A systems network (SysNet) approach for interactively evaluating strategic land use options at sub-national scale in South and South-east Asia


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Abstract

This paper presents SysNet, a systems research network in South and South-east Asia, established to develop and evaluate methodologies for enhancing formulation of strategic land use policies. SysNet adopted theory and concepts from both natural and social science approaches. Multiple goal linear programming was used to integrate information on a broad range of alternative land use systems, resource availability and policy objectives, to reveal possibilities and limitations of agricultural resource use and trade-offs between policy objectives. The methodology was developed and applied in and with a network of researchers and stakeholders, for four case study areas in India, Malaysia, the Philippines and Vietnam. An application is presented for Haryana State (India), to illustrate the methodology and its components, as well as the type of questions that can be explored and subsequently discussed with stakeholders. We discuss lessons learnt on how to communicate LUPAS to stakeholders in interactive settings, with details for the Kedah-Perlis case region in Malaysia.

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Introduction

In the late 1980s the sustainability and sustainable development concepts entered the political debate as well as the agricultural research agendas. It was recognised that land use policies and agricultural research must address the integrated nature of unsustainability at various hierarchical levels. Analysis of and influencing the use of land and other natural resources require integral consideration of a suite of problem dimensions and objectives. Research has responded in several ways. The public debate on inter-relationships between environment and development (following e.g. UNCED, 1992) triggered the introduction of new concepts in land use planning (FAO, 1995), and the creation of the so-called ecoregional research initiatives worldwide (TAC, 1993, 1994; Bouma et al., 1995). It also resulted in broad consensus that stakeholders should be involved in research supporting sustainable development, since the interpretation of sustainability in terms of natural resource use systems managed by people is ambiguous, and hence its inclusion in research is not value-free (Parker et al., 2002). In addition, it was recognised that integrated studies require intensive communication with stakeholders to increase chances that scientific knowledge can be used in decision making problems (Loevinsohn, 2002; Parker et al., 2002). In the
same way that incorporation of sustainability in the policy agenda could, to some extent, be typified as old wine in new bottles, the arrival of the sustainability notion did not change all fundamentals of research methods. Rather, existing research methodologies were adapted to match a new context and the sustainability debate stimulated integration of research methods and collaboration among disciplines that hitherto had worked more in isolation.

Two complementary agricultural research methodologies, originating well before the advent of the sustainability notion, but affected in their evolution are farming systems research (FSR) and land evaluation (LE). FSR’s primary aim was to increase productivity of the farming system in the context of the entire range of private and societal goals, on the basis of a thorough analysis of the constraints and potentials of existing farming systems (Gilbert et al., 1980). Thereby, FSR viewed the farm and the rural household in a comprehensive manner, recognising the interdependencies between the natural and human environments. Gibbon (1994) identified two developments in FSR, i.e. (i) a focus on participation of farmers and the inclusion of farmer knowledge and experimentation in the research process and (ii) development of techniques of agro-ecosystems analysis and their incorporation in rapid rural appraisal and participatory rural appraisal techniques. There appears to be no sharp boundary between where FSR stops and farmer participatory research starts (Collinson, 2000; Defoer, 2002).

Land evaluation was originally defined as the assessment of the suitability of land for human use in agriculture, forestry or for other purposes (Van Diepen et al., 1991), as part of land use planning. Its prime units of analysis are a region or higher spatial levels, while considering heterogeneity within these units. Van Diepen et al. (1991) identified as major trends in land evaluation since its inception in the 1950s, a shift from broad to specific assessments and increasing use of non-soil factors. Through assimilation of a systems research approach and developments in information technology, a more quantitative, bio-physical type of land evaluation evolved. Incorporation of dynamic simulation models (De Wit and Van Keulen, 1987) and, later, Geographic Information Systems allowed explicit coverage of temporal and spatial variation and handling of massive quantities of spatial data (e.g. Van Lanen et al., 1992). When applied in regional land evaluation or for land use planning purposes, economic considerations were taken into account implicitly or sometimes explicitly, but LE has retained its firm rooting in the biophysical domain of soil scientists and production ecologists.

Fresco et al. (1992) discussed LE and FSR and their complementarity. FSR’s main focus is on current land use and possible improvements, starting primarily at farm (household) scale, in an interdisciplinary context involving mainly agronomists and socio-economists. It is strongly actor-oriented. LE’s emphasis is on future and potential land uses, starting from a regional perspective and its land units, in a multidisciplinary context, involving primarily soil scientists, agronomists and to a lesser extent economists. It is strongly methodologically and biophysically oriented. Fresco et al. (1992) suggested that development and application of an integrated land evaluation and farming systems analysis sequence (LEFSA) could improve land use analysis and planning by combining the strengths of both methods.

