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Quantitative analyses of natural resource management options at different scales

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Natural capital consists of many resources, each with its own dynamics, renewability and movements, but with strong interactions among them. With respect to functioning and performance of agricultural ecosystems, the natural resources that come to mind are land and water, and to some extent air.

More than ever before in human history, the way in which land is being used has become a source of widespread concern. In 1999, the population of the world surpassed 6 billion; hence the demand for accessible and safe food is higher than ever, while the negative impacts of food production on the quality of the natural resources are increasingly recognized. Income of especially the urban population continues to increase, leading on the one hand to changing diets with the associated impacts on land requirements for food production and on the other hand to higher demands for alternative land uses, such as nature, recreation and employment. Moreover, globalization is leading to increasing pressure on the economic viability of food production systems, resulting in a search for more remunerative land uses by many farmers in both the developed and developing world and the eventual abandonment of land. Moreover, there is growing awareness that the availability of water for agriculture is declining, because of increasing competition from other uses, such as industrial and domestic. The sustainability paradigm has been introduced as an umbrella to cover and pay tribute to all these different aspects of the use of land. These developments lead to a call for a basic redirection in the analysis of land use, in which the concept of multi-functionality will play an ever-increasing role. In that situation, where many different (groups of) stakeholders have an active interest in the way the land is used, new methodologies for land use studies are required, as a basis for formulation of land use policies. In these methodologies, the aims and aspirations of the different stakeholders have to be taken into account, but they should be based on thorough knowledge of the agro-technical possibilities and socio-economic boundary conditions under which land use has to take place.

In land use studies, two main directions can be distinguished, i.e. explorative studies that aim at defining the envelope of development possibilities and have their main focus on ‘what would be possible?’ These studies emphasize the bio-physical possibilities, in the belief that, at least in the long run, most human-related factors and attitudes can be adapted (or can be forced in a desired direction), whereas the biophysical conditions can hardly be modified, and thus form a basis for explicit quantification of the options. The second type may be characterized by the term predictive, and focuses on the questions ‘what can be changed?’ and ‘how can desired changes be realized?’ These studies, therefore, emphasize current and foreseeable future situations in terms of the (socio-)economic environment and land use pattern, and consider these as the main constraints to modification. Explorative and predictive
land use studies have distinct and different roles within the process of land use planning and policy formulation. Thus, each phase or step within a so-called land use analysis cycle requires different types of information and thus distinct land use studies.

In this paper, the land use analysis cycle is introduced and recent methodological developments for supporting some of its distinct phases are illustrated. At plot or field level, tools are available to quantify the production possibilities for various crops. Quantification becomes more difficult as less of the production factors are under control. Thus there remains a certain degree of uncertainty in identification of the options for resource management. For rotations, quantification becomes more difficult, as many of the underlying processes are only partially understood. However, successful examples are available.

Illustrations will be given for quantitative analysis of management options at the farm level. In terms of explorative studies these tools appear highly successful and where the socio-economic environment is conducive, results of such analysis can indeed be based for formulation of development options.

Tools have been developed for quantitative analysis at (sub-)regional level, that allow exploration of the outer envelope of development possibilities.

The examples still largely bear an academic character, but since there is increasing demand by policy makers for integrated land use analysis studies, they may serve as building blocks for development of operational methodologies for land use policy formulation and analysis. Their potential impacts on planning procedures and achievement of land use objectives are high, particularly when they are further developed and operationalized in settings that allow participation and involvement of the various user groups.

*Keywords:* Land use analysis; Sustainability; Natural resource management; Multi-functionality
Disentangling poverty and biodiversity in the context of rural development: A case study for Pujiang county, China

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Both, poverty reduction and preservation of biodiversity are high on the global agenda on sustainable development. The relationships between poverty, biodiversity of ecosystems and agricultural development are complex and poorly understood. In this paper we present an integrated framework for analysis of agricultural development and natural resource management options at ecosystem level. We use Pujiang county, in Zhejiang province, China as a case study area to perform the analysis. A regional Linear Programming (LP) model is applied maximizing regional economic surplus given product and labour market conditions in Pujiang. We use the model to determine the consequences of four so-called poverty reduction strategies, i.e. (i) intensification of production, (ii) diversification towards livestock production, (iii) land expansion, and (iv) exit from agriculture, for a set of regional poverty and biodiversity indicators. Diversification seems the most promising poverty reduction strategy, but requires an efficient use of animal manure in cropping systems to avoid environmental problems. Improved nutrient management in cropping systems is effective in reducing the regional nitrogen surplus but less effective in increasing per capita income. The exit strategy is beneficial for reducing poverty and achieving biodiversity goals, but may have important social consequences which are not addressed in this study. Further reduction of rural poverty is hampered by labour constraints during the harvesting period in high value crops such as vegetables and fruits, which calls for research and development in the field of agricultural mechanization.

