A methodology to explore options for rice-based farming systems in a humid subtropical region: a case study for Jiangxi, China

Jiayou Zhong[1,2,3], Huib Hengsdijk[1], Herman van Keulen[1,2], Qinghua Shi[3] and Xiaoming Zhao[3]

[1] Plant Research International, P.O. Box 16, 6700 AA Wageningen, the Netherlands, www.plant.wageningen-ur.nl
Email: huib.hengsdijk@wur.nl
[2] Plant Production Systems, Wageningen University, P.O. Box 430, 6700 AK Wageningen, the Netherlands, www.wur.nl
Email: herman.vankeulen@wur.nl
[3] Jiangxi Agricultural University, Jiangxi 330045, China, www.jxau.edu.cn, Email: zjyou666@vip.163.com

Abstract

Jiangxi Province, a typical humid subtropical region, is one of the major rice producing areas in China, with more than 85% of its arable area under rice-based cropping systems. Major problems and developments in current systems include: (1) low economic returns of rice production, (2) small farm sizes, (3) decreasing agricultural area due to urbanization, (4) high inputs of labor, fertilizers and biocides, (5) the use of large quantities of irrigation water in the production of late season rice, (6) declining agricultural labor force, (7) increasing demand for a more luxurious and diversified diet which meets food safety standards. Current rice-based farming systems need to change to be able to deal with these problems and to respond to new developments. This paper describes a generic methodology to explore options for rice-based farming systems taking into account various possibly conflicting goals of stakeholders in rural land use of Jiangxi. It consists of four major parts: (1) identification of objectives, (2) quantification of input-output combinations for production activities, (3) an interactive multiple goal linear programming model, and (4) analysis of results. Key to this approach is the quantification of input-output combinations of alternative production activities, which are categorized into three types: (1) rice-based crop rotations, (2) mixed crop-animal systems, and (3) rice-duck coexisting system. The described method can be used in other land use studies exploring options at farming systems level.

Media summary

A methodology is developed to explore options for rice-based farming systems in one of the major rice producing areas in China, namely Jiangxi Province.

Key words

Multi-criteria method, land use exploration, IMGLP, farming systems analysis

Introduction

Jiangxi is a typical humid subtropical region (24^{0}29'-30^{0}04'N, 113^{0}34'-118^{0}28'W) and has been one of the major rice producing areas of China since the Dong Han Dynasty (25-220 AD). Jiangxi exported rice to other regions since 107 AD. Except for those in the capital city, nearly two-thirds of the government-built granaries were located in Jiangxi during the Dong Jin Dynasty (317-420 AD). The area sown to rice reached 3 Mha in 1224 (Liu and Wei 1999). Among the 2.14 Mha of arable land in 2002, 1.89 Mha is irrigated and used in rice-based farming systems. Rice is the most important crop in the region, with an average sown area in the last three years of 2.8 Mha (JXSB 2003). Rice-based farming systems, which comprise double rice-based crop rotations (85% of the area) and single rice-based crop rotations (15%), have been dominant since the 1960s. Major crop rotations include early season rice (ESR) - late season rice (LSR) - fallow or a winter crop (Chinese milk vetch, oilseed rape, vegetables, annual ryegrass etc.), and single mid-season rice (SMSR) followed by fallow or a winter crop (Chinese milk vetch, oilseed rape, vegetables, annual ryegrass etc.), vegetables-LSR and ESR-sweet potato or soybean. The area sown to rice has gradually declined from a record high of 3.4 Mha in 1978 to 2.8 Mha in 2003. Rice production increased from 10 Mt in 1978 to a record high of 16 Mt in 1996, and then gradually decreased to 14 Mt in 2002 (JXSB 2003). Increasingly, rice-based farming systems face a series of interrelated problems, which need to be analyzed in an integrated way to explore and identify appropriate alternatives. This study describes a methodology to explore alternative cropping scenarios at farming systems level.

