequent runs, and in a final run, all alternative technologies are assessed simultaneously. For analyses at other scales, both current and alternative technologies are included in the model runs.

The different models can assess various agro-economic and environmental indicators, such as quantity of crop and animal production, income, resource use (land, labour, water), fertilizer and biocide use, and nutrient loss.

Table 3. Description of production technologies (Laborte et al., 2006).

Technology	Yield	Nutrient management	Pest and weed management	Labour use
Current practice (CP)	CP	CP	CP	CP
Hybrid rice (HYR)	25% higher yield for rice	Additional 50 kg of organic materials for the seedbed; 15% higher recovery than CP	Same as CP	More labour for land preparation and crop establishment[a]
Balanced fertilization (BFS) for rice and corn	15% higher yield for rice and corn; same yields for other crops	Use of organic and inorganic fertilizers at specified rates; 15% higher recovery than CP for rice	Same as CP	4-5 more labour days ha^{-1} for hauling and application of organic fertilizer and crop care[a]
Site-specific nutrient management for rice (SSNMr)	15% higher yield for rice; same yields for other crops	As calculated by QUEFTS in TechnoGIN[b]; 15% higher recovery than CP for rice	5% less insecticide and fungicide (rice only)	20% more labour for monitoring and crop care[a]
Site-specific nutrient management for all crops (SSNMa)	15% higher yield for rice; same yields for other crops	As calculated by QUEFTS in TechnoGIN[b]; 15% higher recovery than CP	5% less insecticide and fungicide	15-20% more labour for monitoring and crop care[a]
Integrated pest management (IPM)	Same as CP	Same as CP	70-85% less insecticide; 10-20% less fungicide; 10% (rice) to 90% (vegetables) less herbicide	10 more labour days ha^{-1} for plastic mulching (vegetables); 20% more labour for monitoring and crop care[a]

[a] Labour requirements for harvesting/threshing per hectare are higher because of higher yields. In TechnoGIN, this parameter is expressed per ton of output. Labour use for harvesting/threshing per ton of output is unchanged.

[b] The QUEFTS module (QUantitative Evaluation of the Fertility of Tropical Soils; Janssen et al., 1990; Witt et al., 1999) in TechnoGIN calculates fertilizer requirements by subtracting nutrient supply from indigenous supply, from crop uptake and dividing the residual by the nutrient recovery fraction.

Three analyses at different scales

Assessing technology adoption at the farm scale (Chapter 3) – Analysis 1

For the first analysis, possible adoption of the four alternative technologies has been evaluated from a whole-farm perspective for the four major farm types in Batac. The farm household models were parameterized, based on the farm survey, to represent their resource endowments. Tables 4 and 5 illustrate the differential adoption behaviour among the farm types and the effects of adoption on agro-economic and environmental indicators.

Results show that all alternative technologies are promising in terms of adoption by farmers. In particular, IPM and HYR show the highest rate of adoption. HYR gives the highest increase in food production, whereas BFS, SSNM and IPM give the highest positive environmental benefits as reflected in the large reductions in nitrogen loss and biocide use. IPM shows the highest rate of increase in discretionary income.

Table 4. Simulated response of farm households to availability of alternative technologies in terms of the absolute (ha) and relative (%) areas allocated to the alternative technologies – analysis 1 (farm household model).

Farm household type[a]	Technology simulation[b]					
	HYR	BFS	SSNMr	SSNMa	IPM	All technologies
Poor	0.75	0.57	0.75	0.57	0.82	0.85
	(88)	(67)	(88)	(67)	(96)	(100)
Average-IR	0.92	0.92	0.42	0.31	0.93	0.95
	(97)	(97)	(44)	(33)	(98)	(100)
Average-RF	0.73	0.50	0.50	0.45	0.88	0.91
	(80)	(55)	(54)	(50)	(96)	(100)
Better-off	2.09	1.12	1.69	1.45	2.48	2.54
	(82)	(44)	(67)	(57)	(98)	(100)

[a] Poor: households with a farm size of 0.85 ha, of which one-third is owned; Average-IR: average households with 0.95 ha of mostly surface-irrigated land; Average-RF: average households with 0.91 ha, most of which are without surface irrigation and half are in the uplands; Better-off: households with a farm size of 2.54 ha and owning almost 1 ha of farmland.

[b] Numbers refer to cultivated land (in hectares) where farmers adopt the technology. Values in parentheses refer to proportion of total cultivated land (own and rented land that is left fallow is excluded). HYR: hybrid rice production, BFS: balanced fertilization strategy (for rice and corn), SSNMr: site-specific nutrient management (for rice), SSNMa: site-specific nutrient management (for all crops), IPM: integrated pest management. For each technology run, only current practice and the corresponding technology are included. Under ‘all technologies’, current practice and all alternative technologies are included in the simulations.

Because of differences in resource endowments and circumstances, farm households' adoption rates of alternative technologies and their impacts vary considerably. In all technology simulations, relative profitability, labour and capital requirements and availabilities are the key factors for the adoption of alternative technologies.

Table 5. Simulated impact of adoption of new technologies on farm households' welfare, food production and environmental indicators (% change over base run) – analysis 1 (farm household model).

Indicator	Farm household type[b]	Technology simulation[c]					
		HYR	BFS	SSNMr	SSNMa	IPM	All technologies
Discretionary income[a]	Poor	2	1	2	2	5	7
	Average-IR	3	1	1	1	2	4
	Average-RF	2	0	1	1	6	8
	Better-off	2	0	1	1	5	7
Rice production	Poor	25	12	15	11	0	22
	Average-IR	25	15	8	6	0	25
	Average-RF	25	10	10	9	0	22
	Better-off	38	19	24	22	11	36
Biocide use	Poor	–2	–1	–1	–1	–45	–15
	Average-IR	1	1	–2	1	–49	–5
	Average-RF	0	1	0	–1	–42	–20
	Better-off	–1	–1	–1	–2	–44	–19
N loss	Poor	–13	–20	–4	–12	0	–21
	Average-IR	–14	–29	7	0	0	–15
	Average-RF	–10	–16	–2	–11	0	–18
	Better-off	–9	–13	–1	–9	2	–16

[a] Discretionary income is defined as the returns from the sale of crop and livestock production plus wages from off-farm and nonfarm activities minus production costs including interest on loans and cost of consumption of purchased products included in the model.

[b] Poor: households with a farm size of 0.85 ha, of which one-third is owned; Average-IR: average households with 0.95 ha of mostly surface-irrigated land; Average-RF: average households with 0.91 ha, most of which are without surface irrigation and half are in the uplands; Better-off: households with a farm size of 2.54 ha and owning almost 1 ha of farmland.

[c] HYR: hybrid rice production, BFS: balanced fertilization strategy (for rice and corn), SSNMr: site-specific nutrient management (for rice), SSNMa: site-specific nutrient management (for all crops), IPM: integrated pest management. For each technology run, only current practice and the corresponding technology are included. Under 'all technologies', current practice and all alternative technologies are included in the simulations.

Assessing different constraints at municipal scale – Analysis 2

Comparison of actual and model results of the most comprehensive municipal model (model 2) with only current and both current and alternative production activities is shown in Table 6. Gross incomes from the farm survey are similar to the model results. Similarly, land allocation for rice, tobacco, and corn from statistics are similar to the results of the model when only current technology is included. Including alternative technologies results in a shift in land allocation from tobacco to vegetables.

Table 6. Comparison between actual and model results.

Characteristics[a]	Actual[e]		Model results (Model 2 - Municipal-R +FT+Inf+Mkt)	
	Farm survey	Statistics	Current technologies only	Current and alternative technologies
Gross income (10^6 pesos)[b]				
Crops	354	n.a.	359	353
Livestock	197[f]	n.a.	255	251
Wages	254	n.a.	252	247
Crop activities				
Area sown[c] (10^3 ha)	5.5	6.9	7.3	7.3
Rice[c]	3.2	4.3	4.4	4.4
Tobacco	1.0	0.6	0.7	0.4
Corn	0.5	0.4	0.4	0.4
Vegetables	0.4	1.0[g]	1.4	1.7
Number of animals at the farm (10^3 animals)[d]				
Cattle	5	5	6	6
Pigs	8	9	9	9
Poultry	83	106	110	110
Biocide use (kg a.i. ha^{-1})	1.4	n.a.	1.4	1.1
Fertilizer use (kg NPK ha^{-1})	261	n.a.	250	226
N loss (kg N ha^{-1})	n.a.	n.a.	53	41

[a] All values are per year.
[b] Total value of output (yield × price). 1 US$ = 51 pesos (2001).
[c] Double-cropped areas are counted twice.
[d] Farm survey data refer to number of animals at the farm in July 2001, whereas the statistical data refer to an inventory in December 1999. Simulation results refer to the maximum number of animals at the farm in a month.
[e] Data from farm survey were aggregated based on number of farms belonging to each group. Statistics are from the Municipal Agriculture Office of Batac.
[f] The present value of all animals on the farm (except draught animals) at the time of the interviews. The model results, however, show the gross income in a year after all animals have reached maturity age and are sold. [g] Includes vegetables not included in the model.

Table 7. Results from four different municipal models – analysis 2.

Characteristics[a]	Model 2 Municipal-R (+FT+Inf+Mkt)	Model 3 Municipal-R (+FT+Inf)	Model 4 Municipal-R (+FT)	Model 5 Municipal-A
Type of model	Representative farm (with farm structures + spatially varying prices + price formation)	Representative farm (with farm structures + spatially varying prices)	Representative farm (with farm structures)	Aggregate municipal model
Gross income [b] (10^6 pesos)				
Crops	353	594	789	1,106
Livestock	251	253	247	78
Net income [c] (10^6 pesos)				
Crops	100	340	458	855
Livestock	42	43	42	21
Wages	247	250	245	–[f]
Crop activities				
Area sown[d] (10^3 ha)	7.3	7.4	8.3	9.4
Rice[d]	4.4	4.2	4.4	3.8
Off-season vegetables	0.4	0.6	1.1	2.6
Tobacco	0.4	1.7	2.3	2.3
Capital intensity (10^3 peso ha^{-1})	11	10	11	27
Gross returns to labour[e] (10^3 peso d^{-1})	0.3	0.7	0.8	2.3
Number of animals purchased (10^3 animals)				
Cattle	6	6	6	6
Pigs	21	21	20	0
Poultry	566	589	589	0
Environmental indicators				
Biocide use (kg a.i. ha^{-1})	1.1	1.1	1.2	2.2
N loss (kg a.i. ha^{-1})	41	32	33	30

[a] All values are per year. [b] Total value of output (yield × price). 1 US$ = 51 pesos (2001).

[c] Crops: value of output – labour costs – other costs; livestock: value of output – non-labour costs. Costs for family labour for crop production were imputed for the representative farm models to make income comparable across models. For models 2-4, other costs include payment of land rental, interest on loans and transaction costs.

[d] Double-cropped areas are counted twice.

[e] Total value of output less purchased inputs divided by total labour use for crop activities.

[f] Not accounted for in the model.

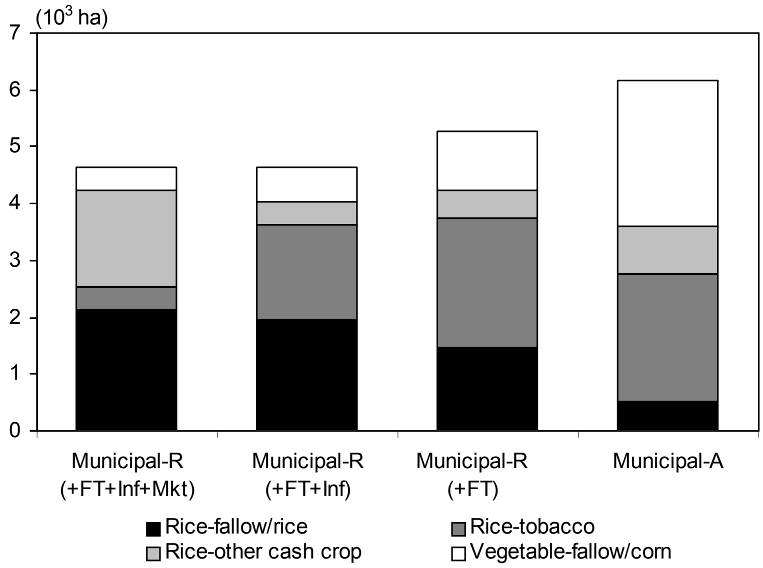

Figure 2. Simulated land allocation from different models by land use type for Batac municipality – analysis 2.

As more than half of the total area is grown using SSNMa and IPM – more fertilizer - and biocide use-efficient technologies for vegetables – growing vegetables becomes even more profitable. Moreover, as a result of adoption of alternative technologies, biocide use and nitrogen loss are both lower by more than 20%.

Results of the four different models at municipal scale are compared (Table 7; Figure 2). The first three columns present results for the 3 variants of the Municipal-R models (models 2-4) and the last column shows results for the Municipal-A model.

When prices of crops are assumed to be fixed at current levels (i.e., they do not drop as a result of greater supply), gross crop income increases by 68% and net income more than triples (model 2 vs. model 3). The area under tobacco increases more than four-fold. Similarly, the area under off-season vegetables increases by 50%, but the total area under vegetables (wet and dry season combined) is less than half (data not shown). There is a 22% decrease in nitrogen loss as a result of the shift in cropping systems.

Removing additional transport costs for inaccessible farm types (model 3 vs. model 4), results in a further increase in net crop income by 35% over model 3 levels. There is an expansion of area sown; the off-season vegetable area increases by 83% and that of tobacco by 35%.

Excluding farm types (model 4 vs. model 5) results in an increase in gross crop income by 40%. Net income from crop activities increases by 86%, but income from animal activities is halved due to the limited selection of livestock activities in the model. Rice area decreases by 14%, and that of off-season vegetables increases by 136% over model 4 levels. As a result, capital intensity for crop activities more than doubles and returns to labour triples. Farm households' resources are limited. In particular, capital is a major constraint to intensification. Not including farm types in the simulation assumes farm households have access to resources in proportions that are not available to them individually, thus overestimating the value of the objective function. As a result, the model selects more profitable input-intensive crops, such as off-season vegetables and tobacco, at the expense of rice. Biocide use, however, increases by 83% as a result of the shift in cropping systems.

These results illustrate the constraining effects of limited demand, inadequate infrastructure and farm structure on natural resource use options and the associated income and externalities from agriculture. Ignoring these sources of aggregation bias results in higher income and expansion of areas under profitable crops, such as off-season vegetables and tobacco, and contraction of rice-fallow and rice-rice systems (Figure 2). It thus indicates the potential implications if some of these constraints, e.g. poor infrastructure, can be alleviated. However, we need to know the costs associated with each policy measure to assess its feasibility and cost effectiveness.

Multi-scale analysis – Analysis 3

In the third analysis, results for Batac were derived from models at different scales – hence models in which the economic objective has been optimized at different scales (Table 8). The summed results of the farm household models (column 2) show results from optimization of individual farm household objectives. Columns 3 and 4 (models 4 and 5) show the results from the municipal model with representative farms and the aggregate municipal model, respectively. Biophysical options were explored for the provincial scale (column 5), from which results for Batac municipality were extracted (column 6).

Results of the summed farm models (summed model 1) and the representative farm model (model 4) show the consequences of pursuing objectives at the farm and municipal scales. When individual farmer objectives are optimized, aggregate gross income from crop activities is 25% higher and that of livestock is almost double than when the collective objective is optimized. In the summed farm model the area sown is larger and, in particular, more land is allocated to rice and tobacco, and less to off-season vegetables.

Note, however, that in the summed farm model, the municipal constraints of available labour and water cannot be imposed. Hence, in total, farm households may be hiring in more labour and pumping more water than is currently available for the

Table 8. Comparison of models at different scales– analysis 3.

Characteristic[a]	Summed farm models (summed model 1)	Model 4 Representative farm model (Municipal-R)	Model 5 Aggregate municipal model (Municipal-A)	Model 6 Provincial model	
				Ilocos Norte	Batac
Gross income[b] (10^6 pesos)					
Crops	986	789	1,106	3,710	520
Livestock	479	247	78	2,466	0
Net income[c] (10^6 pesos)					
Crops	619	458	855	2,270	387
Livestock	86	42	21	488	0
Crop activities					
Available area (10^3 ha)	6.8	6.2	6.2	90.8	6.2
Area sown[d] (10^3 ha)	10.8	8.3	9.4	73.8	7.7
Rice[d]	6.3	4.4	3.8	59.1	5.1
Off-season vegetables	0.9	1.1	2.6	4.2	0.9
Tobacco	2.8	2.3	2.3	7.4	1.3
Labour intensity (d ha^{-1})	115	112	71	80	83
Gross returns to labour[e] (10^3 peso d^{-1})	0.7	0.8	2.3	0.5	0.7
Animals purchased (10^3 animals)					
Cattle	13	6	6	80	0
Pigs	26	20	0	253	0
Poultry	1,333	589	0	0	0
Environmental indicators					
Biocide use (kg a.i. ha^{-1})	1.2	1.2	2.2	0.4	0.7
N loss (kg N ha^{-1})	32	33	30	33	29

[a] All values are per year.

[b] Total value of output (yield × price); 1 US$ = 51 pesos (2001).

[c] Crops: value of output – labour costs – other costs; livestock: value of output – non-labour costs. Costs for family labour for crop production for models 1-2 were imputed and other costs include payment of land rental, interest on loans and transaction costs.

[d] Double-cropped areas are counted twice.

[e] Total value of output less purchased inputs divided by total labour use for crop activities.

whole municipality. In addition, the summed farm model does not account for interactions among farm types and this is an important source of aggregation bias. The municipal model, on the other hand, assumes that certain households may be willing to sacrifice own income to attain a higher total collective income. It, however, does not reflect the reality that individual households aim at optimizing own objectives.

Comparison of models 5 and 6 shows that crop income for Batac is reduced by 55% when the objective at provincial scale is optimized. More land is allocated to rice, and less to the more profitable crops (off-season vegetables and tobacco). This land allocation results in an increase in labour intensity and a large reduction in returns to labour. In addition, income from livestock activities was reduced to zero.

Similarly to the previous comparison, the provincial model assumes that resources (except land) from one municipality may be allocated to another municipality if that contributes more to income for the entire province. The municipal model assumes no interaction in resource allocation between itself and the other municipalities within the province.

Discussion and conclusions

This chapter illustrates a multi-scale analysis in terms of insights in trade-offs between achievement of objectives of stakeholders at different scales and revealing aggregation bias issues associated with such analysis.

Results of analyses reveal that differences in resource endowments of farm households result in differential adoption rates of alternative technologies and thus in differential impacts on farm households' agro-economic conditions and on the environment. Adoption is highest for alternative technologies that boost production (HYR) and result in lower production costs (IPM). In spite of profitability, full adoption of alternative technologies, however, is limited by labour and capital requirements and availabilities. Risk is also an important consideration that affects farm households' crop choice.

Limited markets for agricultural products, inadequate infrastructure and resource endowments of farm households have large effects on resource use in the municipality. In contrast to the findings of Jansen and Stoorvogel (1998), the aggregation bias resulting from assuming spatially fixed input and output prices is significant for Batac, The difference lies in the infrastructure quality and distance to markets. In Guacimo County, Costa Rica, distances between farms and markets are relatively small and infrastructure is of a 'reasonable quality'. Poor farm-to-market roads, however, exist in Batac, resulting in high transport costs. Improving road networks to connect far-flung areas with the markets will reduce transaction costs and significantly increase income of farm households and aggregate income in the municipality. Similarly, the aggregation bias involved in omitting farm types significantly affects the municipal goal of economic growth. Of the factors investigated, the aggregation bias involved in assuming fixed prices for agricultural products results in the highest net effect on aggregate income in the municipality. Ignoring the three sources of aggregation bias, however, results in a decrease in the area under rice, which is the staple crop, and an increase in areas under more profitable crops. Quantification of aggregation bias is important because ignoring these when their effects are significant may lead to misleading simulation results and policy conclusions.

Optimizing objectives at different scales results in large differences in aggregate income and resource allocations. The optimal allocation for Ilocos Norte may mean suboptimal allocation of resources for certain municipalities in the province like Batac. Provincial model results show that Batac is suitable for growing more rice which give much lower returns than growing vegetables and tobacco. Total income from crop and livestock activities for Batac are much lower when provincial objectives are optimized. The difference in resource allocations resulting from prioritizing objectives at different levels may prove unacceptable to stakeholders at other levels. The municipal income is highest with crops which pose more risk to farmers; our farm household analysis shows that farmers tend not to select too much of these crops. Similarly, the municipality may not be willing to forego its own objective of attaining high income for the benefit of the whole province.

Analyses of the results from the presented multi-scale approach can provide valuable information for policy discussions and development. Uptake by users and demonstrated impact of model-based methodologies beyond the scientific community is, however, still very restricted and often absent. Although it is increasingly recognized that user involvement and preferably a participatory attitude towards the development of decision support and impact assessment systems is essential (cf. McCown et al., 2002; Higgins et al., 2004), application of this principle is often cumbersome (cf. Sterk et al., 2006). Our experience in Ilocos Norte shows that stakeholders at the municipal and provincial level recognize the need for such tools for land use analysis (Roetter and Laborte, 2000) Based on our experiences in stakeholder workshops (Van Ittersum et al., 2004) and bilateral meetings with stakeholders, we anticipate that the results of the presented multi-scale analysis can enhance transparent discussion among stakeholders about the implications on resource use of various objectives and priorities at different levels.

CHAPTER 6

Mathematical description of the models

Introduction

This chapter presents the mathematical descriptions of the six models used in this book. The first section presents a detailed description of the farm household model. Subsequent sections present the differences in the previous model specifications. The second, third, fourth and fifth sections describe municipal models for Batac with different specifications. Lastly the sixth section, describes the provincial model for Ilocos Norte.

Model 1: Farm model

The farm household model represents an average household in a farm household group. To simplify notations, we omitted the farm type subscripts in the equations below. For a description of the subscripts see Table 1.