\textit{Keywords:} Diversification; Intensification; Environment; LP; Sustainability; Ecosystem approach
Policy reforms, rice production and sustainable land use in China: A macro-micro analysis

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This paper presents a macro-micro analysis of the impact of policy reforms on agricultural production, input use and soil quality change for a major rice-producing area, namely Jiangxi Province. The paper starts with an overview of major policy reforms implemented in recent decades, from the introduction of the household responsibility system (HRS) at the end of the 1970s to the rural income support policy introduced in 2004. It is followed by a quantitative assessment of the impact of market liberalization policies on the economic environment of farm households in Jiangxi Province. Econometric analyses based on provincial, national and world market data are used to explain changes in agricultural input and output prices in Jiangxi Province over time. Next, the impact of China’s recent income support policy and recent price trends on farm household choices with respect to activity choice (particularly rice and livestock) and input use (fertilizers, pesticides, manure) is assessed for two villages with different degrees of market access in Northeast Jiangxi Province. Two village-level general equilibrium models are used to analyse household decision making and interactions between households within these villages. The parameters are estimated and calibrated from an extensive survey held in these villages in the year 2000. Finally, the impact of land tenure policy on farm management decisions (labour, manure and chemical input use), soil quality (available P and K and total N and C) and rice yields is analysed through an econometric analysis of plot-level data for three villages. Two-stage least squares (2SLS) is used to control for interactions with yields and for feedbacks towards input use. The main conclusions drawn from the analysis are:

- The world market price has become the main determinant of the prices of grain in Jiangxi Province and in China since 1994.
- The profitability of fertilizer application in Chinese agriculture has increased considerably during the 1990s, particularly in Jiangxi Province.
- Recent grain price increases seem to aggravate agriculture related environmental problems in Northeast Jiangxi Province.
- The grain price increases since the second half of 2003 have a much larger effect on farm household incomes and production decisions than the direct income subsidy and (to a lesser extent) the abolition of the agricultural tax.
- The recent rural income support policy does not reach its goal of promoting grain production. It reaches the goal of reducing income inequality only within villages, not between villages.
• Consolidating small, fragmented plots into a smaller number of large plots will increase input-use efficiency contributes to soil quality improvement by increasing the availability of the two major yield-limiting factors in rice production in the research area, the available phosphorus and potassium in the soil.

*Keywords:* Market policy; Rural income policy; Land tenure; Price changes; Input use; Soil quality; Village economy; Household responses
Rice trade in a liberalized world: A review of economic studies

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Rice is the most important staple crop in Asia and demand is expected to increase dramatically. Already now, more than 20% of global calories consumed come from rice and for low-income countries this is even 29%. At the same time trade in rice only accounts for 6.5% of total rice consumed, which is substantially less than other major crops. Recent studies show that totally liberalizing global rice trade will significantly increase economic welfare by up to $7.4 billion per year. This paper points out that while the benefits of free trade are substantial, there is also sufficient evidence to support arguments for price stabilization and that there is common ground between these seemingly contradicting regimes. The effects of stabilizing safeguard mechanisms are illustrated with model results for Indonesia.

Keywords: WTO; Doha round; Trade; Trade policy; Rice markets
Comparative studies on rice farming systems in Japan, Bangladesh, Indonesia, Thailand and West African countries

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During 1961–2003, Japan decreased per capita paddy production and consumption from 180 to 84 kg but paddy yield increased 5.3 to 6.4 t ha⁻¹. The marked decline of rice cultivated area might relate to the degradation of present Japanese environment through the loss of multi-functionalities of sawah systems. Although per capita paddy production kept constant about 400 kg, since the paddy yield steadily increased 1.8 to 2.6 t ha⁻¹ during the same period, Thailand has been major rice exporter in the world. Bangladesh increased paddy yield doubly 1.7 to 3.4 t ha⁻¹, but decreased slightly per capita paddy production, 266 to 233 kg during 1961–2000. Although both per capita paddy production and paddy yield increased sharply 120 to 235 kg and 1.9 to 4.5 t ha⁻¹ respectively during the same period, since the per capita consumption also increased 145 to 250 kg, Indonesia imported the highest amount of rice in the world in 1997. During the same period, although per capita paddy production increased 5.5 to 14 kg in Ghana, 6 to 30 kg in Nigeria, and 20 to 30 kg in West Africa, since per capita paddy consumption also increased 14 to 38 in Ghana, 9 to 48 in Nigeria, and 26 to 56 in West Africa, the importation of rice increased dramatically in West Africa.