Awareness within the research community has increased over the last decade, that both quantitative methods with a strong future-orientation and more process-oriented studies with a strong emphasis on context have a role to play in promoting management and policies aimed at sustainable land use. More specifically, there is an increasing call for multi-scale approaches and integration of natural and social science approaches. The ecoregional research approaches (Horton et al., 2002) fit in this perspective. For the international agricultural research centres (CGIAR), for instance, Rabbinge (1997) typified this type of research as the fifth phase in the development and research focus. Since the beginning of the 21st century, integrated natural resource management (INRM) research is the notion that covers interdisciplinary research aiming at sustainable management of natural resources, emphasising both the role of human actors and socio-economic and biophysical research methodologies (Sayer and Campbell, 2001).

This paper presents the SysNet research approach, implemented in a project executed from 1996 to 2000, as one of the first formal ecoregional projects. SysNet was a systems research network established to develop and evaluate methodologies for identifying land use options at sub-national scale to support agricultural and environmental policy formulation in South and South-east Asia. SysNet continued the development of methodology for exploring land use options (Van Ittersum et al., 1998). Such methodology combines quantitative land evaluation with multiple goal linear programming (MGLP), production ecological insights and economics (Spronk and Veeneklaas, 1983; De Wit et al., 1988; Rabbinge and Van Latesteijn, 1992).
The aim of the paper is to present and discuss SysNet as an attempt to develop and apply land evaluation methodology to the benefit of policy development processes. Before presenting the SysNet research approach, we position SysNet and its potential role within a policy development cycle (section on ‘Positioning the SysNet approach in a policy development cycle’). The section on ‘The SysNet research approach’ gives the overall presentation of the project, further elaborated in the section on ‘SysNet’s research and network deliverables’, focusing on the research methodology, results and research and stakeholder networking within SysNet. The last section concludes with a reflection on the essential but also clearly delimited role of the scientific methodology in a process of policy design to enhance sustainable land use, and on how such methodology can be communicated to stakeholders. The paper by Roetter et al. (2004) provides more details on technical operational aspects of the SysNet methodology.

**Positioning the SysNet approach in a policy development cycle**

The identification of a possible role and agenda of agricultural research in the process of sustainable development requires careful analysis of development cycles of natural resource use policies. In reality such cycles are highly non-transparent and any attempt at schematisation of such a cycle in research represents perhaps an ideal picture rather than an actual situation. On the basis of the synoptic view on land use planning processes, proposed by Dent and Ridgway (1986), we propose a highly schematised development cycle to structure thinking on natural resource use policies (Fig. 1). The cycle is centred on the stakeholders, to prevent the policy development of ending in a top-down procedure lacking a solid basis and to overcome what has been called the ‘silence of the users’ (Dent et al., 1994; Fresco, 1994). The different phases of the policy development cycle require different types of information, to be generated by different land use analysis and modelling approaches.

The policy development cycle, presented in Fig. 1, is open to different interpretations. One view might hold that biophysical potentials of and constraints on the system should be considered before analysing economic and social desirability and feasibility. In this view, focusing on policy levers in the very early stages of development of INRM policies will ignore biophysical and technical opportunities of the system. An implicit assumption underlying this view is that feasible policy levers exist or may be developed to achieve the physically and politically attainable goals. If this is not the case (second view), as particularly social scientists and economists may argue, the limited power and specificity of policy need to be considered early in the development cycle.

Information requirements and corresponding research approaches differ fundamentally for each of the two views, sketched above. The SysNet approach has followed the first philosophy, in the sense that only after the identification of policy objectives and technically feasible options, issues of policy instruments and implementation are considered. It aims at exploring strategic opportunities and limitations of agricultural land use at sub-national level. Opportunities to satisfy a range of objectives are shown as well as trade-offs between these objectives, for time horizons of 5–20 years.

