Adapting and using the bio-economic model FSSIM to assess the impact of agricultural policies on sustainable development of arable farming in Taihu Basin, China

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MSc thesis Plant Production Systems
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Abstract

Water pollution is a major problem in China. This is also the case for the Taihu lake. Main causes of water pollution are industry, domestic sewage and agriculture. Successful measures to reduce pollution from industry and domestic sewage have been implemented, and therefore non-point source pollution from agriculture becomes the major source for the water pollution. The agriculture in the Taihu lake basin causes overload of nutrients in the water body due to excessive use of fertilizer inputs, which are higher than needed to support the high yields.

The aim of this study was to perform an ex-ante integrated assessment of the impact of agricultural land use policies on nutrient pollution and on sustainable development at large at farm type level in Taihu Basin. Sustainable development is needed to improve the situation of the Taihu Lake Basin, as policies improving the environment will not be effective if they are not economically and socially acceptable.

In order to assess the impacts of the policies on agricultural sustainability in Taihu lake basin, the bio-economic farm model FSSIM (Farm System SIMulator) is used. FSSIM developed in the European context, was changed to fit to the Chinese case study. As database for input and outputs of agricultural activities TechnoGIN (Technical coefficient Generator for Ilocos Norte province) was used.

FSSIM-China has been programmed such that in each run the base year (2008), baseline (2015) and policy scenario (2015) are simulated. The base year exactly reproduces the observed activity levels in 2008, due to the PMP (Positive Mathematical Programming) calibration method. The data used are based on field survey of 320 farmers in 2008. Changes in results for the baseline and the policy scenario (2015) are dependent on the elasticity of the crop-management combinations in the model, which is a part of the PMP procedure and the height of the prices, costs and yields which are estimated by trends of historical time series. Four policy options were used to assess the effect on sustainability: 1) FF (formula fertilizer) use 2) Stimulation of SSNM (Site Specific Nutrient Management), 3) stimulation of MT (mechanical transplanting) and 4) buffer zones.

The results show that the use of FF application will be higher in the baseline than in the base year. Just applying fertilizers with a different contribution of N, P and K is however not enough to reduce nutrient leaching, and therefore improved SSNM including change of timing and amounts should be stimulated. In case of stimulating SSNM, then the FF application as practiced in the base year will decrease compared to the base year and the use of SSNM will increase. The stimulation of SSNM is a good option for improving the water quality of the Taihu lake, while still being economically and socially acceptable. It is only difficult to stimulate the use of SSNM, due to the high need for training and education of the farmers while labour is limited. Extra subsidy for SSNM could help to stimulate the use of SSNM and could prevent the decrease the food production, because farmers are going to cultivate more single crops compared to rotations due to good off-farm opportunities. The stimulation of MT does not help to improve the water quality, but the use of MT machine is very important for farmers, because it saves labour. Saving labour is so important, because in most cases working off-farm leads to a higher income than working on-farm. The fourth policy option is the buffer zone. Buffer zones have at farm level little impact, but compensation payments are nevertheless too low. Buffer zones are expected to have a large impact on the water quality. Scale enlargement is tested as a policy scenario. Scale enlargement did lead to more mechanisation on the farm if labour was limited. If labour was limited then the environmental outputs decreased due to cultivation of fewer crops, if labour was not limited the environmental outputs did not decrease in the policy scenario compared to the baseline.

The model chain TechnoGIN-FSSIM has proven to be useful to ex-ante assess agricultural policies at farm level in Taihu Basin. Constraints for the adaptation of technologies, and impacts on environmental, economic and social indicators are evaluated, allowing to better target policies.

Key words: Taihu lake; Sustainability; Bio-economic farm model; Nutrient leaching; SSNM; Policy assessment

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Table of contents

1. Introduction

1.1 Problem

Water pollution is a major problem in China. Fresh water sources of good quality are scarce, although China has a large number of fresh water ecosystems (Chen et al., 2003). The Taihu lake (Figure 1) is a large fresh water ecosystem in China which also has problems with the water quality. It is essential that the water quality of the lake improves, because the Taihu Lake is an important drinking water source for cities within the basin and it is a well-known place for tourists. The lake also serves for many other purposes like storage of flood water, shipping, irrigation and aquaculture (Reidsma et al., 2009 and Guo et al., 2004).

The lake Taihu is one of the five largest freshwater lakes in China (Figure 1). The total surface area of the lake is 2,338 km^2, the water storage capacity is $52 \cdot 10^8$ m^3 and the total area of the Taihu lake basin is 36,500 km^2. More than 200 rivers enter into Lake Taihu (Huang and Zhu, 1995). The lake is located in the Changjiang delta, the most industrialized area in China with a high population density. The Taihu lake basin occupies 0.4% of China's area, 3% of China's population, but it contributes about 10% of Gross National Product and 15% of province revenues (Qin et al., 2007). The Taihu lake basin is an agriculturally productive and economically important region in China (Reidsma et al., 2009).