Except for the arsenic pollution problems in Bangladesh, the Green Revolution technology widespread in Asia Developing since the 1970s showed no serious problems on soil fertility degradation at the moment. Long-term monitoring will be important. The Green Revolution, however, not yet occurred in West Africa and Sub-Saharan Africa, the regions with the most serious food and environmental crises in the world. The potential of sawah-based rice farming in West Africa is enormous. Although lowland soils fertility and hydrological conditions in West Africa may be the lowest in the world, since the agro-ecological conditions are quite similar to those of north-eastern Thailand, the sawah-based rice farming can overcome such soil fertility problems through the enhancement of the geological fertilization process, conserve water resources, and the multi-functionality of the sawah type wetlands. This is a sawah hypothesis (Hirose and Wakatsuki, 2002). Asian African collaboration with the interfaces of Europe and USA will be a key for sustainable sawah development.

The term sawah refers to levelled and bunded rice fields with inlet and outlet connecting irrigation and drainage. The term originates from Malayo-Indonesian. The English term, paddy or paddi, also originates from the Malayo-Indonesian term, padi, which means rice plant. In order to avoid confusion between the terms rice plant, paddy, and man-made rice growth environment, the author propose to use the term sawah.

Keywords: Bangladesh; Ghana; Geological fertilization; Indonesia; Japan; Nigeria; Sawah-based rice farming; Sustainable rice production; Trend of rice production during 1960–2000; Thailand; West Africa
Ecological and economic sustainability of rice cultivation in Europe and the Mediterranean region

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Rice is at present an important crop in many European and Mediterranean areas, where it is cultivated on a total of about 1,300,000 ha. The most important rice-producing countries are Egypt, Italy and Russian Federation. The average crop yield is quite variable as it ranges from 9.8 t ha⁻¹ in Egypt to 3.4 t ha⁻¹ in Russian Federation. Rice is cultivated in different types of soils: light, heavy, hydromorphic. In some regions, soils are saline or very saline. Most rice fields are permanently flooded with waters mainly coming from rivers. About 80% of the European and Mediterranean rice area is cultivated with japonica varieties and the remainder with indica-type varieties. In the European rice area the spread of mechanization led to the increase of the average farm size. Average milled rice consumption ranges from about 5 kg capita⁻¹ yr⁻¹ in most European countries to 42 kg capita⁻¹ yr⁻¹ in Egypt. In Southern European countries about 80% of the consumed rice belongs to japonica varieties, while in Northern Europe long-grain indica-type varieties are usually preferred. Main qualitative traits of rice are related to the shape, colour, processing and cooking features of the grains. Rice eco-systems are currently facing with numerous issues, such as poor crop establishment, low temperatures, water scarcity, biotic and environmental stresses, inefficient agronomical practices, which result in a low return from rice production. Most of these issues can be addressed by improving the co-operation among rice research institutions and applying rice integrated crop management systems.

Keywords: Rice ecology; Rice farm organization; Rice market; Rice constraints, Rice quality
Government intervening and excessive loss of farmland conversion in China

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On the theoretical analysis of expense loss and excessive loss of farmland conversion, this paper employs province-level panel data to compute the excessive loss of farmland conversion in China from 1989 to 2002, excluding 1997 and 1998 with the frontier production function. The result shows that the excessive loss of farmland conversion in China is 203,213 ha in 1989-1996 and 1999-2002, which is 13% of the total conversion amount. The excessive loss in the Eastern region is more serious than that of the Central and Western regions. The policy reform direction is not only to accelerate the construction of land markets in the future, but also pay more attention to the market in the Eastern region nowadays.

Keywords: Farmland conversion; Market allocation; Excessive loss
Opportunities for yield increases and environmental benefits through site-specific nutrient management in rice systems of Zhejiang Province, China

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Environmental pollution by nitrogen (N) leaching or runoff from rice fields and high pesticide use has become serious concern in China. Average N application rates are high and fertilizer-N use efficiency is low compared with other major rice growing countries. In Zhejiang, rice farmers apply 150–250 kg ha⁻¹ fertilizer N and 7–10 sprays of pesticides per season to maintain yield levels of 6–7 t ha⁻¹. Fertilizer and pest management strategies of farmers are not based on plant nutrient demand and pest control requirements, and appear to be largely directed at risk avoidance. To provide farmers with options for high yielding, yet more resourceful management options, a new site-specific nutrient management (SSNM) approach was developed at Zhejiang University in collaboration with the International Rice Research Institute (IRRI). The main objective of this paper is to introduce SSNM as an important component of sustainable resource management in rice ecosystems. The approach comprises of guidelines that allow farmers to adjust domain- and season-specific fertilizer recommendations to actual growing conditions in their fields. Recommendations are developed for profitable grain yield targets considering plant nutrient demand, indigenous nutrient supply, nutrient balance, nutrient use efficiency, as well as socio-economic factors. The agronomic performance of SSNM has been evaluated in farmers’ fields in the past seven years (1998–2004). With SSNM, average grain yield increased by about 0.5 t ha⁻¹ over the farmers’ practice, while N use efficiency increased significantly. About 30% of both fertilizer N and pesticides could be reduced through adoption of SSNM, which would effectively eliminate an unnecessary source of pollution in the rice ecosystem. Larger scale dissemination of SSNM for rice is under way in Zhejiang province, but stronger institutional support is urgently required.