Leeuwis (2000) argues that design of natural resource use systems must consider activities and processes rather than products. The dominant processes are experiential learning and negotiation or ‘social learning’. He hypothesises that no meaningful change or innovation in hard and soft systems can be brought about without some degree of effective co-ordination between inter-dependent social actors. Röling (in Leeuwis and Pyburn, 2002) wrote ‘social learning is about the interactive way of getting things done in theatres with actors who are interdependent with respect to some contested natural resource or ecological service’. SysNet adopted this line of thinking and considered design of natural resource management systems as a learning and negotiation process, rather than a top-down decision process. This implied strong emphasis on interactive methodology development and creation of a network mode as a means to enhance social learning for land use negotiation (Röling, 1994; Walker, 2002).
In summary, SysNet’s specific objectives were:

1. To develop a scientific-technical methodology for exploring land use options, using a quantitative systems analysis approach;
2. To develop an operational methodology for supporting a research and stakeholder network in sites representing various ecoregions in Asia.

More specific targets for the SysNet project were to:
(i) identify potential conflicts in rural development goals, land use objectives and resource use; (ii) identify technically feasible, environmentally sound and economically viable land use options that best meet a well-defined set of rural development goals, and (iii) 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. It is important to note that at its launch SysNet was particularly ambitious in developing scientific-technical methodology, rather than in its involvement of users and stakeholders. Hence, SysNet should be regarded as a pilot project for developing and evaluating innovative land use analysis methodology, while using views from social sciences, to the benefit of strategic land use policies. The latter, however, was done with fairly limited resources and experience.

The SysNet research approach

_NRM in Asia_

More than any other continent, Asia will face daunting challenges to feed its rapidly growing population, manage its scarce natural resources and serve multiple economic, ecological and social objectives. The population in Asia is projected to increase from 3.4 to 4.3 billion over the next 25 years. Average crop land area per capita is less than 0.2 ha, and in some countries (e.g. China, The Philippines, Vietnam) only ca. 0.1 ha is available. Of the agricultural land (arable and permanent crop land), 34% is irrigated, twice the global average and higher than in any other continent (agriculture accounts for 85% of the total water use in Asia). Use of fertiliser is also high (ca. 140 kg/ha/year). Particularly in South and South-east Asia, pressure on land resources is higher than anywhere else, and still increasing.4

Rice is the dominant agricultural commodity in Asia; the continent accounts for 90% of the world’s rice production and consumption. Rice is mainly grown for on-farm and local consumption; less than 5% is traded in the international market. Future rice demand is a function of population growth, income and relative prices of substitute crops and products, and is projected to increase by 70% over the next 30 years (Hossain, 1997). Considering the lack of scope for area expansion, this implies that average rice yields should increase from 3.7 to 6.3 tons/ha. Moreover, water resources are limited and declining. Demand for other agricultural commodities, particularly meat and other animal products, will increase as a consequence of economic development. These agricultural challenges are associated with changing labour markets and increasing urbanisation due to economic development, and an emerging concern for environmental and ecological issues. This combination of issues represents a strategic challenge to land and natural resource use in Asia, at various hierarchical scales.

The SysNet project opted for the sub-national scale (provinces or states) as the prime unit of analysis. This scale of analysis on the one hand allowed inclusion of stakeholders from a variety of (mainly planning) agencies, and on the other hand, was manageable for national agricultural research systems (NARS) teams in terms of complexity and data availability.

SysNet approach and methodology

SysNet developed scientific-technical methodology within a systems analytical framework, as well as operational networks of national and international scientists and stakeholders (Fig. 2). The steps in Fig. 2 emphasise the iterative nature of the operational

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4 All statistics from Food and Agriculture Organisation of the United Nations and World Bank.
methodology, in consultation with local scientists and stakeholders. Simulation models, expert systems, data base structures, GIS and MGLP were used as core natural systems tools, integrated into a Land Use Planning and Analysis System (LUPAS; Laborte et al., 1999, 2001; Roetter et al., 2000a, b, 2004). Training and consultation workshops formed the major social science tool.

Conceptually, LUPAS builds upon the so-called explorative land use studies as developed in various projects in different countries (Rabbinge and Van Latesteijn, 1992; Van Ittersum et al., 1998; Bouman et al., 1999). These studies combine quantitative information on a broad range of alternative land use systems and policy objectives, to explore land use options, assess the degree of goal attainment and quantify trade-offs at regional scale. The operational structure of LUPAS (Fig. 3) consists of four main parts:

(i) land evaluation, including assessment of resource availability and land suitability, (ii) assessment of input–output coefficients for a broad range of current and alternative land use systems for the various land units, (iii) scenario construction based on policy objectives and development plans, and (iv) quantitative evaluation of scenarios, using MGLP.