Figure 1. Map of the Taihu lake basin.

1.2 Causes of water pollution

Due to rapid development of agriculture and industry, human activities have exerted much influence and pressure on the ecological environment. A large number of pollutants have flown into the lake (Huang and Zhu, 1995); therefore the water quality of the lake and its watershed decreases (Verburg et al., 2008). The decrease in the water quality is leading to eutrophication. Since the beginning of 1980 the eutrophication of the Taihu Lake has become more serious (Guo et al., 2004).

The cause of this decrease in water quality is the increase of nutrient inputs from for example wastewater from industry, domestic sewage and through agriculture (Verburg et al., 2008). The Chinese government already has taken measures to reduce the pollution from the industry to the lake. The factories within the watershed now must treat wastewater before it enters into the rivers (Qin et al., 2007). Non-point source pollution from agriculture is still a major source for the water pollution (Shoa, 2009). Non-point source pollution is characterized by being spatially distributed and varying in magnitude on the basis of interactions between the environment and the agricultural system (Guo et al., 2004). Agriculture in the Taihu Lake region causes an overload of nutrients in the water body due to increased nutrient loss, which is caused by a wide spread nutrient surplus (Guo et al., 2004). The high nitrogen inputs used in the rice-wheat rotation in the Taihu Lake Basin are much greater than needed to support high yields (Ellis and Wang, 1997). Fertilizer applications are often not based on real time nutrient requirement of the crop and/or site specific knowledge of soil nutrient status (Fan et al., 2007). The problem is that agricultural non-point sources are projected to continue growing for a long time (Reidsma et al., 2009).

1.3 Framework of study

Although during the last decade the political awareness of the water quality has increased substantially in China, it still needs more attention and it needs further investigation and evaluation (Shoa, 2009). Therefore, within the LUPIS project (Land use Policies and Sustainable Development in Developing Countries) a case study has been initiated to ex-ante assess the impact of land use policies on water pollution in Taihu Basin, in the context of sustainable development. Already several disciplinary studies have been performed on the water pollution issue (Zhang et al., 2003; Roelcke et al., 2002; Guo et al., 2004), however this study aims at an integrated assessment of the problems related to the water pollution of the Taihu lake. Assessing impacts on sustainable development is needed to improve the situation of the Taihu Lake Basin, as policies improving the environment will not be effective if they are not economically and socially acceptable.

The aim of the LUPIS project is to assess the strengths and weaknesses of proposed new policies and innovations prior to their introduction through the use and development of tools and models (Nesheim et al., 2008). Assessments cover the multiple dimensions of sustainability: economic, environmental and social development. Building blocks for this projects are methodologies developed in the EU projects SENSOR (Sustainability Impact Assessment: Tools for Environmental, Social and Economic Effects of Multifunctional Land Use in European Regions; Helming et al., 2008) and SEAMLESS (System for Environmental and Agricultural Modelling; Linking European Science and Society; Van Ittersum et al., 2008) (Reidsma et al., 2008). For a sustainability impact assessment, a balanced set of indicators should be selected. An indicator framework has been developed in LUPIS that aims to translate the vision of sustainable development. Indicator selection starts with defining sustainable development targets, then linking the Land Use Functions (LUFs) accordingly, and finally selecting indicators per LUF. LUFs represent most important sustainability issues and are defined as goods and services associated with land use, they refer to regional preferences with regard to the functionality of land (Perez-Soba et al., 2008 and Reidsma et al., 2010).

1.4 SEAMLESS

The SEAMLESS Integrated Framework (SEAMLESS-IF) is developed for an ex-ante, integrated evaluation of agro-environmental policies and agro-technological innovations in the European Union (EU), from field-farm to region and European Union, as well as global interactions. For integrated assessment of the impact of land use policies on water pollution in Taihu Basin, approaches from SEAMLESS provide a good basis.

At farm level, SEAMLESS-IF uses FSSIM (Farm System SIMulator). FSSIM is developed to consider the response of the major farm types to policy changes and technological innovations (Louhichi et al., 2007). FSSIM includes a data module for agricultural management (FSSIM-AM), which computes the technical coefficients and costs for ranges of current and alternative agricultural activities. FSSIM also includes a mathematical programming part (FSSIM-MP), which aims to capture resource, socio-economic and policy constraints and the farmers objectives (Van Ittersum et al, 2008). In this case study FSSIM-MP is adapted to the case study context and FSSIM-AM is replaced by TechnoGIN (Technical coefficient Generator for Ilocos Norte province; Ponsioen et al., 2006) which was developed for application in South-East Asia. TechnoGIN is adapted to be able to link it directly to FSSIM-MP.