Keywords: Rice; Fertilizer nitrogen; Site-specific nutrient management
Management strategies for saving water and increase its productivity in lowland rice-based ecosystems

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Traditional lowland rice production in Asia requires much water: it consumes more than 50% of all irrigation water used in Asia. Water resources are, however, increasingly getting scarce and expensive. The supply of water for irrigation is endangered by declining water quality, declining resource availability, increased competition from other users, and increasing costs. Rice is especially sensitive to declining water availability since it requires more water than any other food crop and it has relatively low water-use efficiency. At the farm level, water inputs can be reduced by decreasing the relatively large and unproductive losses from seepage, percolation, and evaporation. In the last decade, researchers have studied and developed a number of water-saving irrigation technologies such as saturated soil culture and alternate wetting and drying (AWD) that can drastically diminish these losses. Under these technologies, yields may decline, but they have demonstrated that they save water and increase water productivity. Unfortunately, adoption by farmers is low because extension activities are lacking. Compared with heavy investments needed to develop new water resources, the adoption of water-saving technologies by farmers is low-cost and has great potential to save water. In 2001, we initiated a farmer-participatory project called ‘Technology Transfer for Water Saving (TTWS)’ to transfer and promote AWD among farmers in the Philippines. The TTWS was conceived to develop and implement a framework for transfer, adaptation, and adoption of knowledge on water-saving technologies. Actual measurements from farmers’ fields showed that AWD had the same yield as farmers’ practice and that, on average, it saved 16-24% water and 20-25% costs. Group factors identified for successful collective action to facilitate AWD adoption are group size, service area, profitability, high level of excludability, enhancement of existing social capital, strong leadership to deal with free riders, and close linkages with local governments.

Aerobic rice is a new concept of growing rice using less water: high-yielding rice is grown in nonpuddled aerobic soil using supplementary irrigation just like upland crops. Farmers in China and Brazil where water is scarce or costly are pioneering this system. A group of first-generation elite aerobic varieties have already been developed and released in temperate northern China, replacing traditional lowland rice on some 190,000 ha water-short irrigated area and traditional upland crops on low-lying flood-prone areas. IRRI started an aerobic rice program for the tropics in 2001. The program aims to develop (1) aerobic rice varieties for tropical condition; (2) integrated management practices for water, weeds and nutrients; and (3) sustainable and environment-friendly systems. Objective 1 is being addressed through varietal breeding, screening, and yield trial evaluations. Objectives 2 and 3 are being addressed through field experiments and farmer-participatory R&D. We have now tested and selected three varieties with average yields of 4.4 t ha$^{-1}$ in the wet season and 3.4 t ha$^{-1}$ in the
dry season in farmers’ fields. Yields during the wet season were more stable than those in the dry season. Some farmers got extremely high (>6 t ha\(^{-1}\)) and extremely low (<1 t ha\(^{-1}\)) yields in the dry seasons. However, more aerobic rice varieties are needed and understanding management strategies is essential if this system is going to be successful. Through the adoption of water-saving irrigation technologies, rice land will shift from being continuously anaerobic to partly or even completely aerobic. This will have major consequences on sustainability, such as weed, pest, and disease ecology and nutrient and soil organic matter dynamics.

*Keywords*: Aerobic rice; Alternate wetting and drying; Technology transfer for water savings; Water management strategies
SiRBInt: A new rice simulation model to forecast blast disease

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Pyricularia grisea (Cooke) Sacc. is the causal organism of blast, the most serious disease of rice because of its devastating nature, widespread distribution and existence of several physiologic races. It occurs in epiphytotic conditions in all major rice-growing regions of the world, as well as in Italy. Nowadays, no strategies in current use are based on the dynamics of airborne conidia, the most important means of dissemination of the pathogen, and chemicals and management practices are the only means of blast control. However, blast forecasting may open the possibility of more rational use of fungicides and blast simulation models might prove to be useful in predicting the potential for the disease.

During three growing seasons (2002, 2003 and 2004) and in two different rice fields located in Northern Italy (Sali Vercellese, Vercelli Province and Castello d’Agogna, Pavia Province), concentrations of P. grisea airborne conidia were measured using automatic spore traps. Temperature, humidity, rainfall and leaf wetness were also monitored and direct visual estimation of necrosis on leaves, culms and neck nodes was scored.

Based on the crop growth simulation model ORYZA1, a new dynamic deterministic model (SiRBInt) simulating the rice–blast interaction and including both crop and pathogen growth pattern dependent on weather conditions was developed.

The model is mainly intended to serve technicians working in the extension service and will simulate the potential risk of blast infection. The three years work demonstrated that the model can simulate the blast appearance in field and that it can be used in advising on fungicide application. Validation of the model is needed to verify effect of meteorological data both on rice growth and blast development during a larger number of years.