Farmers are assumed to maximize discretionary income, Z:

$$\max Z = \sum_{c=1}^{C} pc_c^f QC_c + \sum_{a=1}^{A} pa_a^f QA_a + \sum_{m=1}^{M} w_m^{off} \sum_{d\in m} L_d^{off} + w^{non} \sum_{d=1}^{D} L_d^{non} - \sum_{m=1}^{M} E_m$$
$$- \sum_{c=1}^{C} pc_c^m CC_c^m - \sum_{a=1}^{A} pa_a^m CA_a^m$$

The discretionary income is defined as the returns from the sale of crop ($\sum_c pc_c^f QC_c$) and livestock ($\sum_a pa_a^f QA_a$) production plus wages from off-farm ($\sum_m w_m^{off} \sum_{d\in m} L_d^{off}$) and nonfarm activities ($w^{non} \sum_m \sum_{d\in m} L_d^{non}$) minus costs and interest on loans ($\sum_m E_m$) and cost of market consumption of products included in the model ($\sum_c pc_c^m CC_c^m$, $\sum_a pa_a^m CA_a^m$). The crop and animal products produced on-farm are valued at the farm-gate prices (pc_c^f, pa_a^f), whereas purchased products (CC_c^m, CA_a^m) are valued at the prevailing market prices (pc_c^m, pa_a^m). The costs ($\sum_m E_m$) include animal and crop production expenses (e.g., fertilizers, biocides, labour, irrigation) as well as post-harvest costs (e.g., tubes and firewood for flue-curing tobacco).

To incorporate risk in prices, prices of crops are defined as

$$pc_c^f = \sum_{s=1}^{S} ps_s^f pr_s \quad \text{and} \quad pc_c^m = pc_c^f + tc_c \quad \forall c$$

where ps_s^f is the farm price of crop *c* at price state *s* and pr_s is the probability that state *s* will occur. The price states were defined from a cluster analysis on farm prices from

Table 1. Indices in the farm, municipal and provincial models.

Index	Description	Used in model	Elements
a	Animal	All (1-6)	Cattle, pigs, poultry
b	Biocide	All (1-6)	Fungicide, herbicide, insecticide
c	Crop	All (1-6)	Rice (wet season), rice (dry season), white corn, yellow corn (a)[a], yellow corn (b)[a], eggplant, garlic, onion, sweet pepper (off-season), sweet pepper, tomato (off-season), tomato (contract), tomato (non-contract), watermelon, mungbean (dry season), mungbean (third crop), peanut, sweet potato, tobacco, cotton
d	Decade	All (1-6)	1 to 36
f	Farm type	Municipal (2-4) and farm (1)	Poor, Average-IR[b], Average-RF[c], Better-off
i	Animal feed ingredient	All (1-6)	Digestible crude protein (DCP), metabolizable energy (ME)
l	Land-use type	All (1-6)	Single-crop systems: rice-fallow, sweet pepper-fallow, tomato-fallow Double-crop systems: rice-rice, rice-white corn, rice-yellow corn, rice-eggplant, rice-garlic, rice-onion, rice-sweet pepper, rice-tomato, rice-tomato (contract), rice-watermelon, rice-mungbean, rice-peanut, rice-sweet potato, rice-tobacco, rice-cotton, tomato-yellow corn, sweet pepper-yellow corn Triple-crop systems: rice-garlic-mungbean, rice-white corn-mungbean, rice-yellow corn-mungbean
m	Month	All (1-6)	January, February, March, April, May, June, July, August, September, October, November, December
n	Nutrient	All (1-6)	Nitrogen, phosphorus, potassium
o	Tenure arrangement	Municipal (2-4) and farm (1)	Own, share-cropped
p	Product	All (1-,6)	Rice, white corn, yellow corn, eggplant, garlic, onion, sweet pepper, tomato (contract), tomato (non-contract), watermelon, mungbean, peanut, sweet potato, tobacco, cotton
r	Distance from main road	Municipal (2,3)	Near, far
t	Technology	All (1-6)	Current practice (CP), hybrid rice (HYR), balanced fertilization strategy (BFS), site-specific nutrient management for rice (SSNMr), site-specific nutrient management for all crops (SSNMa), integrated pest management (IPM)
s	Price state	Farm (1)	Ten price combinations
u	Land unit	All (1-6)	Surface-irrigated throughout the year, good soil quality, low-land (IGT); surface-irrigated during the wet season, good soil quality, lowland (IGW); surface-irrigated throughout the year, poor soil quality, lowland (IPT); surface-irrigated during the wet season, poor soil quality, lowland (IPW); groundwater-irrigated, good soil quality, lowland (RGL); groundwater-irrigated, poor soil quality, lowland (RPL); groundwater-irrigated, good soil quality, upland (RGU); groundwater-irrigated, poor soil quality, upland (RPU)
v	Administrative regions in Ilocos Norte (city and municipality)	Provincial (6)	Adams, Bacarra, Badoc, Bangui, Banna, Batac, Burgos, Carasi, Currimao, Dingras, Dumalneg, Laoag City, Marcos, Nueva Era, Pagudpud, Paoay, Pasuquin, Piddg, Pinnili, San Nicolas, Sarrat, Solsona, Vintar

[a] Yellow corn (a) is planted in June and yellow corn (b) is planted in July.

[b] Average-IR: average households with 0.95 ha of mostly surface-irrigated land.

[c] Average-RF: average households with 0.91 ha, most of which are without surface irrigation and half are in the uplands.

1985 to 2004 of seven price-variable crops (eggplant, garlic, onion, sweet pepper, tobacco, tomato, and watermelon). Retail prices of crops are defined as the farm price plus the price band between retail and farm price at the base price (transaction cost, tc_c).

As part of the safety-first approach, an additional constraint that income should be enough to cover production expenses (including credit repayments) and consumption expenses at each price state is included:

$$\sum_{c=1}^{C} ps_s^f QC_c + \sum_{a=1}^{A} pa_a^f QA_a + \sum_{m=1}^{M} w_m^{off} \sum_{d \in m} L_d^{off} + w^{non} \sum_{d=1}^{D} L_d^{non} \geq$$
$$\sum_{m=1}^{M} E_m + \sum_{c=1}^{C} \left(ps_s^f + tc_c\right) CC_c^m + \sum_{a=1}^{A} pa_a^m CA_a^m \qquad \forall s$$

Land used for crop production (A_{oult}) is either owned or share-cropped (o). Rental for share-cropped area is 25% of total production. The total land area allocated to cropping systems (l) and technology (t) is limited by available land by quality (a_{uo}):

$$\sum_{l=1}^{L} \sum_{t=1}^{T} A_{oult} \leq a_{uo} \qquad \forall o,u$$

Households may sell labour and hire labour in some decades (d). The total labour requirement for crop production (l_{ultd}^{crop}) comes from family (L_d^{crop}) and hired labour (H_d):

$$\sum_{u=1}^{U} \sum_{o=1}^{O} \sum_{l=1}^{L} \sum_{t=1}^{T} A_{uolt}\, l_{ultd}^{crop} \leq H_d + L_d^{crop} \quad \forall d$$

Labour requirements for livestock activities are provided entirely by family labour. Family labour that can work off-farm (L_d^{off}) and non-farm (L_d^{non}) are limited:

$$L_d^{off} \leq f_{m|d \in m}^{off} l_d^{\max} \qquad \forall d$$
$$L_d^{non} \leq f^{non} l_d^{non\max} \qquad \forall d$$

The total family labour working on-farm (for crops, L^{crop}, as well as for animals, L^{animal}), off-farm and non-farm is limited by the actual available family labour ($l_d^{\max}$):

$$L_d^{crop} + L_d^{animal} + L_d^{off} + L_d^{non} \leq l_d^{\max} \qquad \forall d$$

The wage received when household members work off-farm (w_m^{off}) is lower than the wage for hiring labour (w_m^{hire}), to account for the extra costs incurred in providing food when hiring in labour and the transaction costs involved in working off-farm.

Available water for irrigation comes from surface irrigation facilities and groundwater. Areas that are irrigated throughout the year have access to surface irrigation during the wet and dry seasons, whereas some irrigated areas have access to surface irrigation during the wet season only. During the dry season, groundwater is the source for supplemental irrigation for such areas and rainfed land units. Estimates of available groundwater are based on the daily groundwater inflow in Batac and correction factors for land unit characteristics.

Animals (cattle, pigs or poultry) are kept for backyard farming. They are bought for fattening and are sold after a certain period. Feed requirements are met by commercial feed and crop residues.

Consumption must fulfill the minimum consumption per capita ($ca_a^{\min}, cc_c^{\min}$) of family members (*sf*):

$$\sum_{c \in p} CC_c^t \geq cc_p^{\min} sf, \qquad CA_a^t \geq ca_a^{\min} sf \qquad \forall c, p, a$$

Consumption consists of products produced on-farm (CC_c^o, CA_a^o) and purchased from the market (CC_c^m, CA_a^m):

$$CC_c^t = CC_c^o + CC_c^m, \qquad CA_a^t = CA_a^o + CA_a^m \ \forall c, a$$

Capital constraints are calculated per month. To simplify calculations, enough capital for a limited number of animals is assumed to be available and is excluded in the capital constraint calculations. The monthly expenses for crop activities come from own capital used for farming activities (O_m) and credit (X_m):

$$\sum_{u=1}^{U} \sum_{o=1}^{O} \sum_{l=1}^{L} \sum_{t=1}^{T} tc_{ultm} A_{uolt} + w_m^{hire} \sum_{d \in m} H_d = O_m + X_m \qquad \forall m$$

Debt is the sum of debt and credit with interest minus repayments in the previous month:

$$D_{l,m} = \left(D_{l,m-1} + X_{l,m-1}\right)\left(1 + i\right) - \sum_{l=1}^{L} R_{l,m-1} \qquad \forall l, m$$

Loans are repaid at the end of the crop season and the maximum amount that can be borrowed depends on the land allocated to crops:

$$D_{lm} \leq \alpha \sum_{u=1}^{U} \sum_{o=1}^{O} \sum_{t=1}^{T} A_{uolt} \qquad \forall l, m$$

The capital used each month is restricted by the capital that is available for farming activities in that particular month (K_m):

$$O_m \leq K_m \quad \forall m$$

The cropping year starts in June and, during this month, the debt is assumed to be zero and available capital for farming activities (K_m) is set to the start capital (sk):

$$K_{m='June'} = sk$$

The available capital for a month depends on unused capital from the previous month ($K_{m-1} - \sum_{l=1}^{L} O_{l,m-1}$) and repayment to used capital ($\sum_{l=1}^{L} O_{l,m-1}^{r}$).

$$K_m = K_{m-1} - \sum_{l=1}^{L} O_{l,m-1} + \sum_{l=1}^{L} O_{l,m-1}^{r} \qquad \forall m$$

Repayment to used capital is paid at harvest time.

Model 2: Municipal model for Batac using representative farms, infrastructure differentiation and market constraints – Municipal-R (FT+Inf+Mkt)

The objective function maximized is economic surplus:

$$\begin{aligned} \max Z = & \sum_{c=1}^{C} \left(\alpha_c - 0.5\beta_c \sum_{f=1}^{F} \sum_{r=1}^{R} QC_{frc} n_{fr} \right) \\ & + \sum_{f=1}^{F} \sum_{r=1}^{R} \left(\sum_{m=1}^{M} pa_a^f QA_{fra} - \sum_{m=1}^{M} E_{frm} - \sum_{c=1}^{C} tc_{rc} QC_{frc} - \sum_{a=1}^{A} ta_{ra} QA_{fra} \right. \\ & \left. + \sum_{m=1}^{M} w_{rm}^{off} \sum_{d \in m} L_{frd}^{off} + w_{fr}^{non} \sum_{d=1}^{D} L_{frd}^{non} - \sum_{c=1}^{C} P_c^m CC_{frc}^m + \sum_{a=1}^{A} pa_a^m CA_{fra}^m \right) * n_{fr} \end{aligned}$$

The economic surplus is a function of sales from crop (QC_{frc}) and livestock (QA_{fra}) production, wages from off-farm ($\sum_{m} w_{rm}^{off} \sum_{d \in m} L_{frd}^{off}$) and nonfarm activities ($w_{fr}^{non} \sum_{m} \sum_{d \in m} L_{frd}^{non}$) minus production costs including interest on loans ($\sum_{m} E_{frm}$), transaction costs for sold products ($\sum_{c=1}^{C} tc_{rc} QC_{frc}$,$\sum_{a=1}^{A} ta_{ra} QA_{fra}$) and cost of market consumption of products included in the model ($\sum_{c=1}^{C} P_c^m\ CC_{frc}^m$, $\sum_{a} pa_a^m CA_a^m$). The animal products produced on-farm are valued at fixed farm-gate prices (pa_a^f), whereas purchased animal products (CA_a^m) are valued at the prevailing market prices (pa_a^m).

For market-sensitive crops (garlic, onion, eggplant, sweet pepper, tomato, watermelon), retail prices are determined as: $P_c^m = \alpha_c - \beta_c \sum_{f} \sum_{r} QC_{frc} n_{fr}$, where QC_{fr} is the total sales of crop c in Batac as calculated by the model, n_{fr} is the number of farm households of farm type *f* and *r* distance from the market, and the coefficients α_c and β_c are calculated as follows:

$$\beta_c = \frac{-p_c^m}{e_c^r q_c}, \qquad \alpha_c = p_c^m + \beta_c q_c, \qquad e_c^r = e_c^N \frac{1}{K} - \sigma_c \frac{1-K}{K}$$

where p_c^m and q_c are the retail price and total production, respectively, at the base year (2001); e_c^N and e_c^r are the demand elasticities for the national and Batac municipality, respectively; σ_c is the supply elasticity in regions other than Batac; and K is the ratio of Batac's output to the national output. The national demand elasticities and supply elasticities from other regions were assumed to be the same as those estimated for the Philippines using the IMPACT model (International Model for Policy analysis of Agricultural Commodities and Trade; Rosegrant et al., 2002). Subsequently, farm-gate price is derived by subtracting from the derived retail price the difference between the consumer price and farm-gate price in the base year.

The costs ($\sum_m E_{fr}$) include animal and crop production expenses (e.g., fertilizers, biocides, labour, irrigation) as well as postharvest costs (e.g., tubes and firewood for flue-curing tobacco).

All farm level constraints as in model 1 apply except for equations pertaining to risk in prices. In this model, risk is not explicitly included. In addition to farm level constraints, municipality constraints on available land by quality, labour by decade and month, irrigation water by month and maximum number of animals are included. Also a constraint on rice self-sufficiency in the municipality is included.

Model 3: Municipal model for Batac using representative farms, and infrastructure differentiation – Municipal-R (FT+Inf)

The objective function maximized is the sum of discretionary income of the farm types weighted by the number of farms belonging to each type and distance to road (n_{fr}):

$$\begin{aligned} \max Z = \sum_{f=1}^{F}\sum_{r=1}^{R}\Bigg(& \sum_{c=1}^{C} pc_c^f QC_{frc} + \sum_{a=1}^{A} pa_a^f QA_{fra} + \sum_{m=1}^{M} w_m^{off} \sum_{d\in m} L_{frd}^{off} + w_f^{non} \sum_{d=1}^{D} L_{frd}^{non} \\ & - \sum_{m=1}^{M} E_{frm} - \sum_{c=1}^{C} tc_{rc} QC_{frc} - \sum_{a=1}^{A} ta_{ra} QA_{fra} \\ & - \sum_{c=1}^{C} pc_c^m CC_{frc}^m - \sum_{a=1}^{A} pa_a^m CA_{fra}^m \Bigg) n_{fr} \end{aligned}$$

All prices here are fixed based on current levels. A constraint that the municipality should be self-sufficient in rice is included. Except for the assumption of fixed output prices, all other constraints are the same as in model 2.

Model 4: Municipal model for Batac using representative farms – Municipal-R (FT)

The objective function maximized is the sum of discretionary income of the farm types weighted by the number of farms belonging to each type (n_f):

$$\max Z = \sum_{f=1}^{F}\left(\sum_{c=1}^{C} pc_c^f QC_{fc} + \sum_{a=1}^{A} pa_a^f QA_{fa} + \sum_{m=1}^{M} w_m^{off} \sum_{d\in m} L_{fd}^{off} + w_f^{non}\sum_{d=1}^{D} L_{fd}^{non} - \sum_{m=1}^{M} E_{fm} \right.$$
$$\left. - \sum_{c=1}^{C} pc_c^m CC_{fc}^m - \sum_{a=1}^{A} pa_a^m CA_{fa}^m \right) n_f$$

A constraint that the municipality should be self-sufficient in rice is included. All other constraints are the same as in model 3.

Model 5: Aggregate municipal model for Batac – Municipal-A

The objective function maximized is net income:

$$\max Z = \sum_{c=1}^{C} pc_c^f TC_c + \sum_{a=1}^{A} pa_a^f TA_a - \sum_{m=1}^{M} E_m$$

The income is defined as the gross income from crop ($\sum_c pc_c^f TC_c$) and livestock ($\sum_a pa_a^f TA_a$) activities minus production costs. The costs ($\sum_m E_m$) include animal and crop production expenses (e.g., fertilizers, biocides, labour, irrigation) as well as post-harvest costs (e.g., tubes and firewood for flue-curing tobacco).

A constraint that the municipality should be self-sufficient in rice is included. Constraints on available land by quality, labour by decade and month, irrigation water by month are included in the model. Land rental, consumption, capital and wage income are not included in the model.

Model 6: Aggregate provincial model for Ilocos Norte

The objective function maximized is net income:

$$\max Z = \sum_{v=1}^{V} \sum_{c=1}^{C} pc_c^f TC_c + \sum_{v=1}^{V} \sum_{a=1}^{A} pa_a^f TA_a - \sum_{v=1}^{V} \sum_{m=1}^{M} E_m$$

The income is defined as the gross income from crop ($\sum_v \sum_c pc_c^f TC_c$) and livestock

($\sum_{v}\sum_{a} pa_a^f TA_a$) activities minus production costs. The costs ($\sum_{v}\sum_{m} E_m$) include animal and crop production expenses (e.g., fertilizers, biocides, labour, irrigation) as well as post-harvest costs (e.g., tubes and firewood for flue-curing tobacco).

An additional constraint that the province should be self-sufficient in rice is included. Like in model 5, constraints on available land by quality, labour by decade and month, irrigation water by month are included in the model. Land rental, consumption, capital and wage income are not included in the model.

CHAPTER 7

Agricultural policy assessment: A multi-scale model study for Ilocos Norte province, Philippines

Abstract

To stimulate sustainable rural development, effective policies geared towards increasing agricultural productivity and profitability in a sustainable way, while at the same time realizing other goals of various stakeholders should be implemented. Stakeholders at various scales, however, have diverse and often conflicting goals. Hence, tools are needed to evaluate the effectiveness of policies in attaining stakeholders' objectives at different scales and their implications. This chapter aims at using such tools in assessing the implications of existing and proposed agricultural policies, i.e., (1) promotion of technological innovations, (2) attainment of food self-sufficiency, (3) price liberalization, (4) environmental protection, and (5) infrastructure development, for income, food production, resource use, and environmental indicators at the farm, municipal (Batac) and provincial scales in Ilocos Norte province, Philippines.

Technological innovations showed the strongest positive effect on income and rice production across all scales. Analysis of results suggests that investments in research and extension have potentials in raising income and attaining rice self-sufficiency aims (in the case of rice technologies). Food self-sufficiency aims can be achieved, but conflict substantially with economic objectives. Liberalization of rice prices results in lower income for farmers, but benefits rice consumers as a result of lower rice prices. Improvements in and/or expansion of irrigation systems can contribute to increased rice production, however, at the expense of income. Similarly, volumetric water pricing can result in more efficient water use at the farm and municipal scale, but again at the expense of income. Many of these results seem trivial, but the model-based analysis quantifies the effects for the economic, agricultural and environmental dimensions of the problem.

Comparisons of optimizations for the province and Batac municipality show potential conflicts in food production aims of the province and economic objectives of the municipality. The study also shows that different model specifications may result in different policy evaluations, associated with aggregation bias. Care, therefore, must be taken in selecting the appropriate model to use in policy evaluations.

Keywords: Multi-scale analysis; Linear programming; Natural resource use; Farm household model; Policy analysis

Introduction

Agricultural development remains a key issue in the national economy of many developing countries that heavily lean on the agricultural sector. Agriculture can serve as an engine for economic development as it provides food to meet the growing demand, employment in rural areas, and raw materials for processing in rural industries. Effective policies geared towards increasing agricultural productivity and profitability in a sustainable way, while at the same time realizing other goals of various stakeholders are needed.

With respect to agricultural development, perceptions, goals and aspirations of different stakeholders may vary considerably. Interviews with decision-makers at different scales (i.e., farmers and policy makers at the provincial and municipal scale in Ilocos Norte province in the Philippines) brought to the fore that different stakeholders have different perceptions about the main problems in the province (Chapter 2). As a result, priorities of decision-makers at different scales may not entirely coincide, hence they may have different goals. Although across scales economic objectives are common, the importance attached to some social and environmental goals differ. Policy makers at the provincial level, for instance, are interested in food self-sufficiency of the entire province and beyond (region, national) and collective welfare of its constituents, while at the same time making sure that these goals should be achieved with minimum negative effects on the environment. Farmers, on the other hand, strive for individual goals, such as increasing income, subsistence of the household and minimizing risk, which may conflict with societal goals of food-self sufficiency and/or resource conservation. Hence, decisions at one scale may be optimal for goal attainment at that particular scale, but may conflict with goals at other scales.

In a series of consultative meetings with farmers and planners and policy makers at the provincial and municipal scales (1997-2004), various programmes and policies aimed at stimulating agricultural development were presented. In the first meeting with stakeholders under the SysNet project[1], official land use plans were presented for the province of Ilocos Norte and 10 municipalities. This resulted in lively discussions on inconsistencies and conflicts between municipal and provincial level planning. One of the insights obtained was the need for more discussion, information exchange and better coordination between the municipal and provincial planning processes (Van Paassen et al., 2006).

The policy debate and discussions in this and subsequent meetings were confusing because of lack of insight in the consequences and trade-offs associated with the policies or programmes presented. Likewise, it was not clear whether municipal and

[1] Systems Research Network for Ecoregional Land Use Planning in Tropical Asia (SysNet) was launched in 1996 and developed and evaluated a methodology for land use analysis in four case study regions including Ilocos Norte province, Philippines.

provincial objectives and policies were convergent and production targets were attainable under present conditions. Considering this situation, there is a need for tools to evaluate the effectiveness of existing and proposed policies in attaining stake-holders' objectives at different scales and to analyse their possible implications for resource use and the environment. In fact, our experience in Ilocos Norte shows that the municipal and provincial decision makers do recognize the need for such tools (Roetter and Laborte, 2000).

