Can computer models stimulate learning about sustainable land use? Experience with LUPAS in the humid (sub-)tropics of Asia

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Abstract

In many rice-cultivating regions of East and South-east Asia there is severe competition for land and water resources. This calls for the exploration of future technology and policy options in support of sustainable land use. Sustainable land use encompasses ecological, economic and social learning through interaction among people. People’s ability to cope with conflicts in land use objectives requires (a) the acquisition of knowledge and skills to address complex problems and (b) the participation of a diversity of actors influencing and affected by the (land use) decisions being made.

Science can contribute by integrated research. The SysNet project (1996–2000) attempted such integration for four rice-cultivating regions in Asia, by developing the modelling framework LUPAS (Land Use Planning and Analysis System) in close collaboration with stakeholders. Question is whether and how SysNet-LUPAS enhanced learning about sustainable land use.

Examination of the functional, communicative and methodological learning about sustainable land use revealed that LUPAS did break new ground in the different learning domains. Learning varied among the cases, depending on factors such as width and depth of scientific expertise of local research teams, planning culture and

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structure, bio-physical and socio-economic settings. Most notably, it enhanced functional learning about integrated modelling and regional land use by local research organizations. Furthermore, local planners and agricultural experts gained knowledge about systems thinking and tools, local resource availability, environmental problems, the potential of new technologies and policies, prevailing knowledge gaps and, last but not least they learned about the diverging development priorities perceived at the different planning levels. LUPAS scientists, on their turn, attained methodological learning: they recognized their role as stakeholder, identified specific learning needs of different land use planners, adjusted LUPAS to facilitate the exchange of perspectives and development aspirations amongst provincial planners, municipalities and farmer representatives. They recognized the challenge of a multi-scale approach.

**Keywords:** Land use; Learning; Integrated analysis; Modelling; resource conflicts; rice; Asia

1. Introduction

The World Commission on Environment and Development, in their (WCED, 1987) report *Our Common Future*, challenged policy makers and society (including the scientific community) to achieve sustainable development through satisfying human development needs while preserving the earth’s life support systems. This important report expressed an important shift from raising awareness of global environmental problems to focus on actions in support of the integration of environmental, economic and social imperatives – as underlined, subsequently, in the United Nations Conference on Environment and Development (UNCED, 1992) and its Agenda 21. Since the second Club of Rome report ‘No limits to Learning: Bridging the human gap’ (Botkin et al., 1979) it had been widely recognized that a gap exists between the nature of the task to deal with the growing complexity of the sustainable development challenge and societies’ ability to respond and cope with it. Bridging this gap requires foremost the ability to learn, acquire the knowledge and skills required to address complex and rapidly shifting development problems, as well as participation of a diversity of actors that influence and are affected by the decisions being made.

The issues at stake in rice-based ecosystems of the (sub-)humid tropics of Asia are complex (e.g. rice supply versus increase of farmers’ income; intensification and diversification versus environmental concerns) and require integrated, interactive research and planning. In 1996, the International Rice Research Institute launched the SysNet project (Systems research network for eco-regional land use planning in tropical Asia) to develop a model-based, integrated planning methodology. SysNet
developed LUPAS: Land Use Planning and Analysis System (LUPAS) (Roetter et al., 2005) that applies a transdisciplinary system approach, integrating knowledge of various disciplines. It is a Multiple Goal Linear Programme (MGLP)-based model framework, enabling agricultural experts and planners to explore outer boundaries of agricultural potential, as well as the trade-offs between various socio-economic objectives and ecological sustainability. Scientists of ‘the Wageningen School of De Wit’ developed various MGLP-based model frameworks (Bouman et al., 2000; Van Paassen, 2004), but the SysNet project is one of the first that explicitly focuses on interactive research and planning, and the involvement of local stakeholders.