Keywords: Rice blast; Pyricularia grisea; Airborne conidia; Modelling; Forecasting
Methods and information for quantifying inputs and outputs of cropping systems

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For resource use analyses at the field scale, and exploration of options for future land use at the regional scale, input-output relationships for present and possible future cropping systems should be quantified. For each combination of crop(s), land unit and production techniques the outputs (i.e. yield level and the related environmental impacts) and the required inputs (i.e. demand for labour, machinery, nutrients, and water) need to be calculated. This paper describes methods and information required for quantification of inputs and outputs of cropping systems.

For the analyses of input-output relationships, target yields are often the major characteristics which need to be derived for both current and future cropping systems. For establishing yields of current systems, information from agricultural statistics and field surveys are to be used. The representativeness of such yield data for large areas around the measurement location and in particular for regions with a large variation in environmental conditions, may be problematic. For establishing yields of future-oriented systems for a range of biophysical conditions over a region and a range of possible types of crop management and production techniques (e.g. crop variety, sowing date, nutrient management), model application in combination with a geographical information system and geo-referenced data bases appears to be the best approach.

Technical Coefficient Generators (TCG) allow the rapid quantification of inputs and outputs of large numbers of current and future-oriented cropping systems in an area under study. TCGs are important tools for the integration of different types of information and data enabling well-balanced decision-making with respect to resource use. Their application may result in improved data collection, may help to set the research agenda with respect to land use processes for which knowledge is incomplete but relevant, and may contribute to the identification of trade-offs between production, economics, and environmental impacts of land use systems.

Keywords: Crop model; Cropping system; Crop yield; Land use; Production technique; Resource use efficiency; Systems analysis
New challenges for a multi-scale approach to land use system modelling

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This manuscript presents 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: 1. interactions between achievement of objectives at provincial and municipal scales; 2. effects of farm structure, infrastructure and markets for agricultural goods on natural resource use options at municipal scale, and 3. differences across farm types in possible technology adoption and the effect of technology adoption. Finally, the multi-scale method and results from the analyses for Ilocos Norte are discussed, in the wider context of important opportunities and shortcomings of today’s multi-scale assessment of natural resource management.

Keywords: Multi-scale analysis; Linear programming; Natural resource use; Farm household model; Policy analysis
Application of system analysis methodology for land use planning in Tamduong District, Vietnam

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Tamduong district, Vinhphuc province, located in upstream of Red River Delta in the North of Vietnam, where the competition between agriculture for land use to produce food and alternative uses of land grows at an alarming rate. With such pressure, marginal lands are forced into cultivation and species habitats are rapidly decrease. The objectives of the research is to contribute to sustainable agricultural development in the district through novel techniques of resource use analysis and land use planning with specific of: (i) To design innovative production systems that produce sufficient food and that are resource-use efficient and sustainable land use; (ii) To develop scientific-technical approaches that support development of sustainable land use systems through informed decision-making on resource use at various hierarchical levels and interactive policy design, and (iii) To develop operational tools integrated in a decision support system for multi-scale analysis of land use systems and appropriate policy interventions. The methodology comprises three main components: (i) Evaluation of the resources required for agriculture development, (ii) Estimation of inputs and outputs for production activities, and (iii) Optimization of land and resource allocation subjected to policy views and development objectives for analysing slope-soil-crop suitability.

In the first step of qualitative land evaluation, time-invariant terrain and soil properties were used for analyzing slope-soil-crop suitability. The second step takes into account dynamic climatic factors that influence crop-season suitability at each land unit. Thirdly, each land unit was evaluated for its suitability for selected land use types, which are combination of crop-seasons. Data on agricultural production collected at commune level were used to quantify inputs and outputs associated with existing and promising land use types for each land unit. The input-output tables were used in optimization modelling. The GAMS model computes the optimal allocation of resources (land, water, labour and capital) to achieve user-specified development objectives, under certain assumptions about the levels of resource availability with the constraints of water limited up to 40.59 mil. m³ per year, sharing of 1.6 mil. labour-days per month of agricultural labour, and limited of capital for investments, in combination with technology levels. Considering the main target of the district in 2010 is 17.4 mil. US$ income from agriculture production, eleven others scenarios have been developed with its particular bounds. Those bounds are vegetable production up to: 50, 30, 20 and 15 thousand tons, mineral fertilizers use up to 60 and 50 thousand tons, chemical up to 1.33 and 1.07 mil. US$, and the combination of mineral fertilizer and chemical. The results from resources evaluation showed in 22 land mapping units were compiled that suitability for 8 crops and 16 land use types. The results from the optimization model showed that all scenarios satisfied the given target but the scenarios with bounds of vegetation production up to 50 and 30 thousand tons gave highest income by 46.09 and 36.5 mil. US$, respectively.
Scenarios with bounds of mineral fertilizer up to 50 thousand tons and chemical up to 1.07 mil. US$ plus mineral fertilizer up to 50 thousand tons gave lowest income by 19.49 and 19.23 mil. US$, respectively. For the detailed output, the results indicated which land use types are selected, how many resources are needed, and the production levels and incomes expected. The results are mapped to show the spatial pattern of the selected land use types. The outputs provide a rational basis for geographical targeting of different land use types within a particular region. Some conclusion have been drawn as: There are very large gap between current and potential production of agriculture. The potential can be reached by changing of new varieties; investment and increase of natural resources use efficiency. According to the optimization results, vegetable production contributes a high weight for increasing district income in the future. This scenario is feasible because a lot of urbanization and industrialization are carrying out around and close to the district.
Application of systems analysis methodology to Dingras district, Ilocos Norte, Philippines