Various studies have dealt with assessment of the impacts of policies using land use models for specific scales, i.e., farm (Kruseman et al., 1995; Shiferaw et al., 2001), watershed (Barbier and Bergeron, 1999; Shively and Coxhead, 2004), region (Jansen et al., 2005) and national (Deybe, 1998). Policies analysed in previous studies include production-oriented policies such as promotion of productivity-enhancing technologies (Barlow et al., 1983; Barbier and Bergeron, 1999; Jansen et al., 2005); macro-economic policies such as subsidies, taxation, devaluation and market liberalization (Schipper et al., 1995; Deybe, 1998; Barbier and Bergeron, 1999; Shively and Coxhead, 2004); and policies relating to environmental protection (Schipper et al., 1995; Barbier and Bergeron, 1999; Shively and Coxhead, 2004; Jansen et al., 2005).

This chapter aims at assessing – at multiple scales – the implications of existing and proposed agricultural policies, i.e., (1) promotion of technological innovations, (2) attainment of food self-sufficiency, (3) price liberalization, (4) environmental protection, and (5) infrastructure development, for income, food production, resource use, and environmental indicators at the farm, municipal and provincial scales in Ilocos Norte province, Philippines. We seek to highlight the likely directions and magnitudes of changes arising from implementation of such policies. The next section describes the study area and the relevant agricultural policy issues in Ilocos Norte. The third section describes the methodology and the scenarios considered, and the fourth section presents the results and implications of scenario analyses. Finally, conclusions are drawn in the last section.

The study area: Ilocos Norte province, Philippines

Background

The province of Ilocos Norte, situated in the north-western part of the Philippines has a total land area of 0.36 million ha. Administratively, it is sub-divided in 23 administrative units: 22 municipalities and 1 city. Its total population is more than half a million with an average annual growth rate of 1.3%. Batac is the most populous municipality with an average annual growth rate of less than 1%. Population growth rates for both Batac and Ilocos Norte are below that of the country as a whole, because of out-migration.

Batac has a total land area of 16,101 ha, of which two-thirds are in use for agriculture, mostly in rice-based cropping systems. As in the whole province, rice is usually planted in the wet season (June to October), while in the dry season a variety of crops is grown, e.g., tomato, garlic, onion, sweet pepper, tobacco and mungbean.

Agricultural policy issues

National In the Philippines, food security and poverty alleviation are considered top priorities of the national government. The magnitude of poverty (in terms of incidence and level) is highest in the rural areas, where agriculture plays a major role in generating income and employment. As such, development of the agriculture sector is vital in the antipoverty campaign (NEDA, 2004). To ensure food availability and accessibility, food self-sufficiency has been the adopted principal strategy to guarantee that the country can produce its food requirements and become less dependent on the world market which is subject to uncertainties (DA, undated). The rice sector in the Philippines has been heavily protected, but analysis shows that market intervention has exacerbated domestic price fluctuations in the 1990s (Kajisa and Akiyama, 2005) and domestic prices in the Philippines have risen to double that at the world market. World rice prices, on the other hand, have been low and stable since the mid-1980s and trends suggest that this will remain so in the future (Dawe, 2002). So, instead of aiming at self-sufficiency, opening the rice market may be a better option to attain food security for the Philippines (Kajisa and Akiyama, 2005).

One of the factors contributing to high domestic rice prices is high production costs. Fertilizer prices in the Philippines are much higher than world market prices which could be due to monopolistic pricing and high production and distribution costs, associated with inefficient regulatory procedures and requirements (NEDA, 2004).

The Agriculture and Fisheries Modernization Act (AFMA) of 1997 focuses on development of the agriculture and fisheries sector with the following principles: (1) poverty alleviation and social equity, (2) food security, (3) rational use of resources, (4) global competitiveness, (5) sustainable development, (6) people empowerment, and (7) protection from unfair practices. In line with this Act, the national government aims at modernizing the agricultural and fisheries sectors by adopting strategies aiming at increased public investment in irrigation infrastructure, post-harvest facilities and farm-to-market roads, and promotion of productivity-enhancing and cost-reducing technologies (DA, undated). In addition to rehabilitating existing irrigation facilities and expanding irrigated areas, a policy reform of introducing volumetric water pricing for irrigation is included in the Medium Term Philippine Development Plan 2004-2010 to ensure service and mitigate water scarcity (NEDA, 2004). This policy reform has yet to be implemented, but is planned to replace the current fixed irrigation fees charged to farmers.

Under the AFMA, local government units (province and municipality) and other stakeholders develop their own plans and programmes aimed at their respective localities (DA, undated).

Ilocos Norte province The Sustainable Food Security Action Plan and Agro-Fishery-Industrial Modernization Framework (SFSAP-AGRIMODE) was developed to achieve the goal of making 'Ilocos Norte a food-secure province and an agro-fishery-industrial center in the Northern Luzon Growth Corridor through modernization of agriculture and fisheries, and sustainable use of its agro-fishery and forestry-based resources' (PGIN, 1999). In line with these goals, the province aims at developing and promoting sustainable farming practices (e.g., integrated nutrient and pest management); increasing and improving efficiency of existing post-harvest, storage and processing and irrigation facilities; and constructing and improving road networks and market facilities for cost-effective transport of local products (PGIN, 1999).

Batac municipality Similarly, the municipality of Batac aims to 'achieve sufficient production of grains, commercial crops, fishery and livestock, empowerment of farmers and fisher folks; and provide an integrated set of infrastructure in the municipality'. In line with these goals, the municipality has specified targets to increase yields of rice, corn and high-value crops such as vegetables, expand the area under these high-value crops, expand the irrigated rice area and maintain and upgrade existing water impounding projects, and construct and improve farm-to-market roads (Municipality of Batac, 2000).

Methodology

Models at different scales

The policy evaluations are based on results of four out of six models developed in this thesis for the farm household, municipal and provincial scales (see Chapters 5 and 6 for descriptions and mathematical formulations). The four models evaluated in this chapter are:

Model 1: Farm household model for each of four major farm types in Batac.

Model 2: Municipal model for Batac using representative farms, infrastructure differentiation and market constraints – Municipal-R (FT+Inf+Mkt).

Model 5: Aggregated municipal model for Batac – Municipal-A.

Model 6: Aggregated provincial model for Ilocos Norte.

Table 1 presents the details of the models. The models have different specifications but in all the models, an objective is optimized subject to a set of constraints. The different models, however, have different objective functions.

In the farm model (model 1), each farm type is optimizing its own objective function (discretionary income) in complete isolation of the other farm types. The decision variables in the model are land allocation by cropping system and rental of land for crop activities; selling and buying of crop products and livestock; allocation of family labour to crop and animal production activities, as well as to work outside the farm; hiring of labour for crop production activities; and management of credit. The constraints in the model are the resource endowments of the household (available land by quality, family labour, water, capital), subsistence consumption needs (which can be satisfied from own production or through purchasing from the market), opportunities for off-farm and non-farm work, number of animals and their feed requirements, and monthly capital and loans for on-farm activities. The farm model is described and evaluated in detail in Chapter 3.

Two versions of the municipal model for Batac are used here: (1) representative farms model with existing infrastructure and hence transport costs, within the municipality, and constraints that simulate price formation of agricultural products of which the prices are sensitive to municipal production (model 2: Municipal-R – FT+Inf+Mkt), and (2) aggregate municipal model (model 5: Municipal-A).

In model 2, all farms in the municipality are grouped into farm types (as in model 1) with specific constraints for each farm type, but one over-all objective function – economic surplus, which is the sum of producer and consumer surplus. These farm models are aggregated using the number of farms in each group as weights and limits on available resources at the municipal level are also imposed. The infrastructure differentiation implies that each of the four farm types is further differentiated in a group within and one beyond 5 km from the main road. The main road is of high quality and is well-maintained. This road system connects the different municipalities in the province, as well as the different areas within Batac, with the two existing markets in the municipality. The farther from the main road, the poorer is the quality of the roads. Farm types located more than 5 km from the main roads incur additional transport costs for selling crop and animal products, as well as for buying production inputs and products for home consumption. The magnitude of these additional transport costs was derived from averages in the farm survey.

In model 5, Municipal-A, all resources in the municipality are aggregated, as if they form a single large farm. The objective function is net income. In addition to constraints on available resources in the municipality, rice consumption requirements must be satisfied from production in the municipality.

Table 1. Summary description of the different models.

Characteristics	Model: Farm (model 1)	Municipal-R (model 2)	Municipal-A (model 5)	Province (model 6)
Aggregation level	Farm	Municipality	Municipality	Province
Type of model	Farm household model	Representative farms	Aggregate (single farm)	Aggregate (single farm)
Objective function	Discretionary income (individual)	Economic surplus	Net income (collective)	Net income (collective)
Farm types	4 farm types (separate models)	4 farm types × 2 distances from main road[b]	None	None
Sub-regions	None	None	None	23 administrative units (1 city and 22 municipalities)
Land types	8 (IGT, IGW, IPT, IPW, RGL, RPL, RGU, RPU)[a]	Same as Farm	Same as Farm	Same as Farm
Crops	15	Same as Farm	Same as Farm	Same as Farm
Animal activities	3 (cattle, pigs, poultry)	Same as Farm	Same as Farm	Same as Farm
Maximum number of animals	Set for individual farm types	Set for individual farm types and at municipal level (based on current numbers)	Set at municipal level (based on current numbers)	Set at provincial level (based on current numbers)
Renting of land	Farm types can rent up to the area of land they currently rent per land type	Farm types can rent more of the land type they currently rent	Renting of land not included in the model	Same as Municipal-A
Labour	Only cost for hiring labour included in production costs	Same as Farm	All labour included in production costs	Same as Municipal-A
Consumption	Farm households can satisfy family consumption requirement from own production or from the market	Same as Farm; the municipality should be self-sufficient in rice	The municipality should be self-sufficient in rice	The province should be self-sufficient in rice
Capital and credit	Monthly balance; maximum loan and own capital depend on farm type; interest rate is 10% per month	Same as Farm	Not included	Not included
Sources of income	Crop and livestock production, off-farm and non-farm employment	Same as Farm	Crop and livestock production	Same as Municipal-A

[a] Surface-irrigated throughout the year, good soil quality, lowland (IGT); surface-irrigated during the wet season, good soil quality, lowland (IGW); surface-irrigated throughout the year, poor soil quality, lowland (IPT); surface-irrigated during the wet season, poor soil quality, lowland (IPW); groundwater-irrigated, good soil quality, lowland (RGL); groundwater-irrigated, poor soil quality, lowland (RPL); groundwater-irrigated, good soil quality, upland (RGU); groundwater-irrigated, poor soil quality, upland (RPU).

[b] Farm types near and far from the main road are differentiated. Farm types far from the main road incur additional transport costs in selling and buying products and inputs.

The model for Ilocos Norte province (model 6) is an aggregate model with municipalities as sub-regions and with net income as objective function. The resources in each sub-region are aggregated, as if they form large farms and goals for the entire province are optimized (as in Chapter 4). As a result, land and other resources are allocated to each municipality in the province. For comparison with results from models 2 and 5, results for Batac municipality were extracted from this optimization. The model is a typical explorative land use model, aimed at exploring bio-physical potentials and limitations, rather than at predicting likely developments. As in model 5, a constraint that the province has to be self-sufficient in rice is imposed.

Crop production activities in all the models are defined using TechnoGIN, a technical coefficient generator that integrates empirical data with production-ecological and expert knowledge in defining efficiencies in input use (Ponsioen et al., 2003; 2006). All models can be run with only current crop production activities or with both current and alternative crop production activities. For livestock activities, only current practice is available in the model. Quantification of current agricultural activities is based on information from surveys carried out in Ilocos Norte in 1999 (for model 6) and in Batac in 2001 (for models 1, 2, 5), and for alternative crop activities on insights in agro-ecological processes (Chapter 2).

Scenario definition

To evaluate the effects of policies aimed at promotion of technological innovations, attainment of food self-sufficiency, price liberalization, environmental protection, and infrastructure improvements, we formulated alternative scenarios (Table 2).

Baseline The baseline scenario describes the current situation and includes current production practices for 23 cropping systems (3 single crops, 17 double crops, and 3 triple crops). Prices of production inputs and outputs, as well as available resources for 2001 are used. An irrigation fee of 500 pesos[2] per hectare per season is charged for surface-irrigated areas, while costs for groundwater extraction (using an irrigation pump) include only fuel (i.e., there is no additional cost for groundwater consumed). Groundwater availability is derived from information on groundwater inflow per municipality and assumptions on recharge and correction factors for season and land unit. Surface-irrigated areas are assumed to have sufficient water to grow rice, i.e., land units irrigated year-round have enough water for double rice systems and land units irrigated during the wet season only, have enough water for single rice. This scenario includes only current technologies and consumption requirements for 2001.

[2] 1 US$ = 51 pesos (2001).

Table 2. Description of alternative scenarios and models used.

Scenarios	Description	Model(s)
Technological change	Inclusion of 5 alternative technologies: hybrid rice production, balanced fertilization strategy (rice and corn), site-specific nutrient management for rice, site specific nutrient management for all crops, integrated pest management.	1, 2, 5, 6
Food self-sufficiency	Food (in addition to rice) self-sufficiency aims at the provincial/municipal level are met. This scenario is run with and without technological change.	2,5,6
Price liberalization		
Rice	Domestic price of rice is equal to world market price adjusted for transport and marketing costs, and milling rate; the calculated value is 52% lower than the domestic price in the base run.	2
Fertilizer	Domestic price of urea is equal to world market price adjusted for transport costs; the calculated value is 33% lower than the price in the base run.	2
Environmental protection		
Biocide taxation	Additional tax of 20% on biocides.	2
Volumetric water pricing	Water used for irrigation is charged 3.4 pesos[a] m^{-3}.	1,2
Infrastructure improvements		
Better farm-to-market roads	Additional transaction costs for land units far from the main road are removed.	2
Improvements in existing irrigation systems	Existing irrigation systems are improved, such that 50% of the areas currently surface-irrigated during the wet season only, can now be irrigated year-round.	5,6
Expansion of irrigated areas	There is an expansion of surface-irrigated area; 50% of non-irrigated lowland areas can now be irrigated year-round	5,6

[a] 1 US$ = 51 pesos (2001).

Technological change Under the technological change scenario, current *and* alternative technologies are included in the model runs. The alternative technologies considered are (Table 3): hybrid rice production, balanced fertilization strategy for rice and corn, site-specific nutrient management for rice, site-specific nutrient management for all crops, and integrated pest management.

Table 3. Description of production technologies (Chapter 3).

Technology	Yield	Nutrient management	Pest and weed management	Labour use
Current practice (CP)	CP	CP	CP	CP
Hybrid rice	25% higher yield for rice	Additional 50 kg of organic materials for the seedbed; 15% higher recovery than CP	Same as CP	More labour for land preparation and crop establishment[a]
Balanced fertilization for rice and corn	15% higher yield for rice and corn; same yields for other crops	Use of organic and inorganic fertilizers at specified rates; 15% higher recovery than CP for rice	Same as CP	4-5 more labour days ha^{-1} for hauling and application of organic fertilizer and crop care[a]
Site-specific nutrient management for rice	15% higher yield for rice; same yields for other crops	As calculated by QUEFTS in TechnoGIN[b]; 15% higher recovery than CP for rice	5% less insecticide and fungicide (rice only)	20% more labour for monitoring and crop care[a]
Site-specific nutrient management for all crops	15% higher yield for rice; same yields for other crops	As calculated by QUEFTS in TechnoGIN[b]; 15% higher recovery than CP	5% less insecticide and fungicide	15-20% more labour for monitoring and crop care[a]
Integrated pest management	Same as CP	Same as CP	70-85% less insecticide; 10-20% less fungicide; 10% (rice) to 90% (vegetables) less herbicide	10 more labour days ha^{-1} for plastic mulching (vegetables); 20% more labour for monitoring and crop care[a]

[a] Labour requirements for harvesting/threshing per hectare are higher because of higher yields. In TechnoGIN, this parameter is expressed per Mg of output. Labour use for harvesting/threshing per Mg of output is unchanged.

[b] The QUEFTS module (QUantitative Evaluation of the Fertility of Tropical Soils; Janssen et al., 1990; Witt et al., 1999) in TechnoGIN calculates fertilizer requirements by subtracting nutrient supply from indigenous sources, from crop uptake and dividing the residual by the nutrient recovery fraction.

Food self-sufficiency To analyse the implications of achievement of food self-sufficiency, the province and municipality are assumed to produce food requirements for their constituents in 2010. Population estimates for Ilocos Norte and Batac were based on growth rates from the census of population and housing for 1995 and 2000. Resources in 2010 are assumed to be the same as in the baseline scenario. This scenario is run with and without alternative technologies.

Price liberalization Two price policies have been evaluated. Under the *rice price* scenario, domestic price of rice is adjusted to conform to the world market price in 2001. Because the Philippines is an importer of rice, the world market price is converted into c.i.f. (cost, insurance and freight) and adjusted for transport (from the main port in Manila to Ilocos Norte) and marketing costs, and milling rate. The resulting value is 52% lower than the rice price in the baseline scenario. Under the *fertilizer price* scenario, domestic price of urea is assumed to be equivalent to the world market price 2001 (c.i.f.) adjusted for transport costs. The calculated value is 33% lower than the urea price in the baseline scenario.

Environmental protection Two environmental protection policies have been evaluated. Under the *biocide taxation* scenario, an additional 20% tax on biocides is imposed. Although not an existing policy, the assessment can give an indication whether such a policy could be effective in discouraging injudicious use of biocides, which is a prevalent practice, particularly among vegetable growers. In the second scenario, *volumetric pricing of water* for irrigation is examined. A cost of 3.4 pesos m^{-3} is set to irrigation water, either from surface or groundwater sources. This replaces the current water costs (fixed irrigation fee for surface water and fuel costs for pumping groundwater) included in the baseline scenario. In comparison, fuel costs incurred for groundwater use in the baseline scenario are 0.12 pesos m^{-3}, whereas average costs for water consumption of rice under surface-irrigated conditions are 0.16 pesos m^{-3} (based on the irrigation fee of 500 pesos per hectare per season). The estimate for the new water price has been derived from the current price of pumps depreciated over 10 years, the price of duct hose depreciated over 3 years and current prices of fuel, more than two times higher than 2001 levels. This value was then assumed to be taxed 100%. The new water price is 83% below the costs charged to residents in Batac for domestic use.

Infrastructure development Three scenarios are considered: one on market access and two on irrigation. The scenario on improved market access assumes no additional transport costs for purchasing inputs and marketing products for farm types located in remote areas. This could be achieved by better farm-to-market roads and, hence, easier market access for these farmers. The irrigation scenarios include improvements in existing irrigation systems and expansion of irrigation systems. Under the former scenario, existing irrigation systems are assumed to operate more efficiently, such that 50% of the area currently surface-irrigated during the wet season only, has enough water to be irrigated year-round, resulting in an increase in such areas of 6,691 ha for Ilocos Norte and 531 ha for Batac. In the scenario on expansion of irrigated areas, 50% of non-irrigated lowland areas are assumed to be served by year-round irrigation facilities. This results in an increase in total irrigated area by 31% for Ilocos Norte (8,802 ha) and 39% for Batac (475 ha). The impacts of improvements in and expansion of irrigation systems will not be evaluated for models with farm types (Models 1 and 2), because of the difficulty in translating these infrastructural modifications into resource endowments for each household type.

Results and discussion

Baseline

Table 4 shows baseline results for the farm (model 1), municipal (models 2 and 5) and provincial (model 6) models. These baseline results satisfactorily reproduce the current situation, as shown for model 1 (Chapter 3) and model 2 (Chapter 5). Models 5 and 6 are explorative-type models, i.e., they analyse technically feasible options in a given area – and hence their results can not be compared to the current situation.

Model 1 results show similar income values for poor and average households and higher income from crop activities for better-off households. Land allocations to crops also differ, because farmland resources for different farm household types vary in area and quality. The area under rice is largest for better-off and average-IR households, both of which have high proportions of irrigated land.

Models 2 and 5 show aggregate results for Batac municipality. Model 5 results show large differences in net crop income (almost eight times higher) and land allocation compared to model 2 results. Cropping intensities are much higher in model 5 and areas under off-season vegetables and tobacco are five and three times larger, respectively, which results in higher values for biocide residue index and N loss. Although both models are for the same decision level, their specifications differ considerably. The objective function of model 2 considers both producer and consumer welfare, whereas that of model 5 comprises only income of producers. In addition, model 2 incorporates farm structures, transport costs, and market constraints, that are not taken into account in model 5, so, there is no constraint on capital, and resources in the municipality are pooled to attain the highest possible value for its

Table 4. Results of baseline scenario.