1.5 Policies

In this thesis, TechnoGIN and FSSIM-MP are applied to assess the impact of agricultural land use policies to reduce nutrient pollution. The policy scenario is used to assess the effect of different policy options to reduce the agricultural non-point source pollution while still being economically viable and socially acceptable, at farm level in the arable sector.

Reduction of agricultural non-point source pollution can be reduced by stimulating the use of formula fertilizer (FF). Formula fertilizer application involves that extension offices give site specific recommendations on nutrient management based on soil samples, and accordingly farmers use compound fertilizers with a different formula than N:P:K of 15:15:15 (Reidsma et al., 2009). As a policy stimulating the use of FF is already implemented in the base year (2008), this is one of the policy options evaluated for the base year.

Changing the contribution of N, P and K as done in formula fertilizer is one aspect of Site Specific Nutrient Management (SSNM), reducing the total amounts to balance demand and supply and adjusting the timing of application to improve nutrient recovery are additional aspects. Therefore, the influence of optimal SSNM is also evaluated; this is considered the second policy option. SSNM can be defined as the dynamic, field-specific management of nutrients in a particular cropping season to optimize the supply and demand of nutrients according to their differences in cycling through soil-plant systems (Doberman et al., 2002).

A third policy option is stimulating the use of mechanical transplanting (MT). Mechanical transplanting of rice saves labour compared to hand transplanting and it can also reduce pesticide use and increase yields and income (Reidsma et al., 2009).

The last policy option is buffer zones. Buffer zones are fertilizer free zones next to watercourses. It is a catchment area of N and P from the ground and surface water of the nearby agricultural land (Klok et al., 2002). Buffer zones are there for removal of sediment and particulate-bound chemicals from crop land and run-off, doing this by increasing the retention time for soil phosphorus absorption (Zhang et al., 2007). Buffer zones are created by returning agricultural lands to trees. The trees which are planted in the Taihu lake basin are chosen to fit in the local conditions, that they have low input costs, limited fertilizer need and have future benefits. Examples of some tree species in the Taihu lake basin are *Cinnamomum camphora (L.) Presl., Bischofia polycarpa,* and *Salix babylonica* (personal communication Shuyi Feng).

FSSIM will exactly reproduce the farm lay out in terms of crops of the base year by using the Positive Mathematical Programming (PMP) method (Howitt, 1995). Forecasts are made towards 2015 for a baseline scenario (2015) considering business as usual, and for policy scenario options related to SSNM and MT. Forecasts include changes in cropping patterns and technologies used and the associated impacts on environmental, economic and sociological indicators.

1.6 Study area

The water pollution in Taihu Lake is the worst in the North-Western part of the lake, therefore this area is chosen as the case study area of this study (Reidsma et al., 2009). Three municipalities in this region are selected for this study: Wuxi (close to the lake), Changzhou (further from the lake) and Zhenjiang (furthest from the lake) (Figure 1). The Taihu area is an area with little elevation and is largely homogenous, although there are some hilly areas. In this thesis, only the arable sector is analysed. Not only a distinction is made between the municipalities, also a distinction is made between differences in types of farms. Different types of farms make different type of decisions and also respond different to trends and measures. There are four different farm types; the type is based on size and off-farm employment using cluster analysis. Soil types are distinguished within each farm type (Reidsma et al., 2009).

1.7 Objective of the study

The overall aim of this study is to perform an ex-ante integrated assessment of the impact of agricultural land use policies on nutrient pollution and on sustainable development at large at farm type level in Taihu Basin.

To realize this objective several sub-objectives have been formulated:

- Adapt and/or develop the bio-economic model FSSIM, which is developed for the European context in the SEAMLESS-project, and link it to the Technical Coefficient Generator TechnoGIN, so that it can be used for the case study of the Taihu Lake.
- Assess the sensitivity of the TechnoGIN-FSSIM model chain for some important parameters like alpha of PMP and prices.
- Use the model for four farm types in three municipalities to assess the impact of the policies on environmental, economic and social indicators.
- Compare model results with the actual situation in China for validation of the model outcomes.
- Identify policies that can reduce nutrient pollution from agriculture and that are feasible considering other economic, social and environmental impacts.

2. Material and methods

2.1 Input-output relationships

In order to assess changes in cropping patterns and associated impacts on economic, environmental and social indicators due to different policies, all inputs and outputs of agricultural activities need to be assessed. Input and outputs of agricultural activities are assessed by TechnoGIN (Technical coefficient Generator for Ilocos Norte province). FSSIM-AM from the SEAMLESS project is replaced by TechnoGIN. TechnoGIN is developed for South-East Asia and is therefore more suitable for the Chinese case study. TechnoGIN is developed to serve as a tool for quantifying inputs and outputs for cropping systems at field level (Ponsioen et al., 2006). Input-output relations refer to inputs and outputs of land-use systems (crop rotation under specific conditions associated with inputs and outputs) in economic and physical terms and are also called technical coefficients. TechnoGIN thus gives inputs for the bio-economic model FSSIM-MP.