Former land use models did not always focus on ‘the issue at stake’, nor solved ‘the questions asked’ (Van Paassen, 2004; Loevinsohn, 2002; Walker, 2002). To increase relevance and effectiveness (a) modellers should involve end-users (agricultural experts and planners) in the modelling process, and (b) land use planners need to consider the concerns and aspirations of local land users. Effective land use analysis and planning demands substantive knowledge, knowledge about people and networks, and knowledge about social processes (adapted from Leeuwis, 2004; pages 300-301)†:

- **Substantive knowledge**: This refers to the knowledge about the characteristics and functioning of biotic, a-biotic and social systems, and the outcome of possible actions, measures and techniques. **Functional learning** concerns the acquisition of knowledge and skills to attain the desired situation or at least to cope with an emerging situation.
- **Knowledge about people and networks**: **Communicative learning** encompasses gaining insight in each others’ perspectives, underlying assumptions, norms and values, to attain mutual understanding and a shared common goal.
- **Social process knowledge**: **Methodological learning** is about how to shape the learning and negotiation processes for sustainable development in a specific context.

This paper examines the learning and negotiation as attained by the SysNet project. After the introduction, the paper describes whether and how SysNet activities gave way to:

1. Methodological learning by IARC SysNet scientists;
2. Enhanced skills and competences of Asian scientists in integrative analyses and the LUPAS modelling framework;
3. Communicative learning or increased insight into the diversity of stakeholder perspectives and needs;

† These types of learning more or less correspond with first order learning, second order learning and third order learning as defined by Argyris (1976; 1992) and Schön and Rein (1994).
4. Functional learning or increased understanding of agro-ecosystem complexity and the possible effect of various agricultural techniques and policy measures;

5. Negotiation about optimal sustainable land use and development options, amongst land users, agricultural experts and government planners at the various decision making levels.

2. The set-up of SysNet-LUPAS

SysNet was defined as a methodology development project in support of the IRRI coordinated Ecoregional Initiative for the Humid and Subhumid Tropics of Asia (EcoR(I)). The project was expected to contribute to the integrated design, exploration and evaluation of land use options at sub-national level. Under the guidance of IRRI, MGLP experts of the Wageningen University and Research centre (WUR) collaborated with scientists of National Agricultural Research Institutes (NARI) to develop land use analysis tools for Haryana State in India, Kedah-Perlis Region in Malaysia, Ilocos Norte Province in the Philippines and Can Tho Province in Vietnam (Fig. 1) (Van Ittersum et al., 2004). A short characterization of the natural resource issues and regional development goals in these respective areas are given in Table 1.
Table 1. Natural resource management issues and regional development goals in the four SysNet sites.

<table>
<thead>
<tr>
<th>SysNet site</th>
<th>NRM issues</th>
<th>Regional development goals</th>
</tr>
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<tbody>
<tr>
<td>Kedah-Perlis Region, Malaysia</td>
<td>Competition for agricultural land from urban and industrial expansion. Reduced farm labour. Federal policy for the region to remain as the country’s rice bowl.</td>
<td>Intensify and increase rice production. Increase non-food production. Increase labour use efficiency. Reduce use of agro-chemicals by improving resource use efficiency. Increase farmers’ income.</td>
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In 1996, during the first meeting, the scientists formulated the following objectives, strategy and expected outputs:

- **Principal objective**: To develop and apply methodologies to analyse future options for land use and natural resource management at the regional scale to guide policy changes and to assess the scope for agricultural development beyond the constraints of current agricultural and environmental policies.
- **Strategy**: To present an operational methodology for integrating scientific methods and data and a corresponding system (i.e. LUPAS) for quantitative land use
planning at the regional level, and to apply and evaluate the methodology in close interaction with stakeholders in four representative regions (Fig. 2).

- **Expected outputs:**
  - A general methodology and modelling framework for exploratory land use analysis, at the subnational level.
  - Various options for agricultural land use, explored at four representative domains.
  - Teams of trained scientists that can apply systems analysis techniques at the regional level, to identify development potentials, opportunities and constraints.

Implicitly it was expected that agricultural planners, policy makers and other relevant stakeholders become familiarized with the capabilities and applicability of LUPAS.