Characteristic	Model 1 Farm models				Model 2 Municipal-R	Model 5 Municipal-A	Model 6 Provincial model	
	Poor	Average-IR	Average-RF	Better-off			Ilocos Norte	Batac
Objective function[a] (10^6 pesos)	0.10	0.11	0.13	0.28	826	834	2,591	–
Crop activities								
Gross income[b] (10^6 pesos)	0.11	0.13	0.13	0.36	359	1,078	3,537	530
Net income[c] (10^6 pesos)	0.05	0.06	0.06	0.15	104	820	2,213	396
Returns to labour[d] (10^3 peso d^{-1})	0.69	0.66	0.76	0.77	0.4	1.4	0.6	0.8
Available area (10^3 ha)[e]	0.85	0.95	0.91	2.44	6.2	6.2	90.8	6.2
Area sown[f] (10^3 ha)[e]	1.39	1.54	1.41	3.77	7.3	9.4	66.1	7.7
Rice[f]	0.80	1.04	0.77	1.99	4.4	3.8	51.8	5.1
Off-season vegetables	0.10	0.03	0.18	0.45	0.5	2.6	4.2	0.9
Dry season vegetables	0.01	0.01	0.01	0.01	0.9	0	0	0
Tobacco	0.36	0.41	0.36	1.04	0.7	2.3	7.5	1.2
Rice production (10^3 Mg)[g]	3.0	4.4	2.9	7.7	17	15	164	16
Labour intensity (d ha^{-1})	103	108	105	105	108	72	80	84
Land productivity[h] (10^3 ha^{-1})	38	37	45	39	14	87	33	52
Animal activities								
Net income[c] (10^6 pesos)	0.01	0.01	0.01	0.01	43	21	488	0
Environmental indicators								
Biocide residue index[i]	0.03	0.03	0.03	0.09	313	390	883	142
N loss (kg N ha^{-1})	43	34	37	41	53	75	44	55
Water use (10^3 m^3 ha^{-1})	1.6	1.7	1.6	1.5	1.3	1.5	0.7	0.8

[a] The objective function for model 1 is discretionary income; for model 2, economic surplus; and for models 5 and 6, net income. [b] Total value of output (yield × price); 1US$ = 56 pesos. [c] Crops: value of output – labour costs – other costs; livestock: value of output – non-labour costs. Costs for family labour for crop production for models 1 and 2 were imputed and other costs include payment of land rental, interest on loans and transaction costs. [d] Total value of output minus value of purchased inputs divided by total labour use for crop activities. [e] For results of model 1, the unit is in hectare. [f] Double-cropped areas are counted twice. [g] For results of model 1, the unit is in Mg. [h] Land productivity is defined as net income per hectare sown. [i] Biocide residue index is calculated as: use of chemicals per ha × toxicity index × persistence index

objective function. These differences in model specifications explain the large differences in results.

Results from model 6 show both, the optimum situation for the province and the extracted values for Batac. In the province, a high proportion of the area is sown to rice, the staple crop, and the profitable crops tobacco and off-season vegetables. Comparing land allocations in model 5 to the results for Batac in model 6, shows a larger area under rice, but a smaller area under the more profitable off-season vegetables and tobacco, when provincial objectives are optimized (model 6). The consequence is a 50% reduction in net crop income. This exemplifies the conflict between attaining the province's self-sufficiency aims and the municipality's economic objective.

Technological change

The simulations including current and all alternative technologies show the comparative attractiveness of the alternative technologies and possible impacts of adoption (Table 5; Figures 1 and 2). All four farm types adopt alternative technologies, resulting in an increase in discretionary income by 4-8% and in net crop income by at least 8%. Comparatively, hybrid rice seems the most attractive among the alternative technologies examined (adopted on more than half of the farms of each farm type). Rice production increases by more than 22% with the adoption of hybrid rice production. Labour intensity increases by at least 8% because the alternative technologies are labour-intensive. Integrated pest management (IPM) and site-specific nutrient management for all crops (SSNMa) are the other alternative technologies with promising adoption rates.

Similarly, results of model 2 show selection of hybrid rice production (42% of the land allocated to crops), SSNMa (30%) and IPM (28%). Model 2, which includes endogenous price formation for supply-sensitive crops, however, shows a reduction in crop income. The objective function, however, increase by 5% compared to the baseline scenario. This is due to the increase in consumer surplus brought about by the lower prices of some vegetables. As in the farm household models, rice production increases (by 17%) with an expansion in rice area of only 1%. There is a reduction, however, in areas under off-season vegetables and tobacco and an increase in area under dry season vegetables.

Model 5, on the other hand, shows adoption of hybrid rice (48%) and SSNMa (47%) resulting in an increase in net crop income and a large increase in returns to labour, associated with a shift from labour-intensive to less labour-demanding vegetables. With the exception of rice production and environmental indicators, the direction of change is entirely different for most characteristics in Table 5. Net income

Table 5. Simulated responses to technological change (% change over baseline results in Table 4).

Characteristic[a]	Model 1 Farm models				Model 2	Model 5	Model 6 Provincial model	
	Poor	Average-IR	Average-RF	Better-off	Municipal-R	Municipal-A	Ilocos Norte	Batac
Objective function	7	4	8	7	5	4	2	–
Crop activities								
Gross income	5	7	4	6	–2	3	5	–2
Net income	10	8	11	11	–3	4	3	–2
Returns to labour	0	–2	–1	–4	–6	64	–6	–2
Area sown	0	0	0	5	0	0	12	1
Rice	0	0	0	10	1	0	15	0
Off-season vegetables	0	–1	0	0	–10	0	0	0
Dry season vegetables	9	0	10	0	40	0	0	0
Tobacco	1	0	1	0	–42	0	0	3
Rice production	22	25	22	36	17	23	16	–9
Labour intensity	8	9	9	8	10	–36	–1	–1
Land productivity	10	8	10	5	–3	4	–8	–3
Animal activities								
Net income	0	0	0	11	–1	0	0	0
Environmental indicators								
Biocide residue index	–13	–4	–19	–12	–49	–6	–12	–11
N loss	–21	–15	–18	–16	–23	–60	–26	–48
Water use	0	0	1	6	0	1	54	1

[a] For units see Table 4.

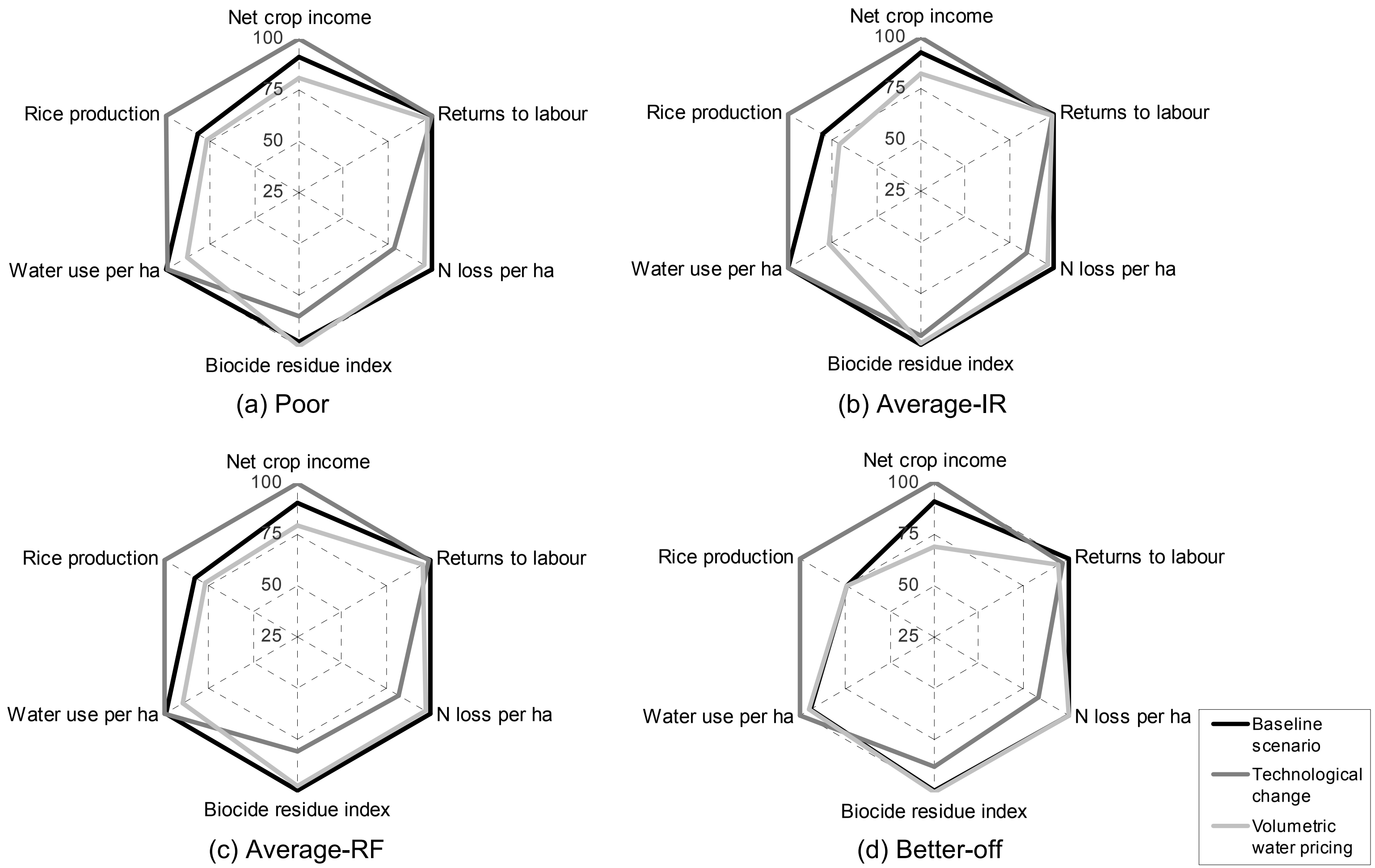

Figure 1. Comparison of results of the baseline and selected policy scenarios for different farm households. The radar plot values are expressed as a proportion of the maximum value for each characteristic per household type (Original values of indicators are per farm per year).

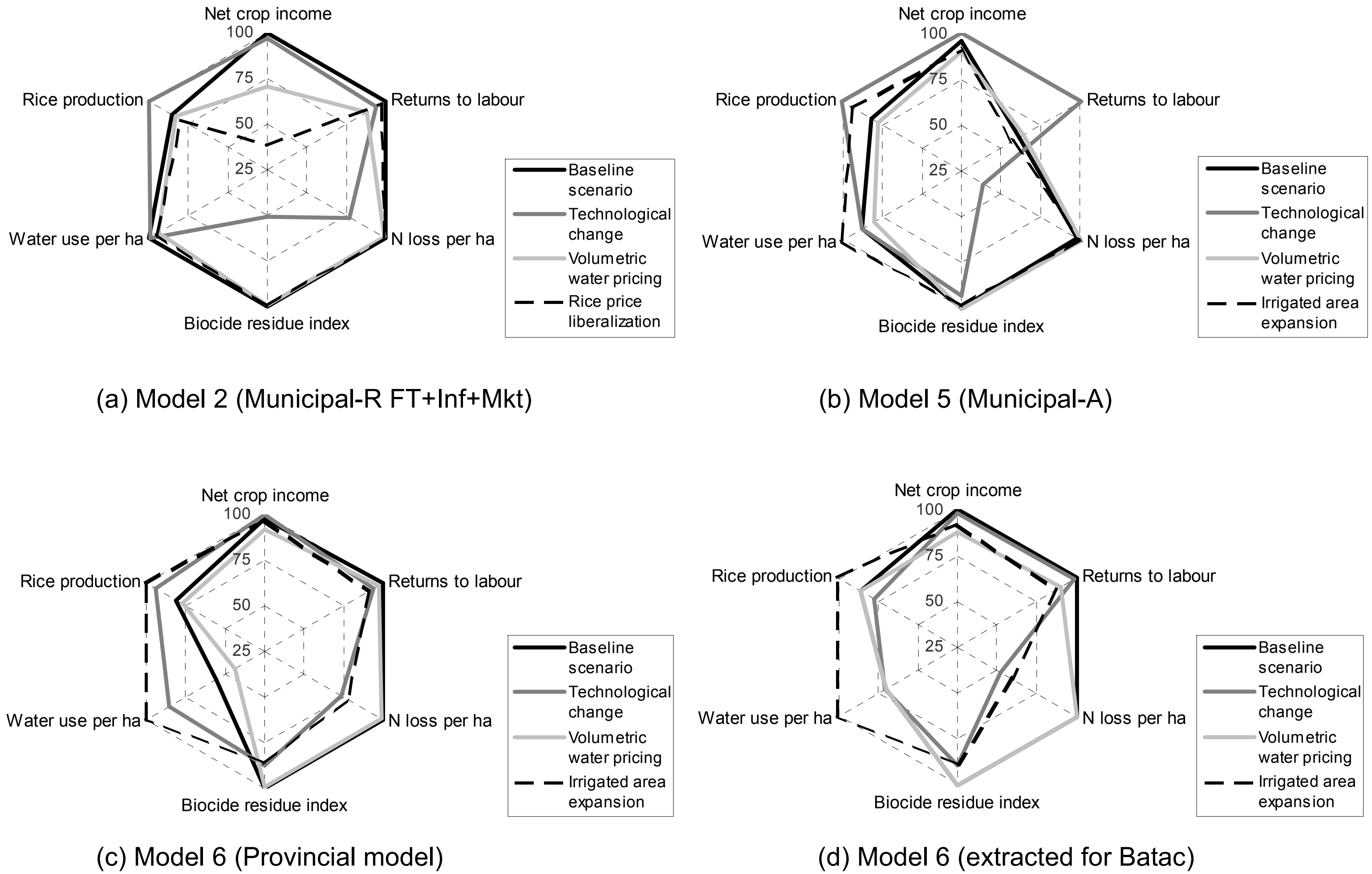

Figure 2. Comparison of results of the baseline and selected policy scenarios for the different models (a, b, c, d). The radar plot values are expressed as a proportion of the maximum value for each characteristic per diagram. Original values of indicators are per year.

and returns to labour both decrease in model 2 but increase in model 5. Labour intensity, on the other hand, increases in model 2 but decreases in model 5. This illustrates that different model specifications can result in different outcomes for policy evaluation.

Results from the provincial model (model 6), show a shift from current practices to IPM (39%), SSNMa (33%) and hybrid rice (15%). Model 6 shows an increase in area sown, albeit only by 1% in Batac and a larger area allocated to rice at provincial level, but not in Batac. The extracted values for Batac, however, show a decrease in crop income, associated with a reduction in rice production.

Technological change results in increased production due to more efficient use of chemical inputs. Rice production increases substantially across all models, which contributes to the national aim of food self-sufficiency. The increase in labour use (models 1 and 2) means higher costs for hired labour for farmers. This, however contributes to increased employment in the rural areas.

In all models, N loss and biocide residue index assume more favourable values, as a result of adoption of technologies promoting more efficient use of fertilizers (SSNMa) and reduced biocide use (IPM).

Food self-sufficiency

When food self-sufficiency for 2010 is imposed, with technological change, net crop income decreases in models 2 and 6, whereas, model 5 shows hardly any change (Table 6). Land that in the baseline scenario was allocated to more profitable crops is transformed to food crops to attain self-sufficiency aims – resulting in income reduction. Crop income decreases strongest in model 2, as a result of a reduction in prices of some vegetables. The objective function, however, increases by 1%, despite the 19% decrease in crop income, due to the increase in consumer surplus as a result of the lower prices.

The reduction is more pronounced without technological change. In both scenario runs, environmental indicators improve under the self-sufficiency scenario, in general, with technological change giving more favourable values. Water use in the provincial model, however, becomes less efficient because of the large increase in rice area (17%). The values for Batac, extracted from model 6 (both with and without technological change) show much larger reductions in economic indicators than those from model 5. These results illustrate the trade-off in achievement of food self-sufficiency targets at the provincial and at the municipal (Batac) scale.

Like in the technological change scenario, the changes for models 2 and 5 differ for most characteristics, showing the effect of different model specifications on outcomes of policy simulations.

Table 6. Simulated responses to food self-sufficiency aims with and without technological change (% change over baseline results in Table 4).

Characteristic[a]	With technological change				Without technological change			
	Model 2 Municipal-R	Model 5 Municipal-A	Model 6 Provincial model		Model 2 Municipal-R	Model 5 Municipal-A	Model 6 Provincial model	
			Ilocos Norte	Batac			Ilocos Norte	Batac
Objective function	1	1	–5	–	–3	–3	–8	–
Crop activities								
Gross income	–9	0	0	–9	–11	–2	–5	–6
Net income	–19	1	–6	–17	–23	–3	–10	–11
Returns to labour	–12	–7	–12	–12	–11	–11	–6	–8
Area sown	2	2	13	0	1	1	0	0
Rice	1	0	17	0	1	0	0	0
Off-season vegetables	–14	0	–1	–2	–8	0	–1	–3
Dry-season vegetables	23	*	*	*	–8	*	*	*
Tobacco	–59	1	–14	–13	–28	1	–9	–14
Rice production	17	23	17	–11	1	0	0	0
Labour intensity	6	7	–1	–1	–3	8	–1	–1
Land productivity	–20	–1	–17	–16	–25	–4	–10	–10
Animal activities								
Net income	–2	0	0	0	0	0	0	0
Environmental indicators								
Biocide residue index	–51	–13	–22	–24	–2	–6	–14	–14
N loss	–25	–60	–24	–46	0	–1	–3	–5
Water use	–5	0	57	1	–4	–1	0	1

[a] For units see Table 4; * Baseline value is 0; value for policy run becomes positive.

Food self-sufficiency targets can be realized, but at the expense of income. Thus, from an economic point of view, it may be worthwhile not to locally produce all food requirements of the municipality or province and rely on the market for other commodities.

The results presented here are based on the assumption that the current resources will still be available in 2010. Resource (arable land and irrigation water) availability, however, may decline in the future as a result of population growth and urbanization. Hence, in reality, reductions in aggregate income for the province and municipality may be even higher than suggested by the results presented here.

Price liberalization

Liberalizing rice prices reduces simulated net crop income by 61% for Batac (Table 7). Rice production also decreases, and the area under off-season vegetables increases. Market liberalization will mean lower income for net rice producers, but will benefit net rice buyers, i.e., most rice consumers. This, however, results in lower rice production and the national and local aim of rice self-sufficiency may not be achieved. The reduction in economic surplus for Batac is, however, modest. But, to make rice production attractive for farmers (sufficiently profitable), more output per unit input (e.g., land, labour and chemicals) is required.

Making urea prices comparable with world market prices, on the other hand, results in only a 4% increase in net crop income with very little change in land allocation.

Environmental protection

A 20% biocide tax is expected to reduce income from crop activities. Results show that although there is a slight reduction in value of the objective function (economic surplus), net income from crop activities increases by 11% (Table 7). As expected, the areas under dry-season vegetables decrease (21%), which are partly replaced by tobacco. The reduction in vegetable production, however, results in higher farm gate prices, and therefore higher net income for vegetable producers. The objective function, however, decreases by 1% because consumers have to pay higher prices for vegetables.

Biocide residue index decreases by 5% with the decrease in area under vegetables. In contrast to the findings of Schipper et al. (1995) and Jansen et al. (2005), showing a small change in biocide use and index, respectively, with a 100% tax on biocides, the effect of biocide taxation in this study is much stronger. This could be due to the higher share of biocide costs in the total input costs in current farmers' practices, particularly for vegetables.

Table 7. Simulated responses to price and environmental protection policies (% change compared to the baseline results of model 2 in Table 4).

Characteristic[a]	Price policies		Environmental protection	
	Rice (–52%)	Fertilizer (Urea –33%)	Biocide taxation (+20%)	Volumetric water pricing[b]
Objective function	–6	1	–1	–10
Crop activities				
Gross income	–5	1	4	–2
Net income	–61	4	11	–29
Returns to labour	–3	3	5	–12
Area sown	–4	0	0	–2
Rice	–7	0	0	–3
Off-season vegetables	7	0	1	2
Dry-season vegetables	–4	1	–21	–2
Tobacco	0	–1	25	0
Rice production	–7	0	0	–3
Labour intensity	0	0	0	0
Land productivity	–60	4	11	–28
Animal activities				
Net income	0	0	0	0
Environmental indicators				
Biocide residue index	–1	1	–5	–1
N loss	0	0	–3	–2
Water use	–5	0	0	–7

[a] For units see Table 4.

[b] The water price used in this analysis is 27% higher than the cost for extracting groundwater and 20% higher than irrigation fees for surface-irrigated farms in the baseline scenario (see text).

Volumetric water pricing, on the other hand, results in a 10% reduction in objective function, and a 29% reduction in net crop income for the municipality (model 2). Similarly, the objective function and income decrease at the farm scale (Table 8; Figure 1). Net income of all farmers is reduced by at least 11%, with better-off farmers experiencing the biggest cut (24%). Cropping intensities for poor and average households also decrease, as larger areas (including surface-irrigated areas) are left fallow during the dry season as a result of costly irrigation. In addition, the area under rice, which consumes large quantities of water, decreases and no rice is grown at all

Table 8. Simulated responses of different farm household types to volumetric water pricing (% change compared to the baseline results in Table 4).

Characteristic[a]	Model 1 - Farm models			
	Poor	Average-IR	Average-RF	Better-off
Objective function	–8	–7	–6	–6
Crop activities				
Gross income	–2	–3	–1	0
Net income	–11	–11	–12	–24
Returns to labour	–3	–1	–5	–6
Area sown	–5	–5	–3	0
Rice	–6	–11	–5	0
Off-season vegetables	0	–2	0	0
Dry-season vegetables	0	0	0	0
Tobacco	–3	–3	–1	0
Rice production	–7	–12	–6	0
Labour intensity	0	–2	0	0
Land productivity	–7	–6	–9	–24
Animal activities				
Net income	0	0	0	0
Environmental indicators				
Biocide residue index	2	–1	–2	1
N loss	–4	–4	–3	0
Water use	–12	–23	–10	0

[a] For units see Table 4.

during the dry season. For better-off farmers, there is no change in cropping intensity nor in area under rice, because in the base scenario, they did not grow rice in the dry season. The modified land allocations result in lower N loss and more efficient water use for poor and average households.

Volumetric water pricing results in increased water use efficiency, but is not an attractive policy for the farmers and conflicts with the aim of attaining self-sufficiency. Rice is highly water-demanding (at least under the current technologies; Bouman et al., 2002) and consequently rice will not be grown during the dry season if this policy reform is introduced. Aside from technical problems of implementation, there are other arguments against volumetric water pricing (Hellegers and Perry, 2006). Without question though, water availability for agriculture will decline in the future and more efficient use of this resource is required. Water-saving rice production technologies, such as alternate wetting and drying and aerobic rice may contribute to more efficient water use in rice (Bouman, 2001). However, technical problems still constrain large-scale introduction of these production technologies.

Infrastructure development

Improving market access of remote areas via an improved road network and hence lower transport costs, results in a slight increase in objective function (Table 9; model 2). This policy is expected to stimulate production of vegetables and result in higher income. As a consequence of the shift to vegetables, there is a small increase in biocide residue index and N loss. However, crop income in Batac declines, even with land use shifting from tobacco to vegetables, because of a reduction in vegetable prices as a result of increased production. The low prices, however, benefit consumers (Table 9).

