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Integrated assessment of agricultural land use policies on nutrient pollution and sustainable development in Taihu Basin, China

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ABSTRACT

Water pollution in Chinese lakes is a major problem. To reduce nutrient pollution and enhance sustainable development in Taihu Basin, China, an integrated assessment of the impacts of agricultural land use policies has been performed, using the technical coefficient generator TechnoGIN and the bio-economic farm model FSSIM. Results show that although promotion of site-specific nutrient management (SSNM), the first policy, can improve regional objectives such as nutrient pollution reduction and food security, its adoption is constrained by labour productivity and availability at farm level. SSNM is more knowledge and labour intensive than conventional management, whereas labour availability is decreasing due to off-farm employment possibilities. In policy scenarios for 2015, environmental impacts are projected to decrease compared to 2008, partly due to the adoption of SSNM. However, the main reason is the decreasing labour availability towards 2015 which causes a switch from double to single cropping already in the baseline scenario for 2015. This leads to lower food production. Abolishing fertilizer subsidies for farmers that do not adopt SSNM, in combination with training appears to be the best way to stimulate SSNM adoption for improving the different land use functions. A second policy, stimulating mechanical transplanting of rice, reduces labour use and can become profitable when subsidized, but on most farm types it will not reverse the trend towards single cropping and has little influence on nutrient pollution. Thirdly, the regional policy of creating riparian buffer zones along water bodies appears to be promising, as it can strongly reduce nutrient leaching from farm land to rivers and lakes. Concluding, the integrated assessment performed in this study showed that policies can reduce nutrient pollution and improve sustainable development, but the changing labour context has a large impact on their impacts and on agriculture in the region.

1. Introduction

China is a country with high economic growth and a rapidly increasing middle-class. Economic growth has led to increasing welfare for most of the population, but it increasingly conflicts with social cohesion and environmental quality. For a sustainable development, land use patterns and land use changes are considered critical (e.g. Foley et al., 2005). In China, urban sprawl has increased, while agricultural land use has become more

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intensive, leading to broad impacts on the environment, such as air and water pollution.

The water pollution in Taihu Lake, one of the five largest freshwater lakes in China, is a representative example of the problems regarding sustainability in China. Economic growth, population growth and technological development have led to industrial pollution, a continuous increase in domestic sewage and intensification of agricultural production. These developments have caused a large increase in nutrient levels in the rivers that run into Taihu Lake, resulting in high levels of eutrophication (e.g. Jin et al., 2006; Guo, 2007; Qin et al., 2007). Taihu Lake serves many purposes, including source of drinking water, storage of flood water, shipping, irrigation, recreation and aquaculture. These ways of use are all threatened and therefore, policies are being formulated to reduce pollution.

The contribution of point-pollution by industries and domestic sewage is decreasing, but nutrient pollution from non-point sources such as agriculture is more difficult to control (Zhang et al., 2001; Qin et al., 2007). Agriculture in Taihu Basin contributes to water pollution as a result of nutrient losses from agricultural land, which are due to the wide spread nutrient surpluses. The levels of nutrient inputs used in Taihu Basin are much higher than those needed to support high yields (e.g. Cao and Zhang, 2004; Guo et al., 2004). Fertilizer applications are generally not based on nutrient requirements of the crops and/or site specific knowledge of the soil nutrient status. Therefore, studies as mentioned above have advocated site-specific nutrient management (SSNM; Dobermann et al., 2002).

Many disciplinary studies have been performed on the nutrient pollution issue (e.g. Roelcke et al., 2002; Wang et al., 2004), but no integrated assessments considering environmental, economic and social indicators simultaneously have been carried out. Policies meant to improve the environment will not be effective, if they are not economically viable and socially acceptable. The objective of this study is to perform an ex-ante integrated assessment of the impacts of agricultural land use policies on nutrient pollution and sustainable development in Taihu Basin.

In order to assess the impacts of agricultural policies, we have adapted, linked and used the technical coefficient generator TechnoGIN (Ponsioen et al., 2006), and the bio-economic farm model FSSIM (Louhichi et al., 2010). An extensive farm survey has been carried out to provide input data for this modelling study, and policy fora have been held to discuss policies, indicators and model results. Three policies have been assessed for 2015, related to (i) stimulation of SSNM, (ii) stimulation of mechanical transplantation of rice, and (iii) implementing riparian buffer zones, and compared to the base year (2008) and a baseline in 2015.

2. Methodology

To structure ex-ante integrated assessments of land use policies on sustainable development in developing countries, a methodological framework has been developed in the LUPIS project (Reidsma et al., 2011), which is used as a guideline for this study. The first phase, pre-modelling, deals with problem analysis and the selection of indicators, considering nine land use functions in the economic, environmental and social dimensions (Table 1). In the second phase, modelling, the impacts of policies on indicators are assessed. In the last phase, post-modelling, the impacts of policies on sustainable development are evaluated based on the selected land use functions. Reidsma et al. (2011) describe these steps for the case study in China, giving the background and context, with selected results at field level. This paper presents the modelling framework and results at farm type level for the arable sector.

2.1. *Case study area*

Taihu Basin is located in the east of China, at the southern Yangtze delta plain (Fig. 1). Taihu Basin crosses the three provinces Jiangsu, Zhejiang, An-hui, and Shanghai city, and has a total area of 36,500 km^2. Taihu Basin is a subtropical region, and is agriculturally productive and economically important for China. Traditional agriculture has sustained

Table 1 – Land use functions (LUFs), related indicators and their values for the base year on farm types 1, 2, 3 and 4 in Wuxi. Indicators related to phosphorus are additionally included in this table. The last column indicates whether a high indicator value is considered positive or negative. For more explanation on LUFs see Reidsma et al. (2011).

Sustainable development dimension	Land use function	Indicator	Unit	FT1	FT2	FT3	FT4	
Economic	Land-based production	Crop production	kg/yr	2931	2536	2550	36,329	+
	Economic production	Net income	yuan/yr[a]	3041	2557	2717	27,728	+
	Industry & services	Input costs	yuan/yr	2620	2310	2535	39,936	+
Social	Provision of livelihood	Labour use efficiency[b]	yuan/day	49	49	44	50	+
	Human health	Biocide index	–	453	491	501	619	–
	Food security	Rice production	kg/yr	1816	1528	1523	20,949	+
Environmental	Abiotic resources	Fertilizer K/N ratio	kg K/kg N	0.20	0.21	0.24	0.23	+
	Biotic resources	Nitrogen input	kg N/ha/yr	365	410	426	545	–
		Phosphorus input	kg P/ha/yr	63	79	98	99	–
	Ecosystem processes	Nitrogen leaching	kg N/ha/yr	84	94	94	133	–
		Phosphorus run off	kg P/ha/yr	0.86	1.08	1.23	1.27	–

[a] One yuan equalled 0.117 euro on 06/12/2011.
[b] Labour use efficiency = net income (in yuan) per labour day.