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![Fig. 2. Steps in developing a system for strategic land use planning and analysis.](image-url)
Important means and milestones for realizing the expected outputs were three international meetings: a training workshop on the MGLP technique, October 1997; a workshop on exchange of methodologies in land use planning, June 1998; and a symposium on methodology and case study presentation in conjunction with external project review, October 1999. Additionally, an in-country training cycle in modelling components for each national SysNet team (March – August 1997) and three cycles of agricultural expert-planner-scientist meetings for each case study (in 1998, 1999 and 2000) were conducted (Roetter et al., 2000a, b).

In the following, project activities that contributed to learning process are presented in chronological order. We distinguish four major stakeholders: (1) SysNet researchers of International Agricultural Research Centres (IARCs) such as the IRRI and WUR scientists, (2) SysNet researchers of the Asian National Agricultural Research Institutes (NARIs), (3) the agricultural experts and planning officers present and (4) representatives of the agricultural industry, trade and various categories of farmers and other land users. First emphasis is put on the learning process of modelling researchers (IARCs and NARIs) and the intended model users (agricultural experts and planners).

3. Project activities and learning

In this section, we illustrate and discuss different outcomes of joint learning: whether and what kind of learning and capacity building was attained in the four cases taking into account differences in team composition, bio-physical and socio-economic settings of the study regions, different national (agricultural and environmental) policy directions and agricultural planning structure and culture.

3.1. Methodological learning by IARC SysNet scientists

At the inception workshop in December 1996, exchange of experiences led to a change in project design. IARC scientists realized that agricultural planners would not automatically familiarize with, appreciate and use LUPAS. To get the interest, trust, and approval of the end-users, explicit efforts for network building and workshops to exchange knowledge and perspectives were needed. Apart from the study of policy papers, it was esteemed essential to meet agricultural experts and planners to ask what issues they struggled with, to demonstrate envisaged capabilities of the LUPAS modelling framework, and to jointly identify the issues and questions to be incorporated in LUPAS. Together with the NARI scientists, they elaborated the model development methodology as depicted in Fig. 2.

In the course of planner-scientist workshops (1998/99) on model development and
evaluation researchers increasingly realized (i) that it was essential to flexibly adapt LUPAS according to the questions that emerged in the discussion, so as to retain momentum and keep participants involved, and (ii) the need for a fast and attractive user interface (supported by GIS) – once LUPAS was mature – to modify scenarios in direct interaction with end-users and run and visualize corresponding results effectively. For this latter purpose, the MGLP user interface was developed during 1999/2000 for case studies Kedah-Perlis and Ilocos Norte. The various workshops demonstrated the diversity of land use planners and local government advisors, the intended end-users. For instance in Malaysia, most of the planning is executed at the national level and regional planners act more as implementers (Riksen and Sterk, 2002; Aminuddin et al., 2002). To be able to implement national policies and plans, these regional planners appreciate the detailed local-specific descriptions of the agricultural potential with present agricultural practices.

They also like to know the possible production increase and resource use efficiency gains through new agricultural techniques, as depicted by the Technical Coefficient Generators (TCGs), but they are less interested in long term future scenarios. Long term scenarios might interest the State Economic Planning Unit (UPEN), which prepares the state development plans to be approved by the State Executive Council (ECO), but these planners did only sporadically attend the regional workshops. Concerning future LUPAS activities, it is deemed essential to further analyse the local planning structure and culture, to identify the information needs of the various experts and planners and to see where the input of a strategic LUPAS framework might be most beneficial, or could be supplemented by modules for tactical decisions.

3.2. Enhanced skills and competences of Asian scientists in LUPAS modelling and integrative analyses

SysNet is one of the first land use modelling projects that put considerable effort in local capacity building. Capabilities in using, modifying LUPAS and interpreting its results require much more than training in using the MGLP technique and associated programming. Generating input to LUPAS requires skills in data management, simulation modelling and GIS and expertise in different disciplines including agronomy (plant and animal sciences), soil science, hydrology, economics, GIS/remote sensing, (spatial) planning and policy analysis, and mathematical programming. Generating meaningful outputs and its interpretation requires at least a few experienced people with multi-disciplinary backgrounds (agricultural/environmental sciences) with good communication skills. In addition, knowledge of the region and good contacts to local government agencies is likely to facilitate both
input and output generation. Redundancy of the required skills is necessary, to cope with career moves, staff redeployments and other organizational developments. And last but not least, it is always beneficial when the director of the NARI provides good backing and stimulation to the scientists involved. SysNet created the following LUPAS modelling capacity at the four NARIs:

- **SysNet-India (IARI):** 12 scientists, covering all disciplinary backgrounds (except for initial lack of GIS/remote sensing expertise) with several (three) versatile and experienced scientists. Strong modelling background with two scientists having about 10 years experience in simulation modelling (at plot/field level); good knowledge of Haryana, but little contacts to government authorities. Good backing of team by director of the institute. The team expanded during SysNet and was later institutionalized as a new (environmental science) group at IARI; stakeholders were not invited for trainings.

- **SysNet-Malaysia (MARDI):** 15 scientists, covering all disciplinary backgrounds (except for temporary lack of expertise in crop ecology and programming); Initially, there were three scientists with good background in modelling (however, chief LP modeller left during year 3); strength in GIS and land evaluation, economics and policy analysis; several versatile and experienced scientists; good knowledge of the Kedah-Perlis region; one scientist with good contacts to local government authorities and to federal planning office. The team was backed strongly by the director general of MARDI (in years 1-3). Number of team members remained constant; however, experienced scientists were replaced by some less experienced junior scientists; stakeholders from the region were sporadically invited for trainings – this was intensified when the MGLP user interface became available.

- **SysNet-Philippines (MMSU, PhilRice-UPLB):** 24 scientists, initially covering all disciplinary backgrounds (except for limited GIS/remote sensing and LP modelling expertise); initially, with several (four) versatile and experienced scientists with a fair to good modelling background; however, brain drain started already in year 2 (PhD abroad, consultancy and later on, jobs abroad) leaving only one experienced scientist available in year 4 – as a consequence, strong IRRI support was required in elaborating LUPAS for the case study. Number of team members declined during project period; local scientists were invited for trainings on systems analysis tools – later on even provincial planning officers and advisors; the team received good backing from the president of MMSU university and director of PhilRice and enjoyed good contacts to local government authorities

- **SysNet-Vietnam (CLRRI):** 15 scientists (initially), not covering all important disciplinary backgrounds (initial lack of GIS/remote sensing and LP modelling
expertise; later on agronomic expertise was lacking); one versatile and experienced scientist. Insufficient modelling background was gradually attained through intensive coaching (special trainings at IRRI); there was good knowledge of Cantho and very good contacts to various government authorities (this declined since 1999). The team was reduced substantially during SysNet, however, those that remained (seven members) improved their skills considerably; many stakeholders from the region and from other universities were invited for trainings on systems analysis tools during 1997/98. Great support of the team by the director of the institute (till 1998).

In the course of the trainings and interactive workshops NARI scientists learned to share disciplinary perspectives and work interdisciplinary. They became interested in the development and use of an integrated tool such as LUPAS (Aggarwal et al., 2001; Aminuddin et al., 2002; Riks en and Sterk, 2002). For the case of the India SysNet team, this new style led to concrete institutional impacts: the team members recruited from different departments of IARI formed the core of a new department on environmental sciences from 2000 onwards. In general, work with LUPAS led scientists to direct their focus more on environmental issues and enable them to better respond to different (emerging) concerns.