Major problems and developments in rice-based farming systems of Jiangxi Province

Double rice cropping systems were developed in the 1960s in response to serious food shortages China faced. Following the recent changes in social and economic circumstances, rice-based farming systems face various problems and developments:

- Economic returns of rice production are low due to its high costs and low grain prices. Average net revenue is 124 and 311 USD ha^{-1} for early and late season rice, respectively, while labor input is 180 days for each crop. Average daily income from the production of double rice is only 1.2 USD (JAAS 2001). Grain quality of ESR is poor resulting in low market prices. Reasons for the poor quality are still under debate, but most likely include high daily maximum temperatures, small difference between day and night temperature and increasing day-length after flowering. LSR and SMSR produce rice with a better grain quality than ESR, but also their quality often does not meet market standards. Once the major rice exporter in China, Jiangxi is rapidly loosing its share in domestic and international rice markets (Liu 2002).
- The prevailing size of farms, i.e. 0.4 ha, is too small for an economically viable enterprise (Li and Ling 1999). The small farm size limits income generation from farming activities and the choice portfolio for new crops and technologies, such as mixed crop-livestock systems.
- The area of arable land has declined from 2.4 Mha in 1990 to 2.1 Mha in 2002, while the population increased in the same period from 38 to 42 million. According to an estimate of Jiangxi Statistical Bureau, the population will reach 46 to 49 million in 2020 and increasingly claim agricultural land for urbanisation.
- In 2002, the use of chemical fertilizers and biocides in Jiangxi reached 525 kg NPK and 26.8 kg (commercial amount) ha^{-1}, while in 1990 it was only 356 and 15.5 kg ha^{-1}, respectively. The average yield of rice was 4905 kg ha^{-1} in 1990 and 5209 kg ha^{-1} in 2002; this implies that the increase in productivity is much lower than that in the use of agrochemicals (JXSB 2003). Biocide residues in food frequently exceed the national maximum residue limits. Nutrients and biocides emissions may pollute the environment, and may cause occupational and public health problems. In addition, biodiversity in rice ecosystems is endangered by the use of agrochemicals. Populations of earthworms, frogs, birds and natural insect enemies, such as spiders and ladybirds have significantly decreased (Ling et al 2001).
- Large quantities of irrigation water are ‘wasted’ in LSR production from August to October when rainfall is low. Irrigation accounts for 62% of the total water use in Jiangxi (JXSB 2003). Although water-saving technologies are available, few farmers use them because such technologies require more labour than conventional water management.
- It is increasingly difficult to meet agricultural labor requirements, because income per capita in agriculture is only one-third of that of urban labourers (Ianchovichina and Martin 2003).
- The rapid development of China’s economy leads to an increased demand for a more luxurious and diversified diet which meets food safety standards. In addition, with the opening of the borders after China’s entry in the WTO, production of high quality agricultural products for international markets offers new opportunities.

Obviously, the production structure of rice-based farming systems in Jiangxi is not adapted to the new developments, while insight is lacking in the technological possibilities to react to them adequately. Innovative research methods are needed to identify technically possible, economically viable and environmentally friendly options for rice-based systems.

Stakeholders and their interests

Since rice-based farming systems dominate rural land use and economy in Jiangxi, their performance is of interest to various stakeholders, i.e. farmers, consumer groups, environmental protection agencies, water and irrigation boards, tourism agencies, nature and landscape conservation groups, and policy makers. They often have different preferences and objectives, which may be at least partially conflicting. For farmers, self-sufficiency in food and income generation objectives has priority. Consumer groups demand farmers to produce a broad assortment of high quality products. Water and irrigation boards are reluctant to allocate more water to rice production in the late season. Environmental protection agencies aim at preventing agricultural production from polluting the environment. Some actions of tourism agencies, aimed at conservation of nature and landscape have led to conflicts with farmers. Policy makers pay close attention to preservation of the natural resource base, environment, nature and landscape, and to enlargement of employment opportunities and the foreign exchange earning capacity of agriculture.

A methodology to explore options for rice-based farming systems

A methodology is being developed to explore options for rice-based farming systems taking into account agro-ecological potentials, market opportunities and various possibly conflicting goals with respect to rural development. This methodology consists of four major components: (1) identification of objectives of ‘all’ interest groups with a stake in rural development, (2) design and quantification of cropping and livestock activities in terms of inputs and outputs, using technical coefficient generators (TCGs), (3) an interactive multiple goal linear programming (IMGLP) model for representative farming systems, and (4) analysis of the results (Fig. 1).