Within SysNet, case studies have been carried out in four regions to develop and evaluate the methodology, and to establish the research and stakeholder networks: Haryana State in India, Kedah-Perlis States in Malaysia, Ilocos Norte Province in the Philippines and Can Tho Province in Vietnam (Fig. 4; Table 1). The case study areas represent situations of rapidly growing and competing demands on land and water resources, representative for many agricultural regions in the humid and sub-humid tropics of Asia. The case studies also represent very different stages of economic development and cultural and political settings. Table 2 presents the core NRM issues and regional development goals in the four regions.

An international training workshop on the exploration of land use options using MGLP (October 1997), and two international symposia, one on exchange of methodologies in land use planning (Vietnam, June 1998, Roetter et al., 1998) and one on methodology and case study presentation (Philippines, October 1999, Roetter et al., 2000a) were complemented by an in-country training cycle for national scientists and three cycles of stakeholder-scientist meetings for each case study (in 1998, 1999 and 2000).
SysNet’s prime outputs were:

- a general methodology for land use analysis, models and expert systems for agricultural productivity estimation at sub-national scale;
- various options and limitations for agricultural land use, explored for four representative case study regions;
- teams of trained scientists that can apply systems analysis techniques at the regional scale, to identify development potentials, opportunities and constraints, and teams of stakeholders that are able to assess potentials and limitations of LUPAS, and that were involved in the definition and evaluation of specific land use scenarios for their regions.

**SysNet’s research and network deliverables**

**Scientific-technical methodology and tools**

The LUPAS methodology has been operationalised for each of the four case studies, targeted at their specific NRM conditions and problems. This was accomplished using a set of common tools for yield estimation, quantification of input–output relations of production activities and optimisation of land use at regional scale under alternative sets of multiple objectives and constraints. For the estimation of crop yields, among others WOFOST (version 7), a generic crop growth model (Boogaard et al., 1998), was used. For those crops for which no operational crop model was available, a database containing estimates of actual and potential yields for 60 annual and perennial crops in diverse environments was developed. For quantification of input-output coefficients for a broad range of actual and alternative land use systems, so-called Technical Coefficient Generators (Hengsdijk and Van Ittersum, 2002, 2003) were designed (e.g. TechnoGIN for Ilocos Norte), following a target-oriented approach (Van Ittersum and Rabbinge, 1997). MGLP models were developed in XPRESS-MP (Dash Associates Ltd, http://www.dash.co.uk). Finally, a user interface (web application) for interactive land use scenario analysis was made operational for two case study areas, i.e. Ilocos Norte and Kedah-Perlis (Laborte ARTICLE IN PRESS

Table 1

Characteristics of the case study areas (first four items) and the four countries (last four items) involved in SysNet (2000). Source: http://www.odci.gov/

<table>
<thead>
<tr>
<th>Item</th>
<th>Haryana (India)</th>
<th>Kedah-Perlis (Malaysia)</th>
<th>Ilocos Norte (Philippines)</th>
<th>Can Tho (Vietnam)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case study area</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total area (10^6 ha)</td>
<td>4.42</td>
<td>1.02</td>
<td>0.34</td>
<td>0.30</td>
</tr>
<tr>
<td>Agricultural area (10^6 ha)</td>
<td>3.72</td>
<td>0.54</td>
<td>0.11</td>
<td>0.25</td>
</tr>
<tr>
<td>Population (10^6)</td>
<td>16.5</td>
<td>1.64</td>
<td>0.50</td>
<td>1.89</td>
</tr>
<tr>
<td>Agricultural labour (10^6 persons)</td>
<td>2.76</td>
<td>0.28</td>
<td>0.36</td>
<td>0.93</td>
</tr>
<tr>
<td>Country</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Agricultural employment (%)</td>
<td>67</td>
<td>16</td>
<td>40</td>
<td>67</td>
</tr>
<tr>
<td>Unemployment rate (%)</td>
<td>n.a.</td>
<td>3</td>
<td>10</td>
<td>25</td>
</tr>
<tr>
<td>GDP real growth rate (%)</td>
<td>6.0</td>
<td>8.6</td>
<td>3.6</td>
<td>5.5</td>
</tr>
<tr>
<td>GDP ($ per capita)a</td>
<td>2200</td>
<td>10,300</td>
<td>3,800</td>
<td>1,950</td>
</tr>
</tbody>
</table>

*aPurchasing power parity.*

Table 2

Natural resource management (NRM) issues and regional development goals of the SysNet regions

<table>
<thead>
<tr>
<th>SysNet site</th>
<th>NRM issues</th>
<th>Regional development goals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kedah-Perlis States, 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>
</tr>
</tbody>
</table>
et al., 2001). For details of these tools, see Roetter et al. (2004).