3.3. Increased insight into the diversity of stakeholder perspectives and needs

In early 1997, consultative meetings were held with researchers and stakeholders in the study regions. In the Philippines, that meeting had already the character of a stakeholder-scientist workshop, with 70 participants representing provincial and municipal planners and agricultural experts, municipalities, farmers and farmer organizations, and SysNet scientists. Official land use plans were presented for the province and for a selection of (10) municipalities. It was the first time that these plans were confronted with each other. This gave rise to lively discussions on inconsistencies and conflicts between municipal and provincial level planning. Some of the insights obtained were: lack of consistent and precise information on land area per land use category, unsatisfactory information on land properties and land suitability for specific uses, and, the need for more discussion, information exchange and better coordination between the municipal and provincial planning process. This experience was one of the key factors for ensuring strong stakeholder participation during the development of LUPAS, culminating in the attendance of the final meeting by the provincial governor, his planning office and advisors and several mayors of the province (Roetter et al., 2000b). Scientists evaluated LUPAS together with the
stakeholders, and the latter recommended to include intercropping, relay-cropping and fisheries in the model. Conflicts identified between the land use objectives of municipalities and the province led to the recommendation to expand the framework to municipal and farm level. In this way, LUPAS would provide insight in the situation and perspectives of the planners and farmers at the various decision making levels, to enhance dialogue and mutual consideration. As SysNet project ended a few months later, these requests were not immediately met. However, they led, among others, to the formulation of the IRMLA project proposal and a PhD study on multi-scale land use analysis for Ilocos Norte (Van Ittersum, this volume).

3.4. Increased understanding of agro-ecosystem complexity and the possible effect of new technologies and policies

For the first time, comprehensive, reproducible pictures of agricultural production activities and resource availability in the four regions became available through the systematic collection of data and information required for the development of LUPAS; the same applies for the generated future land use options based on formalized knowledge. This knowledge and its exchange provided experts with new insights such as feasible objectives for agricultural development in different regions characterized by rice-based systems. This exercise resulted in unique regional databases and maps on resources and quantified input-output relations (technical coefficients) of agricultural activities. While provincial level planners appreciated the generated GIS maps and databases, local planners, agricultural experts and extension officers preferred and made use of the TCGs for various purposes, such as for the extrapolation of agronomic research results or for the design of new experiments. In this way, tools, databases and computer software introduced by SysNet yielded ample spill-over effects benefitting a range research, extension and educational programmes.

Based on profound experience and knowledge of applying systems approaches to agriculture, it was the SysNet team of India who finally made full use of the new tools (GIS, TCG and MGLP) to increase understanding of agro-ecosystem complexity (bio-physical potential, natural and socio-economic resource constraints) and the role of new technologies and policies for agricultural development (Aggarwal et al., 2001). For the first time the bio-physical potential and environmental impact of 14 crops at five different technology levels were presented for the entire state of Haryana, India. Due to a full link to GIS everything was displayed in clear colourful maps. Before, planners and agricultural experts did not have such detailed, local specific data on the agricultural potential and trade-offs, and rather worked with general insights and ‘rules of the thumb’. Now they could make better informed decisions. For the first time they
were able to analyse and quantify environmental effects of various agricultural
techniques (e.g. nitrogen budgets, N-loss to groundwater, biocide impact index etc.).
Haryana, a state that greatly contributed to the success of the green revolution in India,
achieved higher production at the expense of the environment. LUPAS analyses
helped to quantify specific effects of current practices and future scenarios
demonstrated the possibility of new production technologies to increase yields while
reducing emissions (leaching of nitrates, biocide residues) to the environment. With
the use of MGLP, the trade-offs between cereal production, income, environmental
quality and employment opportunities were quantified. Model explorations showed,
for instance, that when assuming no constraints (except for area) and all farmers being
capable of adopting all (advanced) production technologies, Haryana has a bio-
physical potential of producing 39.1 million tons of rice and wheat. However, in such
a scenario, water requirements are three times higher than water currently available,
capital requirements twice as high as currently used, and the biocide index only
slightly higher than at present. When introducing current water availability as a
constraint, the potential would be reduced to 17.1 million tons (as compared to the
10.5 million tons that were harvested in 2000 (Aggarwal et al., 2001)). This exercise
demonstrated the critical and quantified effect of water limitation. This information
stimulated policy makers of Haryana to support research on water-saving production
technologies. In Ilocos Norte, LUPAS work increased the understanding of the
availability of natural resources in space and time. Keen interest of the governor and
his planning staff led to provision of this knowledge via internet
(www.microimages.com/tntserver/nwluzon.htm).