Municipal and provincial models show a decline in income when irrigation systems are improved, such that half of the area currently irrigated only during the wet season can be irrigated year-round. This implies that this land can no longer be used for high-value crops. Some land previously fallow during the dry season or grown with tobacco is shifted to rice, resulting in higher rice production. Similarly, expansion of irrigated areas results in a larger rice area and higher production. Net income for the municipality decreases, but remains the same for the province as a result of higher cropping intensity.

Improvements in and expansion of irrigation systems would contribute to realisation of rice self-sufficiency via increased production of the staple crop. Expansion of the irrigation system, however, requires an investment of 150,000 pesos per hectare, while it results in lower income for the municipality of Batac and the province of Ilocos Norte as a whole. Hence, such investments do not seem to pay.

Conclusions

Assessment of agricultural policies is necessary to examine which are most effective in attaining economic, social and environmental goals. Quantification of the trade-offs in terms of cost of the policy and benefits derived from its implementation would provide helpful input in the policy debate and discussions. The results presented in this chapter show the possible effects of different policies on producer and consumer welfare, food production, resource use and the environment.

Technological innovations show the strongest positive effect on income. Alternative technologies that lead to increased rice production (hybrid rice) and efficient use of chemical inputs (SSNMa and IPM) have high potentials for adoption by farmers and contribute to attaining objectives at farm, municipal and provincial scales. Analysis of results suggests that investments in research and extension have potentials in

Table 9. Simulated responses to infrastructure improvements (% change compared to the baseline results in Table 4).

Characteristic[a]	Improved market access Model 2 Municipal-R	Improvements in existing irrigation systems			Expansion of irrigated areas		
		Model 5 Municipal-A	Model 6 Provincial model		Model 5 Municipal-A	Model 6 Provincial model	
			Ilocos Norte	Batac		Ilocos Norte	Batac
Objective function	1	–6	–3	_	–6	0	_
Crop activities							
Gross income	–3	–4	–1	–8	–4	4	0
Net income	–5	–7	–4	–8	–6	0	–8
Returns to labour	–1	–9	–6	1	–7	–9	–13
Area sown	0	7	6	–9	6	13	9
Rice	0	14	10	–11	13	18	16
Off-season vegetables	3	0	0	0	0	0	0
Dry-season vegetables	8	0	0	0	0	0	0
Tobacco	–13	–15	–11	–9	–13	–9	–5
Rice production	0	15	12	–13	14	24	17
Labour intensity	0	–2	–1	0	–3	0	0
Land productivity	–5	–12	–9	1	–11	–12	–16
Animal activities							
Net income	1	5	0	0	5	0	*
Environmental indicators							
Biocide residue index	4	–2	–1	–5	–2	–14	–11
N loss	1	2	2	2	2	–22	–41
Water use	0	17	47	0	15	81	44

[a] For units see Table 4.

* Baseline value is 0; value for policy run becomes positive.

contributing to increased goal attainment across all scales.

Results also show that food self-sufficiency aims can be achieved but conflict with economic objectives. Alternative technologies, such as those that improve productivity of food crops, can help in attaining self-sufficiency at a lower penalty to economic objectives.

Liberalization of rice prices results in lower income for farmers but, on the other hand, benefits rice consumers as a result of lower rice retail prices. Rice production needs to be made more profitable through improvements in productivity and in use efficiency of external inputs to induce farmers to continue growing rice in spite of the low farm gate prices under this scenario.

Similar to adoption of technological change, expansion of irrigated areas contributes to substantial increases in rice production, This results, however, in lower net crop income, because of a shift of some areas grown with high value crops to rice. As a consequence, water use efficiency is much lower than in the other policy simulations. The losses in terms of income do not seem to warrant the investments required for expansion of irrigation systems, in spite of the gains in rice production. Public investments such as improvements in irrigation systems in the Philippines have been biased towards rice systems. Making irrigation water available for high value crops such as vegetables would contribute to higher income for farmers.

Most policies evaluated result in improved environmental performance. The largest reduction in biocide residue index and N loss is under the technological change scenario, whereas the largest increase in water use efficiency is, not surprisingly, under volumetric water pricing. This policy, however, also results in the largest decrease in municipality and farm-scale objectives. Assessment of volumetric water pricing clearly shows adverse effects on rice production, which negatively affects self-sufficiency aims at the municipal and provincial scales and beyond (region, national) as well as welfare of farm households.

The combination of models presented here, i.e., model 1 for the farm scale, models 2 and 5 for the municipal, and model 6 for the provincial scale, allows identification of possible conflicts between objectives of different stakeholders at different scales (or the same scale). Comparison of results of model 5 and the extracted values for Batac from model 6 shows that prioritizing the province's self-sufficiency aims conflicts with the municipality's economic objectives.

Among the municipal models considered, model 2 most closely resembles reality because of the inclusion of farm structures, transport costs and endogenous price formation for some vegetables. model 5, on the other hand, explores the bio-physical potentials and limitations, without taking into account the current situation. Different model specifications may result in different policy evaluations. Increased production, resulting from technological change may not directly translate into increased income for the farmers as shown in model 1 results, because at the aggregate level, prices may be affected by the increase in production. Hence, the simulated overall increases in income for the municipality assuming fixed prices (model 5) may not be realistic. It is for the same reason that policies on price liberalization were simulated only using model 2. Care, therefore, must be taken in selecting the appropriate model for policy evaluations, because the wrong choice could result in wrong policy conclusions.

The results presented in this chapter illustrate the potentials of the methodology in contributing to current debates on natural resource management, land use and agricultural development. We anticipate that in future meetings with stakeholders in Ilocos Norte, these results can help in structuring the discussions by making more explicit the trade-offs and conflicts associated with prioritizing the various goals of stakeholders at different scales and the implications for welfare of farm households and resource use at the provincial, municipal and farm scales.

CHAPTER 8

Land use models at different scales: Issues and contribution to policy analysis

Introduction

Discussions on land use and resource allocation are contentious. There are many competing claims on limited resources as well as conflicting goals among actors, including decision-makers, at different scales (farm, municipal, provincial, national). Moreover, there is much conjecture and uncertainty with respect to the implications of different alternatives. Discussions on the advantages and disadvantages of prioritizing different goals and implementing different policies would greatly benefit from a quantitative assessment of the associated economic, social and environmental benefits and costs. Tools are needed to aid in increasing understanding, making the gains and losses as much as possible explicit and thus making the policy debate more transparent.

In this thesis, a methodology was developed and applied for analysing land use options at multiple scales – farm, municipal and provincial – illustrated for the province of Ilocos Norte in the northern Philippines. Views of stakeholders, methodological issues and important findings and implications of this study, as well as the prospects for the use of model-based analyses in participatory policy making are discussed in subsequent sections.

Stakeholders' views

Chapter 2 describes the perceptions of stakeholders from farm to provincial level on the main problems in Ilocos Norte, as well as their aspirations for the future. Common problems indicated by stakeholders at various levels pertain to marketing of produce and availability of irrigation water. There are, however, also inconsistencies. In particular, perceptions of stakeholders, even from the same scale, differ on environmental issues and land conversion from agriculture to other uses. Some stakeholders assert that land conversion is taking place at a limited scale in the province, within the legal limits, whereas others consider it a serious problem. Likewise, some actors were of the opinion that environmental problems are hardly an issue, whereas others mentioned several, such as flooding, nitrate pollution, soil erosion, and salinization. The farmers did not raise any environmental issue when asked about their main problems.

In much the same way, priorities of decision-makers at different scales vary, resulting in differences in and even conflicts among goals. Decisions made at one scale may be optimal for goal attainment at that particular scale, but may conflict with goals at other scales. Policy makers at the provincial level aim at food self-sufficiency of the entire province and even beyond (region and national), and collective welfare of its constituents, while at the same time including environmental protection in their agenda. Farmers, on the other hand, strive for individual goals, such as sustaining the household, increasing income and minimizing risk, which may conflict with societal goals of food-self sufficiency and/or resource conservation. Farmers are more concerned with immediate issues (household income and subsistence), whereas policy makers focus on issues with a longer time horizon (e.g., sustainability of agriculture).

The methodology developed in this study allows analysis of the implications of pursuing these disparate goals for economic (income), social (food security, employment), and environmental indicators (biocide use and residue index, N loss, water use) at different scales. It also allows assessment of the effectiveness of possible policies in satisfying objectives of different stakeholders.

Methodological issues

Explorative vs predictive land use models[1]

Explorative studies aim at examining options for the future. This type of studies intends to explore outer boundaries of technical feasibility and, thus, shed light on potentials for and not feasibilities and/or plausibilities of sustainable development. In this approach, an 'unspecified time step' into the future is taken and, particularly for long-term explorations, any socio-economic constraints for development, associated with the current situation, are not considered. Model results cannot be validated, because of large discrepancies between assumptions about the future in the model and the current situation.

Predictive studies, on the other hand, focus on the likely effect of policies on farm household welfare and sustainability indicators. Farmers' behaviour, i.e., their response to policy instruments is explicitly modelled. Contrary to explorative studies, predictive studies start from the current situation and look at what is plausible rather than at what is possible. Therefore, model results from the base run of predictive studies can and must be evaluated against the current situation.

Predictive studies generally deal with short-term effects of policy changes, whereas explorative studies may be used to determine possibilities for the medium- to long-term. It is important to distinguish between these two approaches because of the need to match the appropriate tools with the problem to be addressed.

In this study, the farm household model (model 1; Table 1) and the representative municipal models (models 2-4) for Batac are examples of predictive-type models. Farm types were defined based on farm size, quality of farmland and ownership, number of economically active household members (labour force) and value of farm assets. These characteristics were selected, because they represent the quantity and/or

[1] The terminology of explorative versus predictive land use studies is often used in the 'Wageningen land use analysis school' (see Van Ittersum et al., 1998). On re-consideration, this terminology can cause confusion in some cases, as is rather presumptuous. Alternatively, one could use 'bio-physical' *versus* 'economic' explorative studies.

Table 1. Specifications of models at different scales.

Decision scale	Model-ID	Description	Objective function
Farm	Model 1	Farm household model	Discretionary income (individual)
Municipality	Model 2 – Municipal-R (FT+Inf+Mkt)	Municipal model with farm structures, spatially varying prices and endogenized prices	Economic surplus (collective)
	Model 3 – Municipal-R (FT+Inf)	Municipal model with farm structures and spatially varying prices	Discretionary income (collective)
	Model 4 – Municipal-R (FT)	Municipal model with farm structures	Discretionary income (collective)
	Model 5 – Municipal-A	Aggregate municipal model	Net income (collective)
Province	Model 6	Aggregate provincial model	Net income (collective)

quality of production factors (land, labour and capital) to which farm households have access. Farm households with similar resource endowments are assumed to behave similarly in allocating their resources to different production activities. So, for each of the farm types in the study area, we developed a model that incorporates its essential characteristics.

The aggregate municipal (model 5) and the provincial (model 6) models, on the other hand, are examples of explorative-type models. The results of analyses with these two models illustrate the biophysical potentials of the province/municipality, but do not allow identification of the possible socio-economic constraints to desired land use change at the various decision scales. For that purpose, the regional analysis has to be integrated with the farm household analysis that incorporates farmers' behaviour (e.g., models 2-4). There are, however, aggregation issues involved in integrating farmers' behaviour in regional analysis.

Aggregation

In modelling options for agricultural development in a region (or higher scale), three aggregation issues may arise (Schipper, 1996): (1) aggregation bias may result from omitting relevant farm types, i.e., assuming that all farms within the region have equal access to the same resource endowments and hence the objective function is overestimated, (2) the nature of some variables may change at the regional level, i.e., variables that are exogenous at the farm level may become endogenous at the regional level, (3) the difficulty in analysing decision-making at more than one level simultaneously.

Quantification of aggregation bias is important because ignoring it when its effects are significant may lead to misleading simulation results and hence, policy conclusions. No examples have been found of studies investigating these three sources of aggregation bias in a multi-scale study for one region. To examine the possible effects of the first two aggregation issues and identify their implications for resource use and other indicators, we compared four different specifications of the municipal model (Table 1). Comparing their results shows the potential effects of: ignoring market constraints (model 2 vs model 3), transport problems (model 3 vs model 4), and farm structures (model 4 vs model 5). These analyses show that these factors significantly affect resource use in the municipality (Chapter 5). The aggregation bias resulting from assuming spatially invariable input and output prices is significant for the municipality of Batac, with poor quality farm-to-market roads, resulting in high transport costs. Similarly, the aggregation bias associated with omitting differential access to resources (farm types) significantly affects the municipal goal of economic growth. Of the factors investigated, the aggregation bias involved in assuming fixed prices for agricultural products independent of demand and supply has the strongest net effect on aggregate income in the municipality.

The third aggregation issue, the need to simultaneously consider decision making of farmers and that of policy makers at regional scale, introduces complications. Goals at different scales may be conflicting, and at the same time, decisions made at one scale have an effect on those at another. Two approaches have been followed in modelling interdependence of decisions at different scales (Goreux, 1973; Schipper, 1996): (1) single or integrated modelling, (2) linking self-contained models.

In the first approach, farm types are included in the regional model. One way of incorporating farm decision-making behaviour is by defining the objective function for the region as the sum of the objective functions of the farm types (weighted by the number of farmers in the region) (cf. Schipper et al., 1995; Lopez Ridaura et al., 2005). This, however, reflects collective rather than individual objectives, which, in a way, contradicts the original intention of incorporating farm decision-making behaviour within regional models. Moreover, although rigorous, this approach involves progressive enlargement of the model, and extensive data collection. Another way of incorporating farm-scale decision-making in regional models is to develop an integrated model that optimizes goals of regional policy makers subject to optimal responses of farm households. The concept has been discussed in so-called multi-level optimization models, but such a method is complex and difficult to implement due to the existence of many local optima (Candler et al., 1981; McCarl, 1992).

Instead of an integrated model (approach 1), separate stand-alone models may be created and *ex post* linkages developed (approach 2). This allows development of models with different structures for the different scales. Farm-scale decision-making is then incorporated in the regional analysis through an iterative procedure, in which the results from optimizing the farm models (with individual objectives) are incorporated in the regional model, which in turn is solved using its own regional (collective) objective function. This approach reflects the decentralized nature of decision-making. However, this procedure is very time consuming and it is not *a priori* clear whether the results from such an approach will be useful (Schipper, 1996). Nkowani (1996) attempted to apply such an approach, described by Dent and McGregor, 1993 (cited by Nkowani) in analysing resource use options in the northern Zambia. The method involves defining farm types and optimizing objectives for each farm type under several policy scenarios. The solution to each combination of farm type and policy is then incorporated as activities in the regional model, which is subsequently optimized, using regional objectives. Although conceptually and operationally appealing, the methodology has technical and operational problems (McGregor et al., 2001). Moreover, the method may not be very useful in the policy debate. Selection of specific combinations of farm types and (mutually-exclusive) policies that will contribute to optimization of regional objectives implies that it is impossible to analyse trade-offs among different policies. Analysis of the gains and losses associated with different policies is essential in the transparent discussion of options for agricultural development.

In this study, separate models at the farm, municipal and provincial scales were developed and results were compared. No iterative procedure was employed, however, the first approach, an integrated model, is used in some models (models 2-4) using collective goals as objective functions. The approach presented here is computationally easy and allows comparison of trade-offs in optimizing objectives at different decision scales.

Activities and novel production techniques

The methodology allows synthesizing agronomic knowledge for use in analysing land use options at the farm, municipal and provincial scales. Alternative, innovative production techniques can be evaluated *ex ante* for adoption possibilities and their possible contribution to attaining goals of stakeholders at different scales. This provides a way to test new technologies, such as improved rice technologies developed at the International Rice Research Institute (IRRI) or national agricultural research centres, first for likelihood of adoption by farm households and the implications of their adoption for goal achievement and resource use, before embarking on costly on-farm research, technology promotion and extension.

In the current study, twenty-three dominant annual cropping systems and three animal activities are included in the land use models. A range of crop and animal production activities, currently practiced in Ilocos Norte and growing in importance, such as perennial species and aquaculture, were not included, due to lack of suitable tools for generating their technical coefficients. The difficulties in generating the technical coefficients of these activities are partly associated with their perennial characteristic.

The technical coefficients for some of the crops included in the model are also uncertain. The use of a technical coefficient generator (TechnoGIN) in estimating input-output coefficients, however, makes assumptions and parameters explicit and therefore more easily amenable to testing (Chapter 2).

Methodological strengths and limitations

Scarcity of resources could be an incentive for their better allocation. Decision-making can be greatly improved through development and application of analytical tools that can be used to systematically identify and evaluate options. The methodology developed in the present study allows for such analyses. Methodologies proposed so far, are, almost without exception, partial in terms of issues dealt with, scales being addressed and/or disciplines involved. Bouman et al. (2000) presented models for land use analysis at different scales for Costa Rica, however, without a consistent analysis across all scales for one region. The current thesis presents an operational method for assessing alternative land use patterns, new technologies and policies across three scales – farm, municipality and province – that can deal with multiple issues that are relevant for natural resource use in Ilocos Norte.

We developed the municipal model for Batac with different specifications, ranging from complex, which among all municipal models considered most closely resembles reality (model 2), to simple (model 5). Specific questions may be addressed by a specific model or by models of different complexities (Table 2). The most appropriate model depends on its purpose, the type of questions to be addressed and typical characteristics of the study area. There is of course a trade-off between the cost associated with the development of a more complex model and the benefit gained from greater precision and more possibilities. Complex models require longer development and computing time, but may be necessary for greater accuracy and/or for addressing specific questions. Improvements in accuracy of results from increased detail, however, are subject to the law of diminishing returns (Morrison et al., 1986). Moreover, complex models may be more difficult to understand and explain to target users.

Table 2. Matching the appropriate models to specific questions relating to land use and resource management[a].

Questions	Model 1 Farm	Model 2 Municipal-R (FT+Inf+Mkt)	Model 3 Municipal-R (FT+Inf)	Model 4 Municipal-R (FT)	Model 5 Municipal-A	Model 6 Province
1. What are the land use options and trade-offs associated with optimizing different goals (e.g., economic, social, environmental)?					(*)	*
2. What are the long-term potentials of agricultural production (and associated emissions) in a specific region					(*)	*
3. What is the potential benefit of alleviating/removing resource constraints?	*	(*)	(*)	(*)	(**)	(**)
4. What is the effect of introduction of alternative technologies on economic, social and environmental goals?	***	**	(*)	(*)	*	*
5. Which alternative technologies are likely to be adopted by farmers?	**	*	*	*		
6. Which policies contribute to increased adoption by farmers of alternative technologies?	**	(*)	(*)	(*)		
7. Which policy instruments are effective in attaining objectives of stakeholders?						
Self-sufficiency	(*)	*	(*)	(*)	*	*
Price policies	*	*				
Environmental protection	*	*	(*)	(*)	(*)	(*)
Infrastructure development	*	**	*	(*)	*	*

[a] The number of asterisks show the degree of applicability of models to answer the question. More asterisks means more suitable compared to the different applicable models in the same row. Asterisks enclosed in parentheses means not shown in the analyses presented in this book but model specification may be used to answer such questions.

Developing such complex models is extremely time-consuming for construction, fine-tuning and evaluation, while data-requirements are very high. Involving stakeholders, which is an integral part of the approach presented in this study, requires considerable investment as well. The stakeholders involved in this study were selected, intentionally or unintentionally, from the far larger number with a stake in natural resource management and regional agricultural development in the province. Interaction with stakeholders has been, for the greater part, limited to the agricultural sector, i.e., farmers, municipal and provincial planners, agricultural officers and technicians. Similarly, only a selection of the objectives that were raised by the stakeholders has been addressed in this study. Most of the models presented here, are biased towards income objectives. Chapter 4, however, deals with multiple objectives of provincial stakeholders (model 6), and the farm household model (model 1) includes subsistence aims and risk (in prices) faced by farm households.

Despite its limitations, this study presents an operational link between (sub)regional land use optimization and farm household modelling without the complexities associated with the multi-level optimization approach. The method allows evaluation of the economic, social and environmental benefits and costs of different options for agricultural development and thus has the potential to contribute to transparent discussions on agricultural development in the region.

Main results and policy implications

Prioritizing different objectives

Analysing model results generated by optimizing different goals of stakeholders in the province shows the conflicts in pursuing economic and social goals, in particular goals related to food self-sufficiency and employment (Chapter 4). The objective of maximizing provincial income conflicts with aims of food self-sufficiency and increased employment in agriculture. Optimizing income is associated with a rice production level, 25% below the potential of the province and for employment 15% below the potential. This analysis thus defines the ‘feasible area’, i.e., the outer limits of possibilities and the trade-offs in terms of income, food production and employment.

Similarly, economic and environmental objectives appear conflicting. Maximization of economic objectives results in selection of production activities, such as vegetables, that are highly profitable, but require substantial chemical inputs that are harmful to the environment. Adoption of improved nutrient and pest management strategies, however, could alleviate to a large extent the adverse effects on the environment (Chapter 3).

Comparisons of the effect of prioritizing goals of decision-makers at the farm and municipal scales (aggregated model 1 vs model 2), and municipal and provincial scales (model 5 vs extracted values for Batac in model 6) show large differences in aggregate income and resource allocation when optimizing objectives at different scales (Chapter 5). Optimal allocation for Ilocos Norte as a whole (model 6), results in suboptimal allocation of resources for Batac. Income from crop and livestock activities for Batac is much lower, but rice production is higher when provincial objectives are optimized. This implies a conflict between food self-sufficiency for the province and profit maximization for the municipality.

Resource allocations resulting from prioritizing objectives at one scale may appear unacceptable to stakeholders at other scales. Municipal income is highest when crops are selected posing more risk to farmers; our farm household analysis shows that farmers tend to restrict cultivation of such crops. Similarly, the municipality may not be willing to forego its own objective of attaining high income for the benefit of food self-sufficiency for the province (region, national). The results presented here can enhance transparent discussions by illustrating the trade-offs associated with prioritizing different goals of stakeholders within the same or across different decision scales.

Policy simulations

The implications of existing and proposed agricultural policies, i.e., (1) promotion of technological innovations, (2) attainment of food self-sufficiency, (3) price policies, (4) environmental protection, and (5) infrastructure development, for income, food production, resource use, and environmental indicators have been assessed.