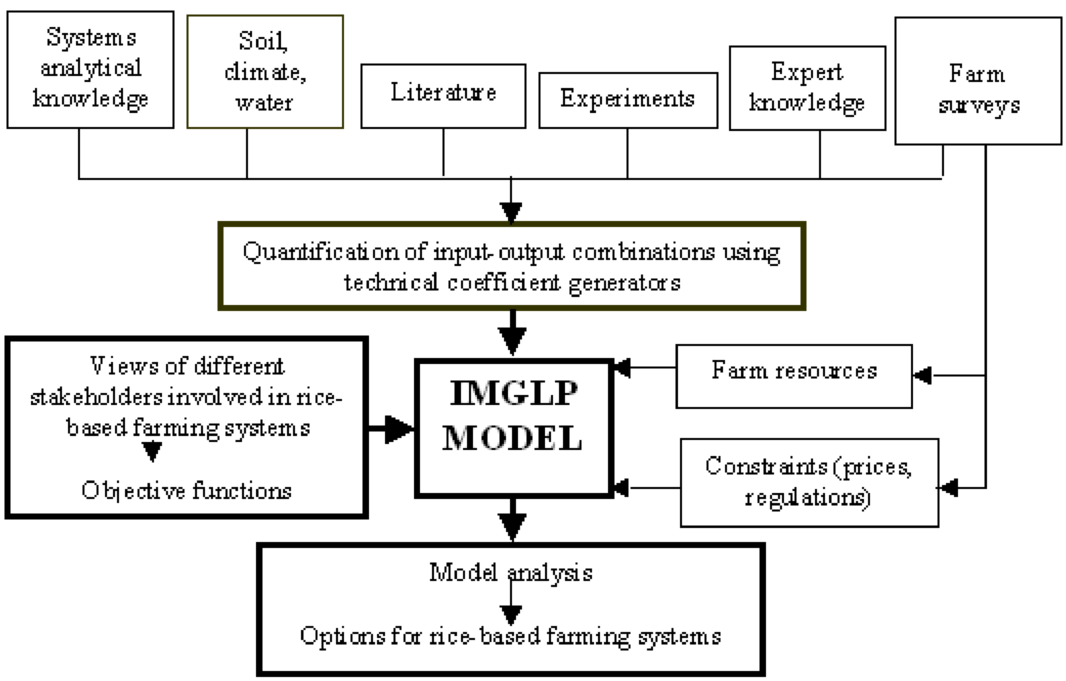

Figure 1. A methodology to explore options for rice-based farming systems in Jiangxi.

Rural development goals are identified through workshops and/or informal interviews involving different stakeholders.

Technical coefficient generators are used to design and quantify production activities at field level, which are divided into three types: (1) rice-based cropping systems (rotations with rice, green manures, oilseed rape, soybean, sweet potato, forage, peanut and/or vegetable crops), (2) mixed crop-animal systems (a combination of crops and animals such as goose, cattle and fish), and (3) rice-duck coexisting system. In the rice-duck system, dating back 800 years in China (Gan 2003), 20-days old ducklings are introduced into the rice field (225 to 300 ducklings ha^{-1}) at tillering stage. Ducks are collected and sold at heading stage. The co-existing period is 50 to 60 days in which ducks feed on living organisms such as insects, weeds, and river snails, while small quantities of concentrates are supplemented. Compared to conventional rice management, almost no manual weeding or herbicide application is needed, and less pesticides and fertilizers are applied. In addition, methane emission from rice-duck systems is 12.2 g m^{-2} compared to 15.6 g m^{-2} in conventional flooded rice (Gan 2003). The target-oriented approach and the concept of best technical means are used to identify and design alternative production activities at field level (Van Ittersum and Rabbinge 1997). For quantification of inputs and outputs of alternative rice-based cropping systems, TechnoGIN will be used (Ponsioen 2003) and for pasture and livestock systems, PASTOR (Bouman et al 1998), while for rice-duck coexisting systems, a new TCG will be developed. Input-output combinations of current rice-based systems are calculated based on results of farm surveys, expert knowledge and systems analytical knowledge. Inputs include seeds, fertilisers, biocides, equipment, machinery, irrigation water, land and labor. Outputs include the quantity and quality of crop and animal products, and a number of associated environmental indicators. These indicators include EEP-soil (environmental exposure to pesticides-soil), EEP-water, and EEP-air (Wijnands 1997), changes in soil nutrient stocks for N, P and K, emissions of N and P to surface- and groundwater, and emissions of N to the air.