The MGLP model within the LUPAS framework allows various analyses, which can be typified in terms of what-if questions, land use scenarios or trade-off analyses, i.e. (i) What-if there will be an increase/decrease in resources (e.g. labour, water, land); (ii) What-if different crops are cultivated (e.g. replacing rice by cash crops); (iii) What-if different production technologies are used (e.g. increasing external input use); (iv) What are optimal resource use allocations (land, water, labour) for given priorities of objectives; (v) What are trade-offs between different objectives (e.g. economic, environmental and food security objectives). Results of these analyses can be presented in tables (degrees of goal attainment), amoebae and bar diagrams (goal attainment and land use) and/or maps (land use allocation) (Roetter et al., 2004).

**Application of the methodology: example Haryana case (Aggarwal et al., 2001)**

Haryana (latitude 27.4–30.6°N; longitude 74.3–77.4°E), India, is a state that greatly contributed to the success of the Green Revolution in India. The agricultural area constitutes 81% of the total area and 47% of the agricultural area is sown more than once a year. Regional objectives of stakeholders, derived from bilateral discussions with policy makers and review of policy documents, can be summarised in five priority objectives:

- increasing food production in the near future;
- maximising income from agriculture;
- maximising agricultural production while maintaining employment opportunities;
- minimising nitrogen losses and pesticide residues from agriculture;
- improving water management through the design of intervention measures to reduce groundwater depletion.

Land units were derived by overlaying a soil map, rainfall map and administrative map (districts), and combining this with the possibility for irrigation. These land units were the basic units for simulation and assessment of input-output coefficients for land use systems. Based on current cropping patterns in the state, 14 crop-based land use types were selected, including rice-wheat (irrigated) and pearl millet-fallow and fallow-wheat (rainfed). Livestock, an integral part of Haryana’s agriculture, was represented with three major milk breeds. Since the major goal in the study was to explore options for increasing production, five technology options were considered: current yield, potential yield and three intermediate levels. The technologies were assumed to be increasingly site-specific and capital-intensive, from current to potential production levels. Input and output coefficients were computed for feasible combinations of land units, cropping systems and the five technologies.

The MGLP model included constraints defining the availability of land (per land unit), water (per land unit), capital (per district) and labour (per district and month). Adoption of technologies is at present generally constrained by the size of the farms, which indirectly relates to the farmers’ capital base. Therefore, potential adoption of capital intensive technologies (3, 4 and 5) was restricted to medium and large farmers. A similar sub-constraint on land-water was introduced to restrict water use per unit area under the various technologies.

For the purpose of illustration, a systematic analysis is presented of the effects of various resource constraints, as determined by developments in other economic sectors or policy objectives, on food production in Haryana (Table 3). Assuming no constraints (except for area) and all farmers being capable of adopting all technologies, Haryana has potential of producing 39.1 million tons of rice and wheat. In such a scenario, water requirements are three times higher than water currently available, capital requirements twice as high as capital currently used and the biocide index only slightly higher than at present. By introducing in successive runs of the MGLP model, a constraint for water use to its current availability and limited technology adoption, the consequences for food production and other objectives are revealed. The analysis shows the potentials and limitations of natural resource use and to what extent alleviation of particular constraints (via appropriate policies, education, socio-economic development or infrastructure) may enhance the resource potential for increasing food production and might affect other, economic and environmental objectives. In addition to results in table-form, maps could be shown with regional land use allocations associated with different scenarios (see for more extensive examples of results Aggarwal et al., 2001; Roetter et al., 2000a, 2004).

**Developing a research network**

Fig. 5 schematises the joint networking and learning process within SysNet, i.e. theory was generated and delivered by the International Agricultural Research Centres, and refined during application within the case studies with the NARS. Subsequently, local governments and development agencies were included in the loop, through the case study applications and the stakeholder workshops. The SysNet project benefited from the research network established in the Simulation and Systems Analysis for Rice Production project (SARP, Kropff et al., 1994) of Wageningen, IRRI and 15 NARS in Asia, in which members of the Indian and
Philippine teams were already involved, but also new teams were established (Vietnam and Malaysia). The various symposia and training workshops (section on ‘SysNet approach and methodology’) resulted in 4 teams of scientists for the case studies, being highly multi-disciplinary, i.e., soil scientists, agronomists, economists and computer programmers were represented in each of the four teams. The necessity to communicate and collaborate across disciplines was mostly new to the researchers, but successful. The international workshops in the Philippines (1997; 1999) and Vietnam (1998) stimulated interaction among the various NARS, as well as collaboration with scientists from the international institutions.