3.5. Negotiation of optimal sustainable land use and development options amongst
different stakeholder groups

The process of negotiating sustainable regional development options among
different stakeholder groups was initiated during the second cycle of stakeholder-
scientist workshops in 1999. Results from different future scenarios were presented as
well as extended scenario runs, conducted upon comments from stakeholders (e.g. on
required minimum food production, income levels or water use). A wide range of
stakeholder groups participated in these workshops in Alor Setar, Kedah-Perlis
(Riksen and Sterk, 2002) and at Batac (Ilocos Norte) (Roetter et al., 2000b). By that
time, however, it became clear that various stakeholders were willing to accommodate:
they were eager to revise their development targets to make them more technically
feasible and more balanced/desirable in socio-economic and environmental terms.
Unfortunately, the fruitful and inspiring discussion lost momentum, due to the
incapability of LUPAS to rapidly generate revised scenarios, proposed by the stakeholders (time requirements for revising scenarios and present model results were too high). SysNet researchers recognized that interactive dialogue, negotiation of alternatives and joint planning required a flexible, user-friendly interface (Laborte et al., 2001); hence they put much effort in the development of the interface, to have it available at the final round of workshops. The user interface allows to externally control/run optimization models and define scenarios through selection/editing of optimization settings and constraints. It is written in HTML and provides the following functions: (1) views of prepared model results (2) comparison of results to analyse trade-offs (pair-wise tables, graphs, maps) and (3) generation of a model run file by submitting a user request form – allowing definition and presentation of new scenarios within 5–10 minutes (Roetter et al., 2005).

During the final workshops in Ilocos Norte and Kedah-Perlis region, policy makers and planners considered this user interface as a great help for the facilitation of the discussion about alternative options. Policy makers from the Philippines as well as from Malaysia requested immediate access to the system, and provision of training and testing by planning officers and agricultural advisors. Apparently, the LUPAS modelling framework addresses a crucial aspect of planning: it enhances the understanding and negotiation of perspectives and goals amongst stakeholders at various decision making levels. Unfortunately, the SysNet project lacked the financial means to adapt LUPAS to new user requests (e.g. to add the farm and municipality level in the Philippines, and to improve/add technical coefficients for perennial crops in Malaysia). It would have been interesting to test, whether an adapted, operational LUPAS model would be able to (a) put ecological issues higher on the planning agenda and (b) make high level planning officers better aware of and consider aspirations and needs of municipalities and farmer categories. Fortunately, methodologies developed in SysNet are being advanced and supplemented in the ongoing IRMLA project (Roetter, 2005, this proceedings; www.irmla.alterra.nl) and other follow-up studies (Van Ittersum et al., this proceedings).

4. Conclusion about LUPAS modelling enhanced learning for planning

In retrospect, we can conclude that the SysNet-LUPAS venture triggered learning by the following stakeholders:

IARC SysNet scientists (original MGLP developers)

Through stakeholder feedback, the IARC SysNet scientists realized the methodology needed a multi-functional user interface for rapid display of results. It
should permit a quick change of goals or assumptions and show the result in a visually attractive, and effective way (in tables, graphs and maps). For that purpose, the MGLP model was linked with a GIS and web-based user interface. The fact that these interfaces were built for Ilocos Norte and Kedah-Perlis must in first instance be attributed to the more participatory agricultural planning culture in the Philippines than in other cases, and the more IT friendly environment in Malaysia.

Furthermore, it became clear that involving stakeholders from different levels had far-reaching consequences for the research process. Planners at provincial and municipal level had different perspectives. Various authors (Mayer and Stirling, 2002; Van Paassen, 2004) note that stakeholders not only put different numerical weightings to goals and criteria they care about, but they want to have all issues included that reflect what they think is relevant. As a consequence, stakeholders asked to add extra activities (Malaysia) or extra modules for the municipal level perspective and the farm perspective (Philippines). Question is, how swift modellers can add activities and modules. This depends on the catalogue of additional information needs as well as on available resources. The kind of flexibility required is usually not manageable in a conventional research project setting. In many cases it might be manageable when an elaborate TCG is available, covering all imaginable agricultural techniques. In practice, even this is often not the case; hence to respond quickly to the issues emerging in planner discussions, scientists are obliged to use ‘gue(s)stimates’ (Veldkamp and Fresco, 1996). When used in a transparent way, the model will still serve its purpose as discussion-facilitation tool. However, there are concerns that planning officers demand precise, reliable data and might refrain from using models with too many gue(s)stimates. Further research on the required balance between accuracy, rapidity and relevance is needed. Different kinds of problems, decision makers and planning cultures will demand a different balance.