Current crop production systems in Ilocos Norte, that are characterized by low yields and inefficient use of fertilizers and biocides, could be improved through active promotion of production technologies that lead to higher crop yields and make more efficient use of inputs. Results show that all alternative technologies analysed in the current study, are promising in terms of adoption by farmers (Chapter 3). In reality, however, technologies such as hybrid rice, balanced fertilization strategy and IPM, though currently being promoted in the province and throughout the country, are not widely adopted yet (PGIN, 1999; Casiwan et al., 2003). Some reasons for non-adoption could be availability of inputs (e.g., hybrid rice F1 seeds, *Trichogramma* for IPM), perceived risks involved in adoption (e.g., pest outbreaks for IPM), insufficient information about or high decision costs involved in knowledge-intensive technologies, or inherent resistance of farmers to change.

Among the policies tested for their effect on adoption of these alternative technologies, reduced transaction costs (through improved infrastructure) and the availability of low-cost credit show the largest positive effects on farmer welfare for all farm types, but have varying effects on the adoption of alternative technologies. These policy instruments serve equitability goals, in having the strongest effect on poor households and the smallest on better-off households.

Food self-sufficiency targets at all three scales can be realized, but at the expense of income. Thus, from an economic point of view, it may be worthwhile not to produce all food requirements of the municipality or province locally, but to rely on imports for some commodities. The reduction in income, however, is smaller with technological innovations, as that increases land and labour productivity, as well as input use efficiency.

Input price policies (i.e., subsidy on fertilizers, taxation on biocides and liberalization of urea prices) did not significantly affect farm and municipal objective functions (Chapters 3 and 7). Under the rice price liberalization policy, however, net crop income for Batac is substantially lower, as a consequence of lower farm gate rice prices. The reduction in objective function, however, is lower, due to the benefits to consumers of lower rice prices.

Most policies evaluated result in improved environmental performance. The largest reduction in biocide residue index and N loss is simulated under the technological change scenario, whereas the largest increase in water use efficiency is simulated under volumetric water pricing. The latter policy, however, also results in the largest decrease in municipal- and farm-scale objectives. Assessment of this policy reform clearly shows adverse effects on self-sufficiency aims, as well as on welfare of farm households.

Improvements in roads, such that transport costs for currently inaccessible farm types would be reduced, results in an increase in net crop income (Chapter 5). The same analysis using a model with endogenized prices, however, gives the opposite result (Chapter 7). This is due to lower farm gate prices resulting from the increase in aggregate production of vegetables that have high transport costs. The net effect of this is that net crop income for farmers is lower, but the lower prices mean that consumers will pay less for vegetables.

Expansion of irrigated systems, on the other hand, results in lower net crop income in both, the municipal and provincial models, because of a partial shift in land use from high value crops to rice, as the water regime in these irrigation systems prevents cultivation of vegetables. The consequence is, however, a substantial increase in rice production (Chapter 7).

Among the policies examined, adoption of technological innovation results in the highest increase in net crop income and rice production (Chapter 7). This suggests that investments in research and extension have potentials in improving welfare of farm households, and increasing income and food production in the municipality and province.

Model-based analysis in participatory policy-making

Land use planning is a complex process. It involves many stakeholders with diverse views and aspirations, and resources are limited. Tools are needed to support the stakeholders in the discussions and negotiations, and to facilitate ultimate arrival at mutually acceptable solutions and appropriate policies. Our experience in Ilocos Norte has shown that stakeholders at the municipal and provincial scales recognize the potential usefulness of such tools for land use analysis (Roetter and Laborte, 2000).

In the process of land use policy formulation and analysis, discussion, negotiation and decision support is required for different sets of questions, for each of which different models are most appropriate. In Table 2 an overview is given of the models, used in the current study to answer some questions. Although not exhaustive, this gives an indication of the type of models available to answer specific questions of stakeholders. An attempt is also made to identify which among these models (is) are most suitable for answering specific questions. Questions related to trade-offs in optimizing different goals are best addressed with multiple goal explorative-type models (models 5 and 6). In predictive-type models in general only one over-all goal is optimized. Similarly, questions pertaining to potential gains (or losses) or effects in the long-term are best analysed with explorative-type models.

The effect of introduction of alternative technologies may be analysed using any of the models presented here. However, if the question relates to likelihood of adoption or its effect, predictive-type models are most suitable, with a preference for the farm household model (model 1), considering that it optimizes individual farm household objectives, rather than a collective objective. Among the municipal models, the one including endogenized prices is best for assessing the impacts of adoption of production-enhancing technologies, as that takes into account the effect of increased production on prices.

All models, in general, may be used to evaluate effectiveness of different policies. Price policies, or those that strongly affect prices, are best assessed with models including endogenized prices. The analysis presented here refers to Ilocos Norte and may be applicable to other areas with similar conditions. However, in areas where prices are not easily affected by supply, models with endogenized prices, which are more complex, may not be necessary.

The method presented in this study can support the planning process in the province and municipalities by contributing to the assessment of the (in)consistencies in plans at lower and higher scales. For the province, for instance, the development plan should take into account the plans of its various municipalities, as well as conform to the regional and national directives (Chapter 1). Using the models presented here, gains and losses incurred in following directives from the higher scale can be quantified and used to support discussions and negotiations on effects of such higher-scale policies on the province. Similarly, during public hearings, where the draft plan is presented to government agencies, the private sector and other stakeholders in the region (Chapter 1), the trade-offs of different strategies can be made more transparent, and thus, discussions on the preferred direction for development are facilitated.

In developing tools in support of decision making of policy makers, simplification and interpretation are required. As the governor of Ilocos Norte put it: detail is required, but the methodology and results need to be translated into terms that planners and policy makers can understand and use (Roetter et al., 2000). In addition, the models have to be flexible. As some issues of stakeholders are solved, new questions emerge, and models should be designed in such a way that they can be easily adapted to remain suitable for supporting stakeholder needs (Van Paassen et al., 2006).

Analyses of the results from the multi-scale approach presented in this study can provide valuable information for policy discussions on development, taking into account prioritization of different objectives. The methodology also allows assessment of effectiveness of policies and new technologies in terms of goal attainment. Based on our experiences in stakeholder workshops (Van Ittersum et al., 2004) and in bilateral meetings with stakeholders, we anticipate that the results of the multi-scale analysis generated in the current study, can enhance transparent discussions among stakeholders on the implications for resource use of various objectives and priorities at different levels. We plan to present the most important results of scenario analyses to key stakeholders in Ilocos Norte, possibly in the second half of 2006.

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Summary

The way in which land is being used has become a source of widespread societal concern, as ever more (groups of) actors consider themselves stakeholders in the decision-making process. The agricultural sector is still by far the largest land user, and in many developing countries, where agriculture is the major sector in the economy, land use issues concentrate on agricultural land use. (Even) within that sector, there are many competing claims on limited, and often declining, resources, as well as conflicting goals among stakeholders at different scales (farm, municipal, provincial, national). Discussions on alternative resource uses, prioritizing different goals, and formulation and implementation of agricultural policies, in the framework of participatory land use analysis, would greatly benefit from a quantitative assessment of the economic, social and environmental benefits and costs associated with the various alternatives.

This study aims at development and application of a multi-scale and model-based approach that can support joint-learning, policy discussions and decision-making with respect to agricultural land use. The methodology is operationalized, in consultation with stakeholders, for the province of Ilocos Norte in the northwestern part of the Philippines, and its most populous municipality, Batac.

The province covers a total land area of 0.36 million ha, about one-third of which is classified as agricultural land. Ilocos Norte's economy is mostly agriculture-based. Its lowland areas are cultivated intensively, while the upland and hilly areas are used sparingly for agriculture. Average annual rainfall is about 2,000 mm, with almost 90% concentrated in the wet season. In the province, 13 national irrigation systems and 649 communal irrigation systems operate, constructed by the National Irrigation Administration (NIA) with an aggregate service area of 35,461 ha. Actual irrigated area covered by these systems is about 80% of the supposed service area in the wet season and 40% in the dry season, due to insufficient water availability and inefficient irrigation systems. In addition, farmers own pumps for supplemental irrigation, especially in the dry season. Agricultural production is characterized by rice-based systems. Rice is usually planted in the wet season (June to October), and in the dry season a variety of other crops is grown, e.g., tomato, garlic, onion, sweet pepper, tobacco and mungbean. The province comprises 23 administrative units: 22 municipalities and 1 city, and is sub-divided into 557 villages or *barangays*. The total population (2000) is 514 thousand with an average annual growth rate of 1.3%. The economically active population comprises 61% of the total. Land holdings of farmers in Ilocos Norte are fragmented, i.e., farm households on average cultivate 4 parcels of 0.4 ha each.

The municipality of Batac is located 15 km south of Laoag City, the provincial capital, and 472 km north of Manila. It comprises 43 villages, 29 of which are classified as rural. It has a population of almost 48 thousand, i.e., on average 3 persons per ha (2000). Annual population growth rate between 1995 and 2000 was, at 0.9%, lower than that of the province. The municipality covers a total land area of 16 thousand ha, of which two-thirds are in use for agriculture, mostly in rice-based cropping systems. Land use is similar to that of the province as a whole, i.e., rice is usually planted in the wet season (June to October), while in the dry season a variety of crops is grown, using mainly groundwater for supplemental irrigation.

Key problems in the agricultural sector, identified by various stakeholders, are related to low productivity and low income. Causes identified include insufficient water for irrigation, high costs of farm inputs and low farm gate prices – associated with poorly functioning markets and high transaction costs, limited capital, low level of farm mechanization, lack of post-harvest and storage facilities, and limited access to improved technologies

Chapter 2 describes the empirical base on which the different models of the multi-scale approach were developed. It provides an overview of the (conflicts in) views and perceptions of stakeholders at the farm, municipal (Batac) and provincial (Ilocos Norte) scales. Current agricultural production activities and farm practices are described, as well as proposed alternative technologies, i.e., hybrid rice production (HYR), balanced fertilization strategy (BFS) for rice and corn, site-specific nutrient management (SSNM, for rice only and for all crops), and integrated pest management (IPM).

Six (optimization) models with different specifications were developed for the different scales:

1. Farm household model for each of four major farm types in Batac;
2. Municipal model for Batac, using representative farms, infrastructure differentiation and market constraints;
3. Municipal model for Batac, using representative farms and infrastructure differentiation;
4. Municipal model for Batac, using representative farms;
5. Aggregated municipal model for Batac;
6. Aggregated provincial model for Ilocos Norte.

In all the models, an objective is optimized subject to a set of constraints. The constraints in the model refer to resource endowments and consumption requirements.

Production activities are defined using TechnoGIN, a technical coefficient generator that integrates empirical data with production-ecological and expert knowledge in defining efficiencies in input use.

Farm types were characterized (Chapter 3) on the basis of a cluster analysis of 150 farm households surveyed in 28 rural villages in the municipality of Batac in 2001. Farm size, quality of farmland and ownership, number of economically active household members (labour force), and value of farm assets were used in the classification, resulting in four farm household types: (i) poor households with a farm size of 0.85 ha, of which one-third is owned, (ii) average households with 0.95 ha of mostly surface-irrigated land (average-IR), (iii) average households with 0.91 ha, most of which are without surface irrigation and half are in the uplands (average-RF), and (iv) better-off households with a farm size of 2.54 ha and owning almost 1 ha of farmland.

The farm household model (model 1) was used to analyse possible adoption behaviour of farmers (Chapter 3). Results show that each of the alternative technologies analysed in the current study is attractive for farmers, in comparison to current practices that are characterized by low yields and inefficient use of fertilizers and biocides, although adoption behaviour with respect to the alternative technologies is different for poor, average and better-off households. Simulations indicate IPM and HYR as the most attractive alternative technologies evaluated, with IPM giving the highest increase in income. The farm household model was used to evaluate the impact of relative price changes (10% increase and 10% decrease in fertilizer prices, 10% increase in biocide prices, 10% reduction in transaction costs and availability of low-cost credit) on technology choice and welfare of farm households. Availability of low-cost credit and a reduction in transaction costs (through improvements in infrastructure) are important determinants of farmer welfare, but have varying effects on technology adoption among different farm types.

Chapter 4 presents an approach for regional analysis that allows optimization of different goals of stakeholders, illustrated for the province of Ilocos Norte. Optimizing the different goals at the provincial scale (using model 6) shows the conflicts in pursuing economic and social goals. This analysis defines the ‘feasible area’ for the province, i.e., the outer limits of possibilities and the trade-offs in terms of income, food production and employment. The objective of maximizing provincial income conflicts with aims of food self-sufficiency and increased employment in agriculture. Maximum income is associated with a rice production level, 25% below the potential of the province and agricultural employment 15% below the potential.

Chapter 5 illustrates the use of a multi-scale method, enabling assessment of multi-purpose natural resource management options, using all six models. It presents an operational link between (sub-)regional land use optimization and farm household modelling in analysing land use options at farm, municipal and provincial scales. Results show that limited markets, inadequate infrastructure and resource endowments of farm households strongly affect resource use and goal achievement in Batac. Omission of these factors in resource use analysis results in so-called aggregation bias, i.e., generation of 'unrealistic' results, as a consequence of oversimplification of reality in the model. As the effects of these factors in the model are significant, ignoring them may result in misleading simulation results and, hence, policy conclusions. This implies that different model specifications result in different policy evaluations, associated with aggregation bias. Care, therefore, must be taken in selecting the appropriate model to use in policy evaluations. The aggregation bias resulting from assuming spatially invariable input and output prices is significant for Batac, where farm-to-market roads are of poor quality. This suggests potentially large benefits from improving infrastructure. Of the factors investigated, aggregate income in the municipality is most strongly affected by the marketing opportunities for some vegetables.

Differences in resource allocations resulting from prioritizing objectives at different levels reveal potential conflicts. Highest municipal income was associated with selection of crops that pose more risk to farmers; our farm household analysis shows that farmers tend to restrict the area of these crops. Similarly, provincial income is highest when resources in the province are allocated such that more of the staple crop rice and less of the highly profitable cash crops are cultivated in Batac, resulting in lower income for the municipality. Hence, food production aims of the province and economic objectives of the municipality are potentially in conflict.

The models presented in Chapter 5, with mathematical descriptions presented in Chapter 6, were used to assess the implications of agricultural policies on income, food production, resource use, and environmental indicators at the farm, municipal and provincial scales (Chapter 7). The policies evaluated were: (1) promotion of technological innovations, (2) attainment of food self-sufficiency, (3) price liberalization, (4) environmental protection, and (5) infrastructure development.

Analysis of the results reveals that technological innovations have potentially the strongest positive effect on income and rice production across all scales. These results suggest that investments in research and extension have potentials in raising income and attaining rice self-sufficiency aims (in the case of rice technologies). Food self-sufficiency goals can be realized, but conflict substantially with economic objectives. Liberalization of rice prices results in lower income for farmers, but benefits rice consumers as a result of lower rice prices. Improvements in and/or expansion of irrigation systems can contribute to increased rice production, however, at the expense of income. Volumetric water pricing results in more efficient water use at the farm and municipal scale, but again at the expense of income in the short-run. Many of these results seem trivial, but the model-based analyses result in quantitative estimates for the effects on the economic, agricultural and environmental dimensions of the problem.

The final chapter (Chapter 8) discusses methodological issues in land use analysis and summarizes important results from this study. The suitability of the various models for answering specific questions of stakeholders is evaluated.

It is concluded that model-based analyses can play a key role in participatory land use policy formulation. Results from the multi-scale approach presented in this thesis can provide valuable information for policy development and assessment. It is anticipated that this enhances transparent discussions among stakeholders on the implications of various objectives and priorities at different scales for resource use. This also allows ex-ante analysis of agricultural and natural resource use policies, including assessment of the potentials of new agro-technologies.

Samenvatting

De manier waarop land wordt gebruikt, wekt brede maatschappelijke interesse omdat een groeiend aantal (groepen) actoren zichzelf beschouwen als belanghebbenden in de besluitvormingsprocessen rond landgebruik. Nog altijd gebruikt de agrarische sector verreweg het grootste deel van de beschikbare grond, en in veel ontwikkelingslanden, waar landbouw de belangrijkste economische sector is, concentreren landgebruikproblemen zich rond agrarisch landgebruik. Binnen de agrarische sector worden zowel concurrerende aanspraken gemaakt op beperkte en vaak afnemende natuurlijke hulpbronnen, en hebben belanghebbenden op verschillende schaalniveaus (bedrijf, gemeentelijk, provinciaal, nationaal) conflicterende doelstellingen. Discussies over alternatief gebruik van hulpbronnen, prioriteiten van doelstellingen en de formulering en uitvoering van landbouwbeleid zouden veel baat hebben bij kwantitatieve schattingen van de economische, sociale en milieukundige baten en lasten die samenhangen met de verschillende alternatieven.

Het doel van dit onderzoek was de ontwikkeling en toepassing van een multischaal, modelmatige benadering die collectief leren, beleidsdiscussies en besluitvorming met betrekking tot agrarisch landgebruik kan ondersteunen. De benadering is, in samenwerking met belanghebbenden, uitgewerkt voor de provincie Ilocos Norte in het noordwesten van de Filippijnen en voor Batac, de dichtstbevolkte gemeente in die provincie.

De provincie heeft een oppervlak van 0,36 miljoen hectare, waarvan een derde voor landbouw wordt gebruikt. De economie is grotendeels gebaseerd op agrarische productie. De laaglanden worden intensief bebouwd, in de hooglanden en heuvelachtige gebieden is de landbouw extensiever. Gemiddeld valt er per jaar 2000 mm regen, waarvan 90% in het natte seizoen. De provincie telt 13 nationale en 649 lokale irrigatiestelsels. Deze zijn aangelegd door de Nationale Irrigatie Administratie (NIA) en hebben een totaal oppervlak van 35.461 hectare. Door gebrek aan water en door inefficiënties in het systeem wordt slechts een deel van die oppervlakte van irrigatiewater voorzien: 80% tijdens het natte seizoen en 40% tijdens het droge seizoen. Aanvullend op deze irrigatiestelsels bezitten veel boeren pompen waarmee, vooral tijdens het droge seizoen, grondwater wordt opgepompt. Rijst is het belangrijkste gewas in alle gewasrotaties. Tijdens het natte seizoen (juni - oktober) verbouwt men vrijwel alleen rijst, in het droge seizoen worden er daarnaast andere gewassen verbouwd zoals tomaat, knoflook, ui, paprika en mungboon (*Vigna radiata*). De provincie telt 23 administratieve eenheden: 22 gemeentes en 1 stad. De gemeentes zijn onderverdeeld in 557 dorpen, ook wel barangays genoemd. De totale bevolking in

2000 was 514.000 en de gemiddelde jaarlijkse bevolkingsgroei is 1,3%. Van de totale bevolking behoort 61% tot de beroepsbevolking. Het grondbezit is versnipperd: gemiddeld bebouwt een agrarisch huishouden vier percelen van 0,4 hectare.

De gemeente Batac ligt 15 kilometer ten zuiden van de provinciehoofdstad Laoag City en 472 kilometer ten noorden van Manilla. In de gemeente liggen 43 dorpen, waarvan er 29 geclassificeerd worden als plattelandsdorpen. In 2000 woonden er ongeveer 48 duizend mensen, gemiddeld drie per hectare. De gemiddelde bevolkingsgroei over de periode 1995 - 2000 was met 0,9% lager dan het provinciale gemiddelde. De gemeente heeft een oppervlakte van 16 duizend hectare, waarvan tweederde in gebruik is voor landbouw, vooral rijst. Het landgebruik is representatief voor de gehele provincie; in het natte seizoen (juni - oktober) wordt overwegend rijst verbouwd, in het droge seizoen daarnaast een heel scala aan andere gewassen. In het droge seizoen wordt in aanvulling op andere bronnen grondwater gebruikt voor irrigatie.

De hoofdproblemen voor de landbouwsector in Ilocos Norte zijn volgens de betrokkenen de lage productiviteit en de lage inkomens. Als oorzaken worden genoemd de beperkte hoeveelheid irrigatiewater, de hoge kosten van externe inputs, lage prijzen die de boeren ontvangen, slecht functionerende markten, hoge transactiekosten, lage mechanisatiegraad, gebrek aan faciliteiten voor opslag en verwerking van producten en beperkte toegang tot verbeterde technologieën.

In Hoofdstuk 2 worden de in het onderzoek gebruikte gegevens beschreven. Het geeft een overzicht van de (soms tegenstrijdige) opvattingen van belanghebbenden op drie schaalniveaus: het bedrijfsniveau, het gemeentelijk niveau (Batac) en het provinciaal niveau (Ilocos Norte). In dit hoofdstuk worden de huidige landbouwpraktijk en voorgestelde alternatieve technologieën beschreven: hybride rijst (HYR), gebalanceerde bemestingsstrategieën (BFS) voor rijst en maïs, precisie nutriëntenbeheer (SSNM, voor rijst alleen en voor alle overige gewassen) en geïntegreerde gewasbescherming (IPM).

Voor de verschillende schaalniveaus zijn zes optimaliseringsmodellen ontwikkeld:

1. Een model op bedrijfsniveau voor de vier belangrijkste bedrijfstypes in Batac;
2. Een model op gemeentelijk niveau voor Batac, gebaseerd op representatieve bedrijven, met differentiatie in infrastructuur en beperkte afzetmogelijkheden;
3. Een model op gemeentelijk niveau voor Batac, gebaseerd op representatieve bedrijven met differentiatie in infrastructuur;
4. Een model op gemeentelijk niveau voor Batac gebaseerd op representatieve bedrijven;
5. Een geaggregeerd model voor Batac; en
6. Een geaggregeerd model voor Ilocos Norte.

In alle modellen wordt een doelstelling geoptimaliseerd, met inachtneming van een set van beperkingen. Die beperkingen hebben betrekking op beschikbaarheid van hulpbronnen en consumptiebehoeften. Productieactiviteiten worden gedefinieerd met behulp van TechnoGIN, een technische coëfficiënten generator, die empirische gegevens met productie-ecologische kennis en expert kennis integreert om efficiëntie van inputgebruik te berekenen.