Stakeholder participation

Stakeholders were involved primarily through stakeholder workshops, and to a minor extent through bilateral contacts between researchers and stakeholders. The process of stakeholder involvement was strongly shaped by the social and political traditions in each of the four countries and the attitude within the four national research teams towards allocating time to either natural science or social science components of SysNet. As a result of various factors, stakeholder involvement was most profound in Kedah-Perlis (Malaysia) and Ilocos Norte (Philippines). Fig. 6 summarises the involvement of various stakeholder groups in various stages of methodology development and application for these two study regions. The five stages in the figure were derived from the generalised 5-point scheme of ecoregional research programs (ISNAR, 1998). Note that SysNet only dealt with the first four stages and not with implementation of land use options.

At the start of SysNet (early in 1997), consultative meetings were held between researchers and stakeholders (incl. farmers), dealing with problem definition and characterisation of current conditions (points 1 and 2 in Fig. 6). Identification and quantification of the major ecoregional topics and processes (point 3) were the subject of the first interactive stakeholder–scientist workshops, held early in 1998. Stakeholders were involved at the beginning and end of the 1-week workshops to identify resource use objectives, assist in data collection and review first results of the prototype LUPAS. In a second round of in-country workshops, in the first half of 1999, scientists and stakeholders reviewed the updated models and databases, resulting in model improvements and filling of data gaps (Point 4 in Fig. 6). The revised LUPAS, including the databases, formed the basis for generating land use options, documenting procedures and tools and presenting the results at the international symposium held at IRRI (October 1999, Roetter et al., 2000a). The third and final

Table 3
Production of selected commodities, income, resource requirements and environmental impact at Haryana state level, when maximising food production, while considering various constraints. The last column shows the current values

<table>
<thead>
<tr>
<th>Item</th>
<th>Unit</th>
<th>Constraints</th>
<th>Current level (1996–1997)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Land</td>
<td>Land + Water</td>
</tr>
<tr>
<td>Food</td>
<td>Million tons</td>
<td>39.1</td>
<td>17.4</td>
</tr>
<tr>
<td>Rice</td>
<td>Million tons</td>
<td>27.3</td>
<td>5.1</td>
</tr>
<tr>
<td>Wheat</td>
<td>Million tons</td>
<td>11.8</td>
<td>12.2</td>
</tr>
<tr>
<td>Milk</td>
<td>Billion litres</td>
<td>6.8</td>
<td>6.3</td>
</tr>
<tr>
<td>Income</td>
<td>Billion rupees</td>
<td>109.9</td>
<td>73.8</td>
</tr>
<tr>
<td>Land used</td>
<td>%</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Irrigation</td>
<td>Billion m³</td>
<td>56.4</td>
<td>17.8</td>
</tr>
<tr>
<td>N fertiliser</td>
<td>Million tons</td>
<td>1.51</td>
<td>0.79</td>
</tr>
<tr>
<td>Employment</td>
<td>Million labour days</td>
<td>666</td>
<td>384</td>
</tr>
<tr>
<td>Capital</td>
<td>Billion rupees</td>
<td>114.2</td>
<td>56.9</td>
</tr>
<tr>
<td>N loss</td>
<td>Thousand tons</td>
<td>61.4</td>
<td>37.6</td>
</tr>
<tr>
<td>Biocide residue index</td>
<td>—</td>
<td>95</td>
<td>94</td>
</tr>
</tbody>
</table>

a Production of oilseed, chickpea, cotton and sugar (jaggery) were fixed at their current level (1996–1997), i.e. 0.99, 0.28, 1.53 and 0.90 million tons or bales (cotton—170 kg per bale).

b Objective function maximised.

c Biocide residue index is defined as (use of chemicals in g/ha * Toxicity index * Persistence index)/100.
(within SysNet) round of stakeholder workshops (2000), aimed at discussing the most recent results of the scenario analyses with regional and municipal stakeholders, to discuss capabilities and limitations of LUPAS and steps needed for transfer of the methodology and tools.

**Analysis of stakeholder participation**

The process of stakeholder involvement was evaluated for the Malaysian case, through: (i) review of the research documents; (ii) semi-structured interviews with stakeholders and scientists; and (iii) participants’ observation (Riksen and Sterk, 2002). The analysis resulted in three key conclusions.