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Concerns about the rapid increase of population stimulated the need to find efficient land use and management systems that improve the well being of people in the agricultural sector, while at the same time protect the environment. Farm household producers are faced with concerns on the suitability of new technologies while considering the profitability of agricultural production as affected by other factors such as land availability, high input costs, intensification and diversification of crops, household consumption, and capital and credit limitations. In this study, a farm household model is used to evaluate the adoption behaviour of four representative farmers in Dingras, Ilocos Norte Province, Philippines. Three alternative technologies were considered: current farmers’ practice (CFP), integrated pest management (IPM), and combined IPM and site specific nutrient management (SSNM). In addition, changes in household behaviour due to the removal of water constraints and changes in prices of biocide and fertilizer were evaluated. The results show that both the adoption of combined IPM and SSNM and the removal of the irrigation system result in a significant increase in farmers’ income combined with a decrease in environmental impact. On the other hand, the effect of changes in input prices is limited. The paper argues that the presented methodology and results can help in the assessment of existing policies and in the formulation of policies for the improvement of the well being of the farmers and the sustainability of production.

Keywords: Farm household modelling; Cropping systems; Integrated nutrient management; IPM; Dingras; Philippines
Application of systems analysis methodology for integrated resource management and land use planning: Omon case study

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There is an urgent need for proper land use planning especially in agricultural regions that at present face rapid population growth coupled with urbanization and industrialization. Such development puts pressure on scarce natural resources such as land and water. Therefore, to ensure sustainable development and food security in a region, appropriate evaluation and management of natural resources and effective land use planning in agricultural production are required.

Under the framework of Integrated Resource Management and Land Use Analysis (IRMLA) project, tools and system analysis methodology, developed by De Wit et al. (1988) and operationalized for East and South-east Asia by Roetter et al. (2005), are applied to Omon district. In this case study area in the heart of the Mekong Delta, the methodology is applied to explore development options and policy interventions for sustainable agricultural production. Information obtained from this study can be used as reference for open discussion on future land use alternatives.

The results from this study show that Omon economy continues to be depending on agricultural production and has great potential for increasing food production, income and employment.

_Keywords_: System analysis; Linear programming; Land use planning; Omon; Rice
The impact of increasing farm size and mechanization on rural income and rice production in Zhejiang Province, China

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Economic growth in China’s agricultural sector lags behind growth in industry and services, creating an ever widening rural-urban income gap. Yet nonfarm growth offer new opportunities for farmers in China’s more advanced provinces like Zhejiang. Increased income in the urban sector creates markets for new products, and migrating farmers rent their land to those staying behind. In this study, we use a simulation model of the farm household to analyze the effects of increasing farm size and the transition from rice to vegetable production.

Our results show that at the present scale of farming, the dual government objectives of increasing rural incomes and increasing rice production are clearly conflicting. Farmers can obtain incomes comparable to nonfarm wages but only when they stop rice cultivation and switch to more remunerating crops. At larger farm sizes, however, labour constraints inhibit farmers from specialization in non-rice crops and rising per capita incomes and increasing rice production go hand in hand. Mechanization is necessary to allow larger increases in farm size.

Keywords: Farm size; Poverty; Mechanization; China
Introducing greenhouse gas mitigation as a development objective in rice-based agriculture: I. Generation of Technical Coefficients