In Hoofdstuk 3 worden bedrijfstypes geclassificeerd op basis van een clusteranalyse van data uit interviews in 2001 onder 150 agrarische huishoudens uit 28 dorpen in Batac. De bedrijfsclassificatie is gebaseerd op bedrijfsgrootte, kwaliteit en eigendomsrecht van de beschikbare grond, arbeidsbeschikbaarheid binnen de huishouding en waarde van bezittingen. De clusteranalyse resulteerde in vier bedrijfstypes: (i) arme huishoudens met een bedrijf van 0,85 ha, waarvan een-derde eigen bezit (de rest wordt gepacht); (ii) modale huishoudens met 0,95 ha; voor het grootste deel met voorzieningen voor irrigatie (modaal IR); (iii) modale huishoudens met 0,91 ha, waarvan het grootste deel zonder irrigatiefaciliteiten en de helft in hoger gelegen gebieden (modaal RF); en (iv) welgestelde huishoudens met 2,54 ha waarvan ongeveer 1 ha in eigen bezit.

Het bedrijfmodel (model 1) is gebruikt om mogelijk gedrag van boeren met betrekking tot acceptatie van nieuwe technologieën te analyseren (Hoofdstuk 3). De resultaten tonen dat alle in Hoofdstuk 2 beschreven alternatieve technologieën aantrekkelijk zijn in vergelijking met de huidige praktijk die gekenmerkt wordt door lage opbrengsten en lage efficiëntie. Overigens treden er wel verschillen op in gedrag tussen de vier bedrijfstypes. Volgens de simulaties zijn IPM en HYR de meest aantrekkelijke alternatieve technologieën, waarbij IPM tot de grootste inkomensstijging zou leiden. Vervolgens is het model gebruikt om de gevolgen van veranderingen in prijzen voor technologiekeuze en welzijn van huishoudens te analyseren. Daarbij is gekeken naar de gevolgen van een 10% stijging en 10% daling van kunstmestprijzen, 10% stijging in prijzen van bestrijdingsmiddelen, 10% daling in transactiekosten en de beschikbaarheid van goedkoop krediet. De beschikbaarheid van goedkoop krediet en de hoogte van de transactiekosten (door verbeterde infrastructuur) zijn belangrijke bepalende factoren voor het welzijn van agrarische bedrijven. Het effect van prijsveranderingen verschilt tussen de vier bedrijfstypes.

In Hoofdstuk 4 wordt een benadering gepresenteerd voor een regionale verkenning waarin verschillende doelen van belanghebbenden geoptimaliseerd kunnen worden (Meervoudige Doelprogrammering). De benadering wordt geïllustreerd aan de hand van de provincie Ilocos Norte. Door het optimaliseren van verschillende doelstellingen op provinciaal niveau (m.b.v. model 6) komen mogelijke conflicten tussen maatschappelijke en economische doelen aan het licht. Duidelijk wordt wat haalbaar is (de ‘grootte van het speelveld’ wordt gedefinieerd, dus de ultieme mogelijkheden) en wat de uitruilwaarden zijn tussen inkomen, voedselproductie en werkgelegenheid. Maximaliseren van inkomen gaat ten koste van doelen als voedselzekerheid en werkgelegenheid in de landbouw. Bij het maximale inkomen is de rijstproductie 25% lager dan het potentieel haalbare niveau en is de werkgelegenheid in de landbouw 15% lager dan wat potentieel haalbaar is.

In Hoofdstuk 5 wordt een multi-schaal methode gepresenteerd waarin alle zes de modellen gebruikt worden. Daarmee wordt een brug geslagen tussen modellering van landgebruik op (sub-) regionaal niveau en modellering van bedrijfshuishoudens bij het analyseren van landgebruikopties op drie schaalniveaus: bedrijf, gemeente en provincie. Resultaten van de analyses laten zien dat het gebruik van natuurlijke hulpbronnen en de mate waarin verschillende doelen kunnen worden gerealiseerd in Batac in sterke mate worden bepaald door beperkte afzetmogelijkheden, inadequate infrastructuur en de beschikbaarheid van hulpbronnen. Wanneer deze beperkende factoren niet in de analyse worden meegenomen produceert het model onrealistische resultaten, het model is dan een te sterk vereenvoudigde weergave van de werkelijkheid. Het niet in de (model)beschouwing betrekken van deze factoren kan serieuze gevolgen hebben wanneer modelresultaten worden doorvertaald naar beleid. Door de gebrekkige kwaliteit van de wegen tussen bedrijven en afzetmarkten bestaan er aanzienlijke ruimtelijke verschillen in factoren zoals prijzen van inputs en outputs. Dit suggereert dat grote voordelen zijn te behalen door verbetering van deze infrastructuur. De resultaten laten tevens zien dat het inkomen op gemeentelijk niveau sterk wordt bepaald door de mogelijkheden om bepaalde groenten te vermarkten.

Op verschillende schaalniveaus en door verschillende belanghebbenden worden uiteenlopende prioriteiten gesteld. Met de in Hoofdstuk 5 gepresenteerde methode wordt duidelijk waar mogelijk belangentegenstellingen ontstaan. Realiseren van het hoogst haalbare inkomen op gemeentelijk niveau vereist dat boeren meer risicovolle gewassen verbouwen; de analyse op bedrijfsniveau laat zien dat boeren geneigd zijn de oppervlakte van deze gewassen te beperken. Vanuit provinciaal oogpunt gezien zou het, in verband met voedselzekerheid, gunstig zijn als in Batac veel rijst verbouwd wordt en minder van de hoog-salderende gewassen zoals groenten. Dat landgebruikspatroon is echter in strijd met economische doelstellingen op gemeentelijk niveau (Batac), want andere gewassen zijn winstgevender dan rijst.

De multi-schaal methode die in Hoofdstuk 5 wordt gepresenteerd, en waarvan de wiskundige formulering in Hoofdstuk 6 wordt gegeven, is in Hoofdstuk 7 gebruikt om de gevolgen van agrarisch en milieubeleid te analyseren. Voor de drie schaalniveaus werden de effecten geëvalueerd op inkomen, voedselproductie, gebruik van natuurlijke hulpbronnen en milieu-indicatoren. Vijf beleidsdoelstellingen/maatregelen zijn geëvalueerd: (1) het bevorderen van technologische innovaties, (2) het veiligstellen van zelfvoorziening in voedselproductie, (3) liberalisering van prijzen, (4) milieubescherming en (5) ontwikkeling van infrastructuur.

De resultaten tonen aan dat technologische innovatie het grootste potentiële, positieve effect heeft op inkomen en rijstproductie, op alle schaalniveaus. Dat suggereert dat investeringen in onderzoek en voorlichting perspectief bieden op inkomensstijging en zelfvoorziening in rijst. Zelfvoorzienend worden in voedsel is haalbaar, maar economisch gezien ongunstig. Liberalisering van de prijs van rijst resulteert in lagere prijzen, wat ongunstig is voor producenten en gunstig voor consumenten. Verbetering en/of uitbreiding van irrigatiestelsels maakt een hogere rijstproductie mogelijk, waarbij weer de kanttekening geplaatst moet worden dat rijst relatief een minder rendabel gewas is. Invoering van een maatregel waarbij de kosten voor waterverbruik voor de boer worden gebaseerd op het gebruikte volume, leidt tot verbetering van de efficiëntie van watergebruik zowel op bedrijfs- als op gemeentelijke schaal, maar gaat ten koste van het inkomen op beide niveaus. Een deel van de modeluitkomsten lijkt vanzelfsprekend. Het voordeel van het gebruik van de modellen is echter dat daarmee kwantitatieve uitspraken kunnen worden gedaan over economische, landbouwkundige en milieukundige indicatoren.

In het laatste hoofdstuk (Hoofdstuk 8) worden methodologische aspecten van landgebruikstudies besproken en de belangrijkste uitkomsten uit dit proefschrift samengevat. Er wordt ingegaan op de bruikbaarheid van verschillende typen modellen voor de beantwoording van specifieke vragen van belanghebbenden.

De conclusie is dat modelanalyses een sleutelrol kunnen spelen in participatieve procedures voor formulering van beleid met betrekking tot landgebruik. De multi-schaal benadering, ontwikkeld in dit proefschrift, maakt het mogelijk om simultaan, landgebruik op verschillende schaalniveaus te analyseren, belangentegenstellingen tussen doelstellingen op verschillende schaalniveaus expliciet te maken en effecten van beleidsmaatregelen te kwantificeren. Er mag daarom worden verwacht dat de benadering een bijdrage kan leveren aan transparante discussies tussen belanghebbenden en derhalve kan bijdragen aan formulering van beter en breder gedragen beleid.

Kabuuran

Ang paraan ng paggamit sa lupa ay naging isang malawakang paksang panlipunan dahil sa marami na ang mga taong nais sumali sa pagdedesisyon sa mga bagay na ito bilang mamumuhunan. Ang agrikultura ang pinakamalaking sektor na gumagamit ng lupa, at sa maraming papaunlad na bansa, na ang pagsasaka ay isang mahalagang sektor sa ekonomiya, ang mga usapin tungkol sa paggamit ng lupa ay nakapokus sa paggamit ng lupang pansaka. Kahit sa mismong sektor ng agrikultura, marami ring naglalaban-laban sa pag-angkin sa limitado at unti-unting nawawalang yaman o kakayahan, at marami rin ang mga nagtatagisang layunin ng mga namumuhunan sa iba't-ibang antas (bukid, bayan, lalawigan, bansa). Ang mga talakayan tungkol sa mga alternatibong paggamit ng likas na yaman, pag-uuna-una sa tutunguhin o tatahakin, at paggawa at pagpapatupad ng mga patakaran o polisiya, gamit ang isang paraang nakikilahok ang lahat sa pagsusuri, ay makatutulong sa pagtaya ng mga benepisyong may kinalaman sa pangkabuhayan, panlipunan, at pangkapaligiran na kaakibat ng iba't-ibang pagpipilian.

Ang pag-aaral na ito ay naglalayong makalikha at maisakatuparan ang isang kaparaanan na sangkot ang maraming antas at nakabase sa isang modelo, na siyang magdadala ng sama-samang pagtatamo ng kaalaman, pagtalakay ng polisiya, at pagpapasiya tungkol sa paggamit ng lupang pansaka. Ang naturang paraan ay isasakatuparan, nang may pagkokonsulta sa mga mamumuhunan, sa lalawigan ng Ilocos Norte sa hilagang kanluran ng Pilipinas, at sa kanyang pinakamataong bayan, ang munisipyo ng Batac.

Ang probinsiyang ito ay may lawak na 0.36 milyong ektarya, at ang ikatlong bahagdan nito ay lupang pansakahan. Ang produksiyong agrikultura ay makikilala sa mga sistemang nakabatay sa palay. Ang palay ay itinatanim sa panahon ng tag-ulan (Hunyo hanggang Oktubre); sa tag-araw, may mga iba pang pananim na kasabay ang palay tulad ng kamatis, bawang, sibuyas, sili, tabako, at munggo. May 23 yunit ng pangangasiwa sa probinsiya: 22 bayan at 1 lungsod, at ito ay nahahati sa 557 barangay o kanayunan. Ang populasyon noong 2000 ay 514 libo; ang pamantayang bilis ng paglaki kada taon ay 1.3%.

Ang bayan ng Batac ay may layong 15 kilometro mula sa siyudad ng Laoag, na siyang kabisera ng probinsiya. Ito ay may layong 472 kilometro mula sa Maynila. Ang Batac ay may 43 nayon, ang 29 nito ay tinatawag na rural o pangkabukiran. Ito ay may populasyong 48 libo, karaniwang tatlong tao sa isang ektarya (2000). Ang bilis ng paglago ng populasyon mula 1995 hanggang 2000 ay 0.9% na mas mababa kaysa sa probinsiya. Ito ay may lawak na 16 libong ektarya; dalawang-ikatlo nito ay lupang pansakahan, na halos lahat ay nakasalalay sa palay. Ang paggamit ng lupa sa bayan ay katulad din ng sa buong lalawigan.

Ang mga pangunahing suliranin sa sektor ng pagbubukid, na inilahad ng mga mamumuhunan, ay kaugnay sa mababang produksiyon o ani at sa maliit na kita. Ang mga nagiging sanhi nito ay kakulangan sa patubig, mataas na presyo ng mga gamit para sa bukid, at mababang presyo ng produkto na kaakibat ng hindi magandang takbo ng pamilihan at mataas na gugol sa mga transaksiyon, limitadong puhunan, mababang antas ng paggamit ng mga makinarya, kawalan ng mga gamit para sa pagproseso at pag-iimbak ng mga inani, at limitadong kakayahan na makinabang sa mga pinahusay na teknolohiya.

Ang ikalawang kabanata ay naglalaman ng mga batayan na kung saan hinango ang iba't-ibang mga modelong pamamaraan na pangmaramihang antas. Ito ay nagbibigay ng isang panlahatang pagtingin sa mga nagsasalungatang kurukuro at pagpansin ng mga namumuhunan sa antas ng bukid, bayan, at lalawigan. Inilalarawan rin dito ang mga karaniwang gawaing pambukid at ang mga ipinapanukalang alternatibong teknolohiya tulad ng produksiyon ng palay na haybrid (HYR), estratehiya sa balanseng pagpapataba ng lupa (BFS) para sa palay at mais, pamamahala ng sustansiya para sa halaman na ayon sa aktuwal na lugar ng taniman (SSNM, para sa palay at iba pang pananim), at ang pinagsamasamang pamamaraan ng pamamahala ng peste sa ligtas at matipid na paraan (IPM).

Ang modelo para sa sambahayang pambukid ay ginamit upang malaman ang posibleng ikikilos ng mga magsasaka hinggil sa paggamit ng makabagong teknolohiya. (Kabanata 3). Ang kinalabasan ng pag-aaral ay nagpakita na gusto ng mga magsasaka ang bawa't alternatibong teknolohiya na sinuri kumpara sa dati nilang sinusunod, na nagbibigay lang ng mababang ani at di-mabisang gamit ng pataba at pamuksa ng peste. Ang paggamit ng teknolohiya ay nag-iiba-iba, depende sa kung ang sambahayan ay mahirap, karaniwan, o nakakaluwag. Ang mga pagtutulad ay nagsabi na ang mga teknolohiya na may pangunahing atraksiyon ay ang HYR at IPM. Ang IPM ang nagbigay ng pinakamalaking kita.

Sa Kabanata 4 ay mababasa ang isang paraan ng pagsusuring pangrehiyon na nagtutulot na matukoy ang pinakamabentaheng hangarin ng mga namumuhunan at iyon ay ginawa para sa probinsiya ng Ilocos Norte. Ang pagsusuri sa kung ano ang pinakamainam na layunin sa antas-pamprobinsiya ay nagpakita ng mga tunggalian sa pagtataguyod ng mga hangaring pangkabuhayan at panlipunan.

Sa Kabanata 5, isang paraan na may maramihang antas ang ginamit upang matantiya ang iba't-ibang pamimilian para maipatupad ang isang maayos na pamamahala ng likas na yaman. Ipinakita nito ang ugnayan sa pagitan ng paghanap ng mabentaheng paggamit ng lupa at ng pagmomodelo ng sambahayang pambukid upang masuri ang pinakamagaling na paggamit sa lupa sa lahat ng antas (bukid, bayan, at lalawigan). Ang mga resultang nakuha para sa Batac ay nagsaad na may mga bagay na nakakaapekto sa paggamit ng likas na yaman at pagtatagumpay na makuha ang layunin: natatakdaang pamilihan, kakulangan sa imprastruktura, at yaman o ari-ariang angkin ng mga sambahayang pambukid. Ang hindi pagsasama sa mga bagay na ito sa pagsusuri ng paggamit ng likas na yaman ay nagbubunga ng 'pagkiling na pangkalahatan' – ito ay nagbibigay ng hindi makatotohanang resulta sanhi ng kapayakan o kasimplihan na ginamit ng modelo upang ilarawan ang tunay na buhay. Dahil ang epekto ng mga bagay na ito ay mahalaga, ang hindi pagpansin o pagsasama sa mga ito sa modelo ay magdudulot ng nakapagliligaw na kinalabasan, at tuloy, maling polisiya. Ang ibig sabihin nito ay ang paiba-ibang pagpapaliwanag sa modelo ay magiging sanhi ng paiba-ibang pagtaya sa mga polisiya. Dapat maging maingat sa pagpili ng naaayong modelo para gamitin sa pag-aaral ng mga patakaran. Ang nabanggit na bayas o pagkiling ay nagmumula sa pagpapalagay na hindi nagbabago ang presyo ng mga gamit o produkto sa bukid, at ito ay mahalaga sa kaso ng Batac, kung saan ang mga daan mula sa bukid hanggang sa pamilihan ay hindi maayos. Maraming magagandang benepisyo ang makakamit kung aayusin ang mga daang ito at iba pang imprastruktura. Sa mga bagay na inimbestiga, ang pangkalahatang kita ng munisipyo ang siyang pinakaapektado ng mga oportunidad sa pagbebenta ng ilang gulay.

Ang pagkakaiba-iba sa pagtotoka ng mga yaman na galing sa pag-uuna-una ng mga layunin sa iba-ibang antas ay nagpapakita ng posibleng labanan. Ang pinakamataas na kita ng bayan ay kaakibat ng mga pananim na nagbibigay ng malaking panganib sa mga magsasaka; ang aming pagsusuri ng sambahayang pambukid ay nagsasabi na nilimitahan nila ang sukat ng lupa para sa mga pananim na ito. Gayundin naman, ang kita ng probinsiya ay pinakamalaki kung gagastahan ang pagtatanim ng palay kumpara sa mga pananim na madaling maibenta sa palengke; ito ay magdudulot ng mas maliit na kita sa munisipyo. Kung kaya, ang layunin ng lalawigan na makapagdulot ng sapat na produksiyon ng pagkain at ang mga layuning pangkabuhayan ng mga bayan ay hindi magkatugma.

Ang mga modelo na inilahad sa Kabanata 5, na mayroong pagpapaliwanag-matematiko sa Kabanata 6, ay ginamit upang tantiyahin ang mga implikasyon ng polisiyang pangsakahan sa kita, produksiyon ng pagkain, paggamit ng likas na yaman, at mga palatandaang pangkalikasan sa antas ng bukid, bayan, at lalawigan (Kabanata 7). Ang mga polisiyang pinag-aralan ay may kinalaman sa mga sumusunod: 1) pagtataguyod ng mga kabaguhan sa teknolohiya, 2) pagtatamo ng sariling kasapatan sa pagkain, 3) liberalisasyon sa presyo, 4) pagkalinga sa kapaligiran, at 5) pagpapaunlad ng imprastruktura.

Sa pag-aanalisa ng mga resulta, makikita na ang mga pagbabagong teknolohiya ang may pinakamalakas at positibong epekto sa kita at produksiyon ng palay sa lahat ng antas. Ang pamumuhunan sa pananaliksik at pagpapakalat ng kaalaman (tungkol sa palay) ay maaaring magpalaki ng kita at makatulong sa pagkakaroon ng sapat na bigas. Ang layuning magkaroon ng sapat na pagkain ay maaaring matamo, nguni't ito ay taliwas sa mga hangaring pangkabuhayan. Ang liberalisasyon sa presyo ay masama para sa mga magsasaka pero mabuti sa mga mamimili dahil sa mas mababang presyo. Ang pagpapaayos at pagpapalawak ng patubig ay magpapalaki ng ani ng palay, subali't mababawasan ang kita. Ang pagpepresyo sa patubig base sa dami ng nagamit ay magbubunga ng mas episyenteng paggamit ng tubig sa mga bukid at mga bayan, nguni't muli, liliit ang kita sa madaling panahon. Ang mga bagay na ito ay mukhang walang kuwenta, nguni't ang analisis na batay sa modelo ay magbibigay ng mga maramihang pagtaya ng epekto sa aspetong pangkabuhayan, pang-agrikultura, at pangkapaligiran.

Ang huling kabanata (Kabanata 8) ay tumatalakay sa mga isyu ng kaparaanan sa pagsusuri ng paggamit ng lupa at ibinibigay ang kabuuran ng mga mahahalagang kinalabasan ng pag-aaral na ito. Ang kaangkupan ng iba-ibang modelo para matugunan ang mga partikular na katanungan ng mga namumuhunan ay pinag-aralan.

Ipinalalagay na ang pagsusuri base sa modelo ay may mahalagang ginagampanan sa paggawa ng polisiya tungkol sa paggamit ng lupa na kalahok ang lahat ng apektado. Ang mga resulta na nakuha sa paraang tinalakay sa tesis na ito ay magbibigay ng makabuluhang impormasyon para sa pagbubuo at paghahalaga sa mga polisiya. Inaasahang ito ay magsisilbing susi upang matalakay nang maliwanag ang mga layunin at mga karapatang mauna sa iba't-ibang antas ng paggamit ng likas na yaman. Ito ay nagpapahintulot sa pagsusuri base sa prediksiyon ng mga polisiya na may kinalaman sa pagsasaka at sa paggamit ng yaman, kasali na ang pagtantiya sa magiging halaga ng mga bagong teknolohiya sa agrikultura.

APPENDICES

Interaction with stakeholders 1997-2004

SysNet Consultative workshop

January 23, 1997, Mariano Marcos State University (MMSU), Batac, Ilocos Norte.

Level/Name	Office	Function
Province		
Angelita R Sabas	Department of Agriculture (Ilocos Norte)	Senior Agriculturist and Officer-in-Charge (OIC) Provincial Agriculturist
Percibal Libed	Department of Agriculture (Ilocos Norte)	Land Use Specialist
Others		
Elias L. Calacal	Mariano Marcos State University (MMSU)	President
Rodolfo A. Natividad	MMSU	Vice President for Research and Extension
Heraldo L Lavaoen	MMSU	Dean, College of Agriculture and Forestry
Stanley C. Malab	MMSU	Director for Research
Charito G Acosta	MMSU	Associate Professor
Epifania O. Agustin	MMSU	Associate Professor
Lori L. de Castro	MMSU	Associate Professor
Victoria R Domingo	MMSU	Agricultural Economist
Marilou P. Lucas	MMSU	Assistant Professor
Teresita F Marcos	MMSU	Key site Coordinator, Rainfed Lowland Rice Research Consortium (RLRRC)
Meriam E. Pascua	MMSU	Professor
Sixto R. Pascua	MMSU	Professor
Carlos M Pascual	MMSU	Associate Professor

SysNet stakeholder-scientist workshop

January 16, 1998, MMSU, Batac, Ilocos Norte.