First, a thorough stakeholder selection, early in the project, or even before its implementation, is critical, to ensure **timely and sustainable** involvement of those representatives that have a stake in policy making on natural resource use. A clear separation of the decision-makers, land use planners and implementers is needed in determining the nature and timing of their involvement, since they have different roles to play in the development process. Addressees and contents of invitation letters, particularly the language (English or Malay) and style in which they are written determine who will read the letter and in fact who are invited. The invitation must be introduced and explained properly: what is the expected role of stakeholders in the research project: data supply, providing feedback on methodology development, becoming an end user of developed tools or of the information generated, etc. Evidently, SysNet’s invitation to stakeholders was perceived ambiguously: some stakeholders perceived their role as supplying data and information (a resource for research), others were motivated because of a possibility to learn about new research methodologies and insights (research as a resource).

Secondly, the evaluation showed that stakeholder workshops were very effective, but not sufficient to create an interdependent relationship between the project scientists and the stakeholders, an essential condition for a participatory approach and the basis for creative, collective learning processes (Leeuwis, 2000). Bilateral contacts in periods between the workshops are needed for various reasons: (i) to increase comprehension of innovative and complex new research concepts and methods; (ii) to increase opportunities for feedback between the project and the stakeholders; and (iii) to enhance sustained participation of the same stakeholders throughout the project. Perhaps as a result of the low frequency of contacts, participation in the workshops was variable; only a few stakeholders participated in all three workshops. Creation of an interdependent relationship could also stimulate perception of the workshops as a ‘safe environment’, for open and critical interaction about, sometimes, politically sensitive issues. Interestingly, some stakeholders who had developed a collegial relationship with the scientist(s) expressed much enhanced comprehension of the methodology.

Thirdly, it took a major effort to introduce the precise purpose of the LUPAS methodology in the process of creating awareness on natural resource management issues and devising policies. A critical factor essential for a proper appreciation of LUPAS appeared the
difference in the time horizon considered in ‘future studies’ and that considered by the stakeholders. LUPAS has been developed for exploring strategic (e.g. 10 years ahead) resource-use options, whereas stakeholders are generally interested in much shorter time horizons. They tend to focus on pathways, i.e. which changes are feasible today or next year, to arrive at a particular target, a few years ahead (De Ridder et al., 2000). It is also essential to convey that LUPAS should be regarded as a learning support tool, rather than a decision support tool.

Discussion and conclusions

Out of a number of possible purposes of integrated modelling for natural resource management (Parker et al., 2002; Dale, 2002), three may apply to LUPAS: (i) a tool for helping to develop an understanding and stimulating awareness of the system being managed; (ii) an exploratory vehicle for scenario building and revealing new options for change; (iii) a device for communicating scientific notions to and/or from a scientifically lay audience. In this section we evaluate communicating scientific notions to and/or from a scientifically lay audience. In this section we evaluate the SysNet project from two perspectives: (1) potential role of LUPAS within policy design trajectories; (2) design of the SysNet project and communication of LUPAS to stakeholders.

The potential role of LUPAS within policy design trajectories

SysNet and its LUPAS target at a specific niche in land use analysis and policy development, i.e. revealing strategic natural resource use conflicts and (in)feasibilities of alternative agricultural resource use options (phase 3, Fig. 1). Conceptually, it appeared to be a difficult step for stakeholders to think about long-term, biophysical options before addressing short-term plausible changes (cf. ‘first view’, section on ‘Positioning the SysNet approach in a policy development cycle’), but during the course of the project this approach was appreciated and enhanced strategic thinking of stakeholders. LUPAS computes trade-offs between conflicting objectives and outer bounds of the feasible solution space for agricultural resource use. These issues are by their nature highly future-oriented, which should be reflected particularly in the objective functions and the number of alternative land uses and production technologies that LUPAS addresses (De Ridder et al., 2000). We consider, for example, the inclusion of environmental objectives, which were considered of minor importance by some stakeholders, as a responsibility of scientists. Science has a role to play in generating information and revealing threats and opportunities, even if that information does not match current interests of policy makers or particular stakeholder groups. More in general, to use the potentials of LUPAS, a very broad and open-minded range of alternative production (and possible other) activities should be evaluated. In addition, an extensive analysis of the sensitivity of the explored options and limitations to changes, in for instance prices, is essential in order not to overlook important opportunities or overestimate particular options.

LUPAS explores ‘what-if’ questions at regional scale by scaling up information from land units, without addressing the farm household or any other intermediate hierarchical level. Hence, results should not be interpreted as predictions. Results of LUPAS should be considered as partial, but relevant information in support of creating societal and political awareness on opportunities and limitations of future natural resource use.