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This study was conceived as an initial step to assess land-use options and residue utilization for mitigating emission of greenhouse gases (GHG) from the agricultural sector. The overall objective was to develop a decision support system to explore the mitigation options by computing GHG emissions alongside with economic returns for rice-based cropping systems. This tool, named TCMGAS (Technical Coefficient Generator for Mitigation Technologies of Greenhouse Gas Emissions from Agricultural Sectors), integrated analytical and expert knowledge with regional databases on bio-physical, agronomic and socio-economical features to establish input-output relationships (‘Technical Coefficients’) related to GHG emissions in agriculture. The approach included emissions of methane (CH\textsubscript{4}) from rice fields, rice straw burning and cattle; carbon dioxide (CO\textsubscript{2}) from fossil fuel and soil organic carbon decline as well as nitrous oxide (N\textsubscript{2}O) from soil, rice straw burning and fertilizer use. Technical coefficients were generated for an entire rice-wheat cropping cycle in the state of Haryana in northern India as a case study. Twenty technologies of rice production, which can be adopted by the farmers, were analyzed for their global warming potential (GWP) and economic return. The technologies differed in terms of water regime, residue management/utilization, soil management and additives, which represented different mitigation options for GHG emissions. With the current farmers’ practice in various districts in Haryana, soil-borne emissions were the major source of GHG contributing 48% of the average GWP (3136 kg CO\textsubscript{2} equivalent ha\textsuperscript{−1}) in rice followed by the indirect sources i.e., production of farm inputs and farm operations (25% of the GWP). Burning of rice straw, animal and inorganic fertilizer contributed 13, 12 and 2% of the GWP, respectively. Emissions from wheat were relatively low (1369 kg CO\textsubscript{2} equivalent ha\textsuperscript{−1}) as there was no CH\textsubscript{4} emission and wheat straw is not burnt. Different mitigation technologies had pronounced effects on the GWP of the rice crop and varied between 1715 kg CO\textsubscript{2} equivalent ha\textsuperscript{−1} with continuous flooding, urea and rice straw used for building materials and 10020 kg CO\textsubscript{2} equivalent ha\textsuperscript{−1} with continuous flooding, and application of nutrients through organic manure. Compared to the current farmers’ practice 13 technologies found to have potential to reduce the GWP by 8 to 51%, but they also reduced the net income of the farmers. Upscaling the estimates to the entire state of Haryana showed that the GWP with the current farmers’ practice in rice is 2617 Gg CO\textsubscript{2} equivalent. Modification of water management from continuous flooding to alternate flooding or application of urea alone instead of urea plus FYM will reduce the GWP by 15% and 29%, respectively, while feeding of rice straw to the animal and supplying N through urea will reduce it by 41% compared the current practice of
burning rice straw and use of FYM. The study showed that the TCMGAS tool could be used for estimating GHG emission from various land-use types and identifying the mitigation options. A detailed cost/benefit analysis is supplied in Vol. II of the paper.

*Keywords:* Carbon dioxide; Land-use planning; Methane; Nitrous oxide; Rice-wheat systems; Systems analysis
Introducing greenhouse gas mitigation as a development objective in rice-based agriculture: II. Cost-benefit assessment for different technologies, regions and scales

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New tools for land use analysis including detailed cost-benefit assessments are needed to integrate resource management for enhancing farmers’ income and mitigating greenhouse gas (GHG) emissions. The paper comprises an assessment GHG emissions and economic returns under different mitigation technologies in three rice growing regions in Asia, i.e. Ilocos Norte Province (Philippines), Zhejiang Province (China) and Haryana State (India). Site-specific data on soil, climate and socio-economics were integrated in the previously developed spreadsheet model TCMGAS (Technical Coefficient Generator for Mitigation Technologies of Greenhouse Gas Emissions from Agricultural Sectors). Three baseline technologies that differed in terms of inorganic/organic N supply have been compared to different mitigation technologies in form of Marginal Abatement Cost Curves (MACs). For the baseline technology of inorganic N (urea) fertilization, amendment with phosphogypsum and nitrification inhibitors are the most promising mitigation options resulting in break even prices of < 10 US$ per ton of carbon dioxide equivalent (CE). Assuming a mix of urea and farm yard manure for the baseline, we have tested several options including different irrigation patterns and husk used as fossil fuel. Mid-season drainage had a better cost-benefit ratio (ca. 20 US$ per t CE) than alternate flooding, but was less profitable than husk utilization (ca. 4 US$ per t CE). Assuming high organic inputs, biogas technology is in most cases the preferable option (ca. 10 US$ per t CE). Finally, we compiled regional MACs for selected administrative units using the outcome from regional optimization models. Implementing the three most promising technologies required 6,000 US$ in Dingras municipality, Ilocos Norte, in the Philippines (ca. 10³ ha of rice land potentially providing emission savings of ca. 3,000 t CE), 50,000 US$ for Pujiang county in China (ca. 10⁴ ha providing ca. 27,000 t CE), and 1.2 million US$ for Karnal district in Haryana (ca. 10⁵ ha providing ca. 220,000 t CE).