Level/Name	Office
Region	
Leonardo A. Quintos	National Economic and Development Authority (NEDA) - Region I
Province	
Pedro Agcaoili	Ilocos Norte Provincial Development Office
Francisco Pilar	Department of Agriculture – Ilocos Norte
Percibal Libed	Department of Agriculture – Ilocos Norte
Municipality	
Rudy Opelac	Municipal Planning and Development Coordinator (MPDC) - Batac
Joselito Cabang	MPDC - Solsona
Alma Apanapao	MPDC - Pasuquin
Elmer Castro	Municipal Agriculture Office (MAO)-Badoc municipality
Francisco Agulay	MAO - Solsona
Rufina Ballesteros	MAO/MPDC
Veronic Coloma	MAO/MPDC
Robert R. Flor	MAO/MPDC
John Ladera	MAO/MPDC
Norma Lagmay	MAO/MPDC
Marilyn Martin	MAO/MPDC
Alphonsus Rigonan	MAO/MPDC
Rolando Rigonan	MAO/MPDC
Silvestre Tabancay	MAO/MPDC
Erdio E. Valenzuela	MAO/MPDC
Farm	
Celedonio Fernando	Farmer leader
Percibal Rebucal	Farmer leader
Benjamin Gudoy	Farmer leader
Paciencio Alviar	Farmer leader
Vitory Cacayorin	Farmer leader
Rodrigo Tuvera	Farmer leader
Others	
Noel Ganatosi	Cotton Research and Development Institute (CRDI)
Eugenio D. Orpia	CRDI
Nellie Castro	National Tobacco Authority (NTA)
Ambrocio P. Gandeza	NTA
Epifania Agustin	MMSU
Charito Acosta	MMSU
Elias L. Calacal	MMSU
Lori L. de Castro	MMSU
Evangeline Galagac	MMSU
Heraldo L. Layaoen	MMSU
Marilou P. Lucas	MMSU
Stanley C. Malab	MMSU
Teresita Marcos	MMSU
Rodolfo A. Natividad	MMSU
Veneranda Q. Otilas	MMSU
Meriam Pascua	MMSU
Sixto R. Pascua	MMSU
Carlos M. Pascual	MMSU

SysNet stakeholder-scientist workshop

May 7, 1999, MMSU, Batac, Ilocos Norte.

Level/Name	Office	Function
Province		
Pedro Agcaoili, Jr.	Provincial Planning and Development Office (PPDO)	Provincial Development Officer (PDO) III
Mercedes Ramos	PPDO	PDO II
Percival Libed, Jr.	Office of the Provincial Agriculturist (OPAG)	Planning Officer II
Municipality		
Camilo Eda	Municipal Planning and Development Office (MPDO)-Bacarra	Municipal Planning and Development Coordinator (MPDC)
Francis Calapini	MPDO-Burgos	MPDC
Jorge Batugal	MPDO-Nueva Era	MPDC
Nestor Hurtado	MPDO-Paoay	MPDC
Sharon Gonzales	MPDO-Pasuquin	MPDC
Alma Apanapao	MPDO-Pasuquin	Eco-researcher
Romulo Hilario	MPDO-Piddig	MPDC
Josita Coloma	MPDO-Pinili	MPDC
Edna Tolentino	MPDO-San Nicolas	MPDC
Joselito Cabang	MPDO-Solsona	MPDC
Placido Cascoupo	Municipal Agriculture Office (MAO)-Adams municipality	Municipal Agriculture Officer (MAO)
Elmer Castro	MAO-Badoc	MAO
Merryline Gappi	MAO-Batac	MAO
Astrophel Caliva	MAO-Burgos	MAO
Wilson Quigao	MAO-Carasi	MAO
Cesar Derrada	MAO-Dingras	MAO Officer in charge (OIC)
Noel Salvatierra	MAO-Dingras	Agricultural technician (AT)
Hermelina Domingo	MAO-Laoag City	AT and OIC MAO
Felicissimo Maulit	MAO-Nueva Era	MAO
Milagros Abara	MAO-Pagudpud	MAO
Dolores Yadao	MAO-Paoay	MAO
Lilia Taylan	MAO-Pasuquin	MAO
Agripino Abara	MAO-Pidig	MAO
Christina Valbuena	MAO-Pinli	MAO
Adelaida Coloma	MAO-Pinili	AT
Nida Alban	MAO-Pinili	AT
Lydia Ganir	MAO-San Nicolas	AT
Ernesto Paquibitan	MAO-San Nicolas	AT
Violeta Sarabac	MAO-Sarrat	MAO
Franscisco Agulay	MAO-Solsona	MAO
Generosa Blas	MAO-Vintar	OIC MAO
Others		
Carlos Pascual	Mariano Marcos State University (MMSU)	SysNet-MMSU team leader
Other SysNet-MMSU team members		

International Symposium: Systems Research for Optimizing Future Land Use

October 11-13, 1999, International Rice Research Institute (IRRI), Los Baños, Laguna.

Level/Name[a]	Office	Function
Province		
Ferdinand Marcos Jr.	Province of Ilocos Norte	Governor
Pedro Agcaoili, Jr.	PPDO	PDO
Francisco Pilar	OPAG	Provincial Agriculturist
Municipality		
Dolores Yadao	MAO-Paoay	MAO
Agripino Abara	MAO-Piddig	MAO
Others		
Carlos Pascual	MMSU	SysNet-MMSU team leader
Teresita Marcos	MMSU	SysNet-MMSU team member
Heraldo Layaoen	MMSU	

[a] Participants came from different countries (India, Malaysia, Philippines and Vietnam). Only stakeholders from Ilocos Norte are included in this list.

Final SysNet stakeholder-scientist workshop for Ilocos Norte

May 2000, Provincial Capitol, Laoag City, Ilocos Norte.

Level/Name[a]	Office	Function
Province		
Ferdinand Marcos Jr.	Provincial Capitol	Governor
Pedro Agcaoili, Jr.	PPDO	PDO III
Mercedes Ramos	PPDO	PDO II
Archie Sarabia	Provincial Capitol	Governor's adviser on agricultural programmes
Municipality		
Merryline Gappi	MAO	MAO
Rudy Opelac	MPDO	MPDC
Others		
Carlos Pascual	MMSU	SysNet-MMSU team leader
SysNet-MMSU team members		

[a] List of participants is incomplete.

Farm survey

June 10-16 and July 1-15, 2001, Batac, Ilocos Norte.

Level/Name	Office	Function
Municipality		
Manama Aganon	MAO-Batac	AT and OIC MAO and ATs assigned to rural villages
Farm		
150 farmers		Farmers from 28 rural villages in Batac

Individual meetings to interview farmers, planners, line agency heads and policy makers in Batac and provincial offices in Ilocos Norte about their perceptions on important natural resource management issues in Ilocos Norte.

May 28 to June 6, 2002, Ilocos Norte

Level/Name	Office	Function
Province		
Pedro Agcaoili, Jr.	PPDO	PDO III
Percival Libed, Jr.	OPAG	Planning Officer II
Arsenio Sandi	Provincial Environment and Natural Resources Office (PENRO)	Forest Management Specialist and Community-Based Forestry Management Coordinator
Pete Labuni	National Irrigation Admistration (NIA) Provincial Office	Senior Irrigation Engineer
Danny Tolentino	NIA Provincial Office	Institutional Development Officer
Municipality		
Jesus Nalupta	Municipality of Batac	Mayor
Merryline Gappi	MAO-Batac	MAO
Manama Aganon	MAO-Batac	AT
Nelia Atuan	MAO-Batac	AT
Erlinda Cabuyadao	MAO-Batac	AT
Premelia Castro	MAO-Batac	AT
Nelson Diculen	MAO-Batac	AT
Guadalope Dutdut	MAO-Batac	AT
Osmundo Pastor	MAO-Batac	AT
Robert Pungtilan	MAO-Batac	AT
Adelaida Quigao	MAO-Batac	AT
Edgar Raquel	MAO-Batac	AT
Nora Nida Rigonan	MAO-Batac	AT
Carmelita Tallon	MAO-Batac	AT
Rudy Opelac	MPDO	MPDC
Norma de Jesus	Municipal Agrarian Reform	Agrarian Reform Officer
Farm		
Inocensio Icuspit		Farmer, Brgy. Baay
Agripina Pambid		Farmer, Brgy. Baay
Nestor Pambid		Farmer, Brgy. Baay
Adolfo Pijera		Farmer, Brgy. Baay
Restituto Caluya		Farmer, Brgy. Colo
Amor Galacgac		Farmer, Brgy. Colo
Alex Pungtilan		Farmer, Brgy. Colo
Gregorio Puyaoan		Farmer, Brgy. Colo
Hernando Puyaoan		Farmer, Brgy. Colo
Others		
Epifania Agustin	MMSU	MMSU Director for Research and IRMLA-Philippine team leader

Individual meetings to verify assumptions made in the farm household model and to some extent check the plausibility of initial model results (with Xiang Bi and Willy Pradel, MSc students from WUR).

October 19-24 2002, Batac, Ilocos Norte.

Level/Name	Office	Function
Municipality		
Merryline Gappi	MAO-Batac	MAO
Manama Aganon	MAO-Batac	AT
Nelson Diculen	MAO-Batac	AT
Guadalope Dutdut	MAO-Batac	AT
Osmundo Pastor	MAO-Batac	AT
Robert Pungtilan	MAO-Batac	AT
Adelaida Quigao	MAO-Batac	AT
Edgar Raquel	MAO-Batac	AT
Carmelita Tallon	MAO-Batac	AT
Crispin Mangabat	MAO-Batac	AT
Farm		
Neil Duldulao		Farmer, Brgy. Baay
Celso Villanueva		Farmer, Brgy. Baay
Fortunato Lipsut		Farmer, Brgy. Tabug
Rogelio Rosales		Farmer, Brgy. Tabug
Roberto Rosario		Farmer, Brgy. Tabug

IRMLA stakeholder-scientist workshop

April 7, 2003, MMSU, Batac, Ilocos Norte.

Level/Name	Office	Function
Province		
Pedro Agcaoili, Jr.	PPDO	Provincial Planning and Development Officer
Jesse Anthony Barut	PPDO	Provincial Planning Assistant
Alberto Blas	PPDO	Provincial Planning Assistant
Percibal Libed, Jr.	OPAG	Planning Officer
Municipality		
Jesse Mata	MPDO-Batac	MPDC
Merryline Gappi	MAO-Batac	MAO
Manama Aganon	MAO-Batac	AT
Nelson Diculen	MAO-Batac	AT
Guadalope Dutdut	MAO-Batac	AT
Adelaida Quigao	MAO-Batac	AT
Nora Nida Rigonan	MAO-Batac	AT
Samson Lopez	Municipal Agriculture and Fisheries Council (MAFC)	MAFC member
Noel Salvatierra	MPDO-Dingras	MPDC
Cesar Derrada	MAO -Dingras	MAO
Cornelio Balbesina	MAO-Dingras	AT
Dolores Garcia	MAO-Dingras	AT
Danilo Soriano	MAO-Dingras	AT
Farm		
Elorder Alcoy	MAFC-Batac	Farmer leader and MAFC member, Batac
Julian Basamot		Farmer leader, Batac
Jesus Arnel Garcia	NGO	Farmer leader, Batac
William Calaranan		Farmer leader, Dingras
Domingo Felipe		Farmer leader, Dingras
Jimmy Valencia	MAFC-Dingras	Farmer leader and MAFC member, Dingras
Others		
Epifania Agustin	MMSU	MMSU Director for Research and IRMLA-Philippine team leader
Charito Acosta	MMSU	IRMLA team member
Artemio Alcoy	MMSU	IRMLA team member
Susan Aquino	MMSU	IRMLA team member
Facundo Asia	MMSU	IRMLA team member
Criselda Balisacan	MMSU	IRMLA team member
Dionisio Bucao	MMSU	IRMLA team member
Isidro Galdores	MMSU	IRMLA team member
Joselito Rosario	MMSU	IRMLA team member
Leah Tute	MMSU	IRMLA team member
Reynold Villacillo	MMSU	IRMLA team member
Saturnino Ocampo	MMSU	MMSU President
Stanley Malab	MMSU	
Rosalinda Santiago	MMSU	
IRMLA-MMSU team members		

Field trip to Batac and Dingras (including courtesy visit to the mayors of respective towns)
April 8, 2003, Batac and Dingras municipalities, Ilocos Norte.

Level/Name	Office	Function
Municipality		
Jesus Nalupta	Municipality of Batac	Mayor of Batac
Robert Castro	Municipality of Dingras	Mayor of Dingras
Merryline Gappi	MAO-Batac	MAO
Erlinda Cabuyadao	MAO-Batac	AT
Nora Nida Rigonan	MAO-Batac	AT
Cesar Derrada	MAO-Dingras	MAO
Farm		
Tobacco farmer		Farmer, Brgy. Colo, Batac
Eggplant farmer		Farmer, Brgy. Colo, Batac
Corn farmers		Farmers, Dingras
Others		
Epifania Agustin	MMSU	MMSU Director for Research and IRMLA-Philippine team leader
IRMLA-MMSU team members		

Individual meetings with stakeholders to elicit information on current practices and alternative production technologies (with Anne Gerdien Prins, MSc student from WUR).
August 3 to 7, 2003, Batac, Ilocos Norte.

Level/Name	Office	Function
Municipality		
Merryline Gappi	MAO-Batac	MAO
Manama Aganon	MAO-Batac	AT
Linda Cabuyadao	MAO-Batac	AT
Osmundo Pastor	MAO-Batac	AT
Dr. Robert Pungtilan	MAO-Batac	AT
Edgar Raquel	MAO-Batac	AT
Nida Rigonan	MAO-Batac	AT
Farm		
Edwin		Farmer, Brgy. Naguirangan, Batac
Gerry		Farmer, Brgy. Colo, Batac
Others		
Engr. Ferdinand Casil	Philippine Rice Research Institute (PhilRice), Batac	Co-facilitator of the farmer field school (FFS) for rice
Virginiano Garo	Agric. Training Institute (ATI)	FFS coordinator
Dr. Epifania Agustin	MMSU	Director for Research and IRMLA-Philippine team leader
Dr. Thelma Layaoen	MMSU	
Ms. Leticia Lutap	MMSU	
Dr. Tess Marcos	MMSU	
Dr. Sixto Pascua	MMSU	
Ms. Mergie Salazar	MMSU	
Mr. Jaime Sampayan	MMSU	
Prof. Rosemarie Sair	MMSU	

Individual meetings with stakeholders to verify assumptions in the farm household model and present preliminary results (with Anne Gerdien Prins, MSc student from WUR and Dr. Mahabub Hossain, Agricultural Economist and Head of Social Sciences Division, IRRI).
October 22 to 27, 2003, Batac, Ilocos Norte.

Level/Name	Office	Function
Municipality		
Merryline Gappi	MAO-Batac	MAO
Manama Aganon	MAO-Batac	AT
Nelson Diculen	MAO-Batac	AT
Guadalope Dutdut	MAO-Batac	AT
Osmundo Pastor	MAO-Batac	AT
Robert Pungtilan	MAO-Batac	AT
Adelaida Quigao	MAO-Batac	AT
Edgar Raquel	MAO-Batac	AT
Nida Rigonan	MAO-Batac	AT
Carmelita Tallon	MAO-Batac	AT
Farm		
Danny		Farmer, Brgy. Pimentel, Batac
Rodolfo		Farmer, Brgy. Quiling Sur, Batac
Others		
Epifania Agustin	MMSU	Director for Research and IRMLA-Philippine team leader
Other IRMLA team members		

IRMLA stakeholder-scientist workshop
March 22, 2004, MMSU, Batac, Ilocos Norte.

Level/Name	Office	Function
Province		
Pedro Agcaoili, Jr.	PPDO	Provincial Planning and Development Officer
Jesse Anthony Barut	PPDO	Provincial Planning Assistant
Roland Ross Irapta	OPAG	Assistant Provincial Agriculture Officer
Municipality		
Noralyn Manahan	MPDO-Batac	Municipal Planning Officer
Merryline Gappi	MAO-Batac	MAO
Manama Aganon	MAO-Batac	AT
Nelson Diculen	MAO-Batac	AT
Ferdinand Casil	MAO-Batac	AT
Cesar Derrada	MAO-Dingras	MAO
Cornelio Balbesino	MAO-Dingras	AT
Gloria Bulao	MAO-Dingras	AT
Nelia Lazaro	MAO-Dingras	AT

IRMLA stakeholder-scientist workshop
March 22, 2004 (continued).

Level/Name	Office	Function
Farm		
Danilo Parbo		Farmer leader, Batac
Domingo Felipe		Farmer leader, Dingras
Jimmy Valencia	MAFC-Dingras	Farmer leader and MAFC member, Dingras
Others		
Epifania Agustin	MMSU	Director for Research and IRMLA-Philippine team leader
Charito Acosta	MMSU	IRMLA team member
Artemio Alcoy	MMSU	IRMLA team member
Susan Aquino	MMSU	IRMLA team member
Facundo Asia	MMSU	IRMLA team member
Criselda Balisacan	MMSU	IRMLA team member
Dionisio Bucao	MMSU	IRMLA team member
Margarita Caluya	MMSU	IRMLA team member
Isidro Galdores	MMSU	IRMLA team member
Joselito Rosario	MMSU	IRMLA team member
Leah Tute	MMSU	IRMLA team member
Reynold Villacillo	MMSU	IRMLA team member
Nathaniel Alibuyog	MMSU	
Marivic Alimbuyuguen	MMSU	
Marissa Atis	MMSU	
Aleta Austria	MMSU	
Lucresia Cocson	MMSU	
Lagrimas Flojo	MMSU	
Thelma Layaoen	MMSU	
Melvilyn Leano	MMSU	
Leticia Lutap	MMSU	
Beatriz Malab	MMSU	
Gliceria Pascua	MMSU	
Miriam Pascua	MMSU	
Zenaida Pugat	MMSU	
Corazon Sabuco	MMSU	
Roseminda Sair	MMSU	

List of publications of the author

Peer-reviewed publications

Laborte, A.G., Van den Berg, M.M., Van Ittersum, M.K., Schipper, R.A., Prins, A.G., Hossain, M., 2006. Adoption of new technologies and its consequences on farmers' welfare and the environment: A model-based case study from northern Philippines, (submitted).

Laborte, A.G., Van Ittersum, M.K., Van den Berg, M.M., 2006. Multi-scale analysis of agricultural development: A modelling approach for Ilocos Norte, Philippines. Agricultural Systems, accepted.

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Laborte, A., 1996. Modeling the potential distribution of threatened species using BIOCLIM and DOMAIN, MGIS Thesis, University of Queensland, Brisbane, Australia.

Laborte, A.G., Roetter, R., Hoanh, C.T., 1999. SysNet Tools: The interactive multiple goal linear programming (MGLP) model and data links to GIS. IRRI Technical Bulletin No. 6. International Rice Research Institute, Manila, Philippines. 31 pp.

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Southeast Asia. Quantitative Approaches in Systems Analysis No. 26, C.T. de Wit Graduate School for Production Ecology and Resource Conservation, Wageningen, The Netherlands, 69 pp.

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PE&RC PhD Education Statement Form

With the educational activities listed below the PhD candidate has complied with the educational requirements set by the C.T. de Wit Graduate School for Production Ecology and Resource Conservation (PE&RC) which comprises of a minimum total of 22 credits (= 32 ECTS = 22 weeks of activities)

Review of Literature (3 credits)
- Land use modelling (2000)

Writing of Project Proposal (5 credits)
- Operationalization of a decision support system for land use planning and analysis: a case study for Ilocos Norte province, Philippines (2000)

Post-Graduate Courses (2 credits)
- Tools for regional land use analysis: a hands-on course (2001)
- ORYZA2000 modelling course (2003)

Deficiency, Refresh, Brush-up and General Courses (3 credits)
- QUASI-introduction (2000)
- Regional agricultural development analysis and policy (2000)
- Scientific writing (2001)

PhD Discussion Groups (5 credits)
- Sustainable land use and resource management with focus on the tropics (2000-2001)
- Statistics, maths and modelling in production ecology and resource conservation (2000-2001)
- IRRI Thursday seminar (2001-2005)

PE&RC Annual Meetings, Seminars and Introduction Days (0.75 credits)
- PE&RC annual meeting: GMO; benefits and risks, desirable or redundant (2000)
- PE&RC 10-years anniversary (2005)
- PE&RC annual meeting: The truth of science (2005)

International Symposia, Workshops and Conferences (4 credits)
- International Crop Science Congress, Hamburg, Germany (2000)
- Integrated Natural Resource Management Workshop, Cali, Colombia (2001)
- Ecoregional research and policy making, Nairobi, Kenya (2005)

Curriculum vitae

Alice Guimmayen Laborte was born on May 25, 1970 in Los Baños, Laguna, Philippines. She graduated from the University of the Philippines at Los Baños in 1990 with the degree BS Statistics (*cum laude*). She taught briefly at the Institute of Mathematical Sciences and Physics at the same University before moving to the Agricultural Economics Department (now Social Sciences Division) at the International Rice Research Institute (IRRI) where she worked as Researcher until 1995. While working at IRRI, she studied part-time and finished the coursework leading to the degree MS Computer Science. In 1995, she left IRRI and the Philippines to pursue postgraduate studies in Australia on an AusAid scholarship. She graduated from the University of Queensland in Brisbane, Australia in December 1996 with the degree Master of Geographic Information Systems. She joined the International Center for Living Aquatic Resources Management (ICLARM, now WorldFish Center) in 1997. In 1998, she re-joined IRRI as Assistant Scientist with the SysNet Project. During this period, she learned about land use modelling and took an active role in model development for the Ilocos Norte province case study, as well as in conducting trainings on GIS and linear programming for SysNet partners in the case study sites. After the completion of the project, she transferred to the Geographic Information Systems-Image Processing Laboratory of IRRI.

In September 2000, she started the PhD research described in this thesis with the Plant Production Systems Group of Wageningen University.

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