Subsequently, the generated input-output coefficients of production activities are used as input data for the IMGLP farm model. This model assesses the performance of current and alternative production activities in terms of their contribution to different objectives. Agricultural, socio-economic and environmental objectives are distinguished, based on the views of different stakeholders. These general objectives will be translated into goals that can be optimised in separate model runs. Extreme values for each of the goal variables are calculated in base runs of the model under a set of basic constraints and requirements. In an iterative and interactive process, goal values are tightened based on the interest of the users (stakeholders) till an acceptable solution is found. In this way, trade-offs among different objectives are made explicit, allowing a more balanced decision-making with regard to new farming systems. Scenarios will be defined comprising coherent combinations of priorities for objectives and explicit assumptions about uncertain developments that are exogenous to the model, such as consequences of farm expansion. Sensitivity analyses for important data and objectives are carried out to test the robustness of the model and its results.

Conclusions

With this methodology, agronomic, environmental and socio-economic consequences of current and alternative production activities for rice-based farming systems in Jiangxi are evaluated and trade-offs among various goals illustrated. The developed method can be used in other explorative land studies at farming systems level. Key in this approach is the quantification of input-output combinations of production activities. Therefore, the study will identify disciplinary knowledge and information gaps, and research priorities will be formulated to improve the sustainability of rice-based farming systems in Jiangxi.

References

Bouman BAM, Nieuwenhuyse A and Hengsdijk H (1998) PASTOR: A Technical Coefficient Generator for Pasture and Livestock Systems in the Humid Tropics: Version 2.0, A User Guide. Quantitative Approaches in Systems Analysis No. 18.

Gan D (2003) Study on mechanism of mitigating methane and ingredient benefits of no-tillage in rice-duck complex system, PhD thesis, Hunan Agricultural University.

Ianchovichina E and Martin W (2003) Economic impacts of China's accession to the World Trade Organization. World Bank Policy Research Working Paper 3053.

JAAS [Jiangxi Academy of Agricultural Sciences] (2001) Feasibility Study of Farm Production Improvement Component, Project of the World Bank (unpublished report).

JXSB [Jiangxi Statistic Bureau] (2003) Jiangxi Statistical Yearbook 2003, China Statistics Press, Beijing.

Li Y, Ling C (1999) Current situation, problems and coping strategy of agricultural land use in Jiangxi. Price Monthly 4, 19-27. (In Chinese)

Ling M, Ji Y and Shen XM (2001) Investigation on biodiversity in farmland in Anji County. Contemporary Ecological Agriculture 3, 72-75. (In Chinese)

Liu C and Wei C (1999) Annals of agriculture, animal husbandry and fishery in Jiangxi Province. Yellow Mountain Press, Hefei.

Liu J (2002) Countermeasures to strengthen the competitive ability of agricultural products in Jiangxi. Rural Economy of China 4, 65-69. (In Chinese)

Ponsioen TC (2003) TechnoGIN: a technical coefficient generator for cropping systems in Illocos Norte province, Philippines. MSc. thesis, Wageningen University.

Van Ittersum MK and Rabbinge R (1997) Concepts in production ecology for analysis and quantification of agricultural input-output combinations. Field Crops Research 52, 197-208.

Wijnands FG (1997) Integrated crop protection and environment exposure to pesticides: methods to reduce use and impact of pesticides in arable farming. European Journal of Agronomy 7, 251-260.

Referenced websites:

www.jiangxi.gov.cn, www.jx-agri.gov.cn, www.travel-jx.com, www.riceweb.org