Keywords: Carbon dioxide; Land-use planning; Methane; Nitrous oxide; Rice-wheat systems; Systems analysis
Modelling the effects of cultivated land conversion on the environment and rural development in the Loess Plateau of P.R. China

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The Loess Plateau is located in the middle reaches of the Yellow River, characterized by semi-arid climate, rugged loess terrains and severe soil loss problems. Among factors leading to the serious land degradation, destruction of natural vegetation as a result of over-cultivation of marginal sloping lands is acknowledged as the most important one. In recognition of the causes, Chinese government initiated a policy program, the so-called Tuigeng Huanlin Huancao (conversion of marginally cultivated lands into forestland and grassland) in the late 1990s, to promote restoration/rehabilitation of degraded environments/vegetation by returning the marginally cropping land into its original forms of land use (forest or pasture). Several studies based on household surveys reported that this policy measure is well-accepted by local people because the farmers can directly get the government subsidy in food grains and cash for the cropland conversion. As a strategic measure for the environmental protection, the ongoing conversion of cultivated land will certainly affect several aspects (e.g. income, food security, employment) of the rural development and performance of the natural environment in the long run.

In combination with the conversion of cultivated land, alternative natural resource use systems and specific policy instruments such as subsidies that encourage further farmland conversion should be adopted, to simultaneously achieve both aims of soil conservation and income improvement in the hilly loess area. For a better understanding of issues related to sustainable development in the region, an integrated analysis is needed on the relationships between environmental, socio-economic and agricultural objectives, to learn about the consequences of possible land use changes (based on present trends) in the near future, and about the further scope for sustainable land use and rural development.

The present study revised and updated an existing model and database of land use exploration for Ansai in the hilly Loess Plateau that integrated biophysical, agro-technical and socio-economic information, and assessed the consequences of different farmland conversion strategies on soil conservation, food production, rural employment and income in the case area of Ansai County. The results can help to identify potential problems associated with the present and possible future conversions (e.g., an increase of unemployment) and offer useful insight for policy-makers to support further policy reforms.

Keywords: Soil loss; Conversion of cultivated land; Ecological restoration; MGLP model
Companion modelling for land management in rice agro-ecosystems: A case study in the highlands of northern Thailand

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Over the last four decades there has been a rapid evolution in research on agro-ecosystems. It is now possible to model increasingly complex subjects: itineraries of techniques, cropping systems, household-based farming systems, regional agricultural systems, agriculture at the regional level, agricultural socio-ecosystems. Usually, the analysis and modelling of agricultural production systems provide decision-making support for individuals making production management decisions at the field and farm levels. However, recently it has also evolved towards understanding and modelling collective decision making at watershed, irrigated scheme or small regional level and the assessment of environmental effects of agricultural production. Gradually, the subject of research extended from the behaviour of a crop population at the field level to the management of heterogeneous cultivated ecosystems exploited by a growing number of protagonists with increasingly differentiated interests, strategies and practices.

To understand how such complex systems work, the dynamic representation of the interactions between the natural environment, agricultural practices, and social and economic determining factors is central. To achieve this, agronomists have started using new methodological tools and are open to interdisciplinary approaches. Particularly they work more closely with ecology and cognitive and decision-making sciences.

There is an old debate between two paradigms. Schematically, on one hand, researchers following a positivist paradigm try to discover the objective truth and to unravel natural laws that drive the system. This knowledge is used to develop and deliver new technologies or new management rules. On the other hand, soft systems are based on the assumption that people construct their own realities through learning in social processes. The role of interdisciplinary teams including natural and social scientists is to understand and strengthen the collective decision-making process through platforms of interactions. The different stakeholders, including scientists, should work out in an interactive fashion a common vision on resource management that would lead to new indicators, shared monitoring procedures, information systems, and concrete alternatives for action. The scientist’s role is partly to feed this platform with ‘objectively true’ knowledge on the biophysical sub-system, and the ways to compare, assess, and implement the concrete alternatives that are collectively decided.

The main methodological principle is to use simulation models integrating various stakeholders’ points of view and to develop and use them within the context of platforms for collective learning. With this objective in mind, we developed the companion modelling approach. We named it ‘companion modelling’ because it is used as a tool in the mediation process (the social dimension of the companion) and it co-evolves with the social process (temporal and adaptive dimension). The next question was the use of these models in an interactive way with stakeholders. Based on the above-mentioned principles, a model, which is a representation among others, should be presented in an explicit and transparent way to
avoid the ‘black-box’ effect. We developed and used role-playing games (RPG) for the purpose of collective learning because, intuitively, a MAS model is a RPG simulated by the computer. Thus, we proposed to set up RPGs, similar to the MAS model, with the objective of making real stakeholders play the game.

This companion modelling (ComMod) approach is illustrated by a case study on soil and water conservation in the diversifying highlands of Chiang Rai Province, upper northern Thailand. This experiment has been carried out for the last three years and the lessons learned from using the ComMod approach in such a context will be presented in conclusion.
Can computer models stimulate learning about sustainable land use? Experience with LUPAS in the humid (sub-)tropics of Asia

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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 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.

\textit{Keywords:} Land use; Learning; Integrated analysis; Modelling resource conflicts; Rice; Asia
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