In short, we can conclude that IARC SysNet scientists were one of the first MGLP modellers, who put much effort in the involvement of local stakeholders, and they learned a lot: They realized they themselves were one of the stakeholders involved with their own subjective perspective; they recognized a diversity of potential model-users with different information needs; they responded by improving the ease-of-use and flexibility of the LUPAS modelling framework; they identified the diversity of perspectives (goal weightings and issues included) at the various decision making levels and saw the necessity of a multi-scale approach to land use system modelling (Van Ittersum, this proceedings).

NARI scientists (potential IMGLP modellers in Asia)

Much time and effort was put in the training of NARI scientists. Required were soil
scientists, agronomists, hydrologists and economists with computer skills, knowledgeable about the area concerned and whose employer would allow them to invest in Interactive MGLP modelling. Agricultural researchers at the NARIs seemed most appropriate to contact: here you could have several researchers together (need for redundancy). Due to the MGLP effort, researchers at NARIs started to work in a more interdisciplinary way and they became more aware of the ecological dimension of agricultural development. In one case (India) the team became a separate department for interdisciplinary research. The major success factor in the India case is the continuity of multi-disciplinary expertise and the application of the systems approach. Some NARI scientists in Vietnam have further developed their capabilities, which enabled them to apply LUPAS independently to new provinces. The Philippine and Vietnam teams have become part of research undertakings to extend the methodology to multiple – level land use scenario analysis.

*Agricultural experts and planners*
Agricultural experts and planners learned about the LUPAS modelling framework, helped to identify the issues to be included in the modelling framework and helped to gather the specific information needed for the modelling exercise. By doing this, they acquired substantive knowledge and knowledge about other people and their perspectives.

*Functional learning*
Stakeholders present at the SysNet99 symposium and in the final stakeholder meetings noted:

- They now better understood the capability of the exploratory methodology. Some expressed their willingness to further apply it in practice.
- Local data availability was fragmented and incomplete. For the modelling, local agronomists collected all relevant data of a given region. The data were screened on validity. For the first time a comprehensive picture of knowledge and knowledge gaps for a given region was generated – allowing informed prioritization of research activities;
- Local agronomists were very interested in the local input/output coefficients of different potential techniques. They learned about the potential of various new techniques for their area.
- MGLP generated specific and reproducible data on the agricultural potential of a specific study region. Before, agricultural experts used more general ‘rules of the thumb’.
• LUPAS incorporated ecological knowledge (e.g. on emissions to the environment, such as nitrate leaching) that local agronomists had not dealt with before in a quantitative manner. The LUPAS exercise increased awareness of the issue of agro-ecological sustainability and put it more clearly on the local policy agenda.

Communicative learning
Through the discussions at the various stakeholder meetings, provincial planners took notice that municipal and farm interests sometimes conflict with provincial interests. The LUPAS meetings made them acquainted with platform dialogues, explicit exchanges and negotiation of perspectives and development priorities, and joint searches for win-win situations. MGLP modelling is useful for regional planners to elaborate appropriate and effective technological and policy choices, considering developments and issues at stake at the national policy level as well as the local level.

Future challenge
Bio-physical and social sustainable planning requires functional learning as well as communicative learning. It is essential that land use modellers, planners and farmers exchange knowledge, interests and development needs. Therefore, NARI modelling scientists and planners should know how to identify the issues-at-stake to be included in the LUPAS model framework. Agricultural innovation depends on agricultural chain development, national policy measures, competing claims on available local resources, agricultural knowledge development and, last but not least, livelihood strategies and aspirations of farmers. A two-pronged approach, confronting farm household model results with regional MGLP results seems promising. Such an analytical framework can visualize and make explicit the perspective of local land users and regional policy makers, triggering discussion and possible dialogue about the common goal for future agricultural development.

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