Recognition of the possible, albeit modest, role of quantitative multiple goal analysis in land use planning processes, immediately triggered the desire of stakeholders to extend the capabilities of LUPAS towards multi-scale issues, particularly the farm household scale, in combination with municipal and provincial scales. Moreover, stakeholders were seeking predictive capabilities, to assess likely or plausible changes in land use. This would enhance the capacities to actually design policies and evaluate a priori or ex post the effectiveness of policies in order to realise specific objectives: phases 4 and 5 of the development cycle presented in Fig. 1 (e.g. Kruseman and Bade, 1998). Hence, a follow-up to SysNet, the IRMLA (Integrated Resource Management and Land Use Analysis in East and South-east Asia—www.irmla.alterra.nl) project, aims at developing and using complementary, predictive farm household models enabling to deal with multi-scale issues and effectiveness of alternative policy instruments.

Design of SysNet and stakeholder interaction

The process of involving stakeholders in a model-based research project was unique, well-received and resulted in many suggestions for improvement. The uniqueness was well illustrated by a statement of a Malaysian stakeholder: “This is the first time we as stakeholders get to interact with scientists. Usually they develop the model, present it to us and we refuse to use it”. Creating and maintaining an interdependent and sustainable relationship between a research project and stakeholders requires a significant and continuous investment with different modes of interactions (workshops, bilateral meetings, written communication, etc.). Evidently, the stakeholder involvement calls for a thorough understanding of the actual planning processes, information needs, hierarchies and key persons involved, determining who to invite and how (cf. Ravnborg and Westermann, 2002; Rykkel et al., 2002).
This prerequisite was only partially met in SysNet at the time stakeholder involvement started. Explicit definition of the precise roles of stakeholders in the project, and a corresponding precise invitation to exactly the right stakeholders (representatives, policy makers and implementers) is vital and requires significant and timely resources.

The successful use of LUPAS is only possible if there is sufficient, shared awareness of problems and the need for solutions among the stakeholders. The project has demonstrated that, once a prototype of LUPAS was operational (preferably with a user-friendly interface) and stakeholders had the proper level of comprehension, LUPAS could serve as a vehicle to demonstrate potential conflicts and reveal strategic resource use options, and stimulate discussion among different stakeholder groups. Stakeholders from Malaysia, the Philippines and Vietnam were keen to extend the use of the methodology. However, presumably the project would have benefited from a more complete identification of problems and information needs as perceived by stakeholders and policy makers. A better contextualisation (cf. David, 2001) would have been an asset in bridging the gap between the information supply of LUPAS and needs of the stakeholders (cf. Walker, 2002; Rykiel et al., 2002).

It is essential to develop and communicate clear concepts on how learning tools such as LUPAS can be used in policy development processes. It is still unclear, and opinions among the various parties involved in SysNet certainly differed, whether it is actually desirable to aim at transferring the tools to planning agencies, or whether the operational use of the tools remains the task of researchers and only the results and insights generated by the tools need to be shared. Most likely, for the majority of the non-scientist stakeholders, emphasis should be on the concept and interpretation of the research methods rather than on the technical aspects. An independent facilitator, assuming an intermediary role between scientists and other stakeholders, might be effective in creating the right and safe environment to realise this (Leeuwis, 2000).

Final conclusions on SysNet and its set-up

SysNet has demonstrated the relevant but also clearly delineated role that quantitative land use analysis methodology using MGLP (LUPAS) can play to enhance insight into the strategic limitations and opportunities of natural resource management. Its highly future-oriented nature enables exploration of new or emerging strategic natural resource use issues and what-if questions, quantification of outer boundaries of natural resource use options, as well as identification of options for compromises among conflicting objectives. SysNet also produced important insight and hands-on experience in how such tools and information may be effectively communicated to stakeholders. The establishment of stakeholder interactions and their maintenance and the actual use of LUPAS as a learning support tool require significant and long-term investments from both researchers and stakeholders, which are hardly feasible in a 4-year research project with a limited budget. In the various case studies of SysNet, however, it was shown that successful interaction can improve the quality of problem analysis and identification of development objectives, targets and constraints, produce a multitude of information and feedback on model approach and preliminary results and stimulate the joint learning. We regard the development and application of ‘natural science’ methodology in a ‘social science’ mode as enhancing understanding of model legitimisation and implementation, and an invaluable source for further methodology development and application. However, for successful establishment of multi-stakeholder platforms that actually use LUPAS, tools and methodologies should be mature and only require slight adaptation, while trained local research teams should be in place and part of the institutional setting.

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