TechnoGIN is programmed in Excel using macros in Visual Basic. TechnoGIN includes several data sheets: technology, crop, land use type (LUT), land management unit (LMU), nutrient, biocide, efficiency, fertilizer and currencies (Figure 2).

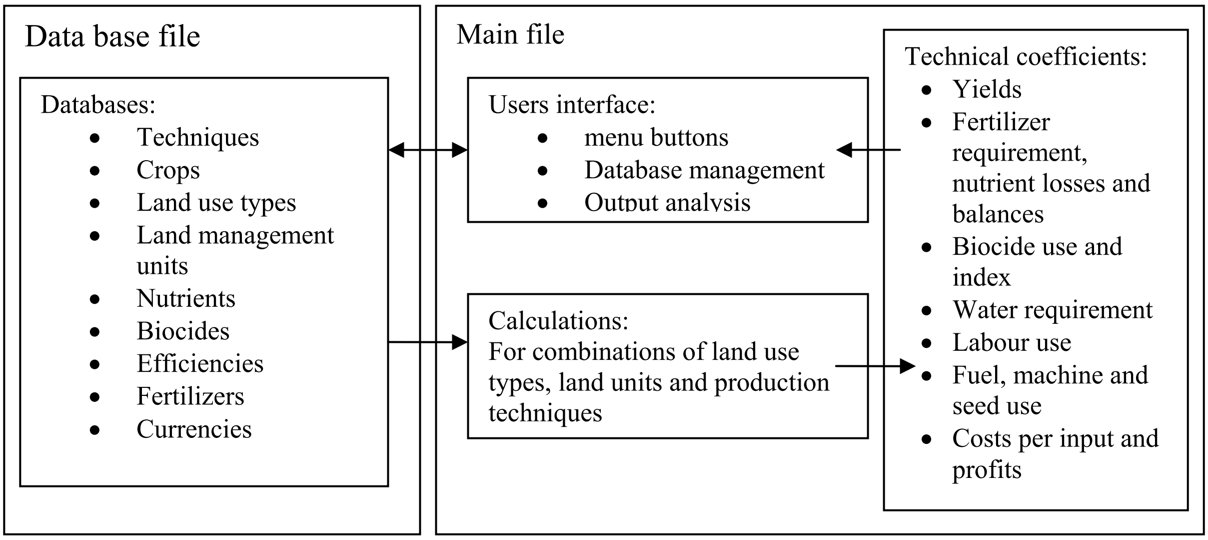

Figure 2. Schematic overview of the structure of TechnoGIN. Arrows represent flows of data (Ponsioen et al., 2006)

To link TechnoGIN to FSSIM, the model was extended such that it forms a complete database for inputs for FSSIM. The original TechnoGIN model has two files: one data file with the inputs, and one model file including the outputs. The code was adapted such that the model file:

i) Creates all input files (.inc) needed for FSSIM, i.e. all technical coefficients which are defined by sets and parameters,
ii) Defines the constraints for each farm type. The technical coefficients are calculated based on the data file by running the model (and worksheets are indicated in grey), while the constraints need to be defined additionally in the model file (worksheets indicated in blue).

The thesis of Kang (2009) uses TechnoGIN to calculate the agro-ecological relationships for the main agricultural activities in Taihu lake basin. So the input-output relationships for the Taihu lake basin are already being described in the thesis of Kang (2009). The data are from a farm survey done in 2008 on 320 farms in Wuxi, Changzhou and Zhenjiang. The land use systems are based on different land use types (rotations). Difference in the Land Use Types (LUTs) with Kang (2009) is that not only rice can be cultivated as a single crop, but now also wheat and rapeseed can be cultivated as a single crop. When looking at the observed activity levels of the crops, it appeared that not all wheat and rapeseed could be allocated to rice-wheat or rice-rapeseed LUTs. As the observed area of rice was in some cases smaller than the observed area of rapeseed and wheat together. Therefore there are upland areas that cannot be used for rice cultivation, and single wheat and single rapeseed are added (Table 1).

Another important change in the files of TechnoGIN is the addition of crops with Site Specific Nutrient Management (SSNM) (Table 1). In the farm survey only Formula Fertilizer (FF) application was reported. However a separation is made for the farmers that use FF application. This separation is made, because from practical experiences it can be concluded that some farmers that say they use FF application do not completely follow the advised fertilizer applications and some do. To estimate the impacts of policies related to this, it is required to assess the current practices and impacts of farmers who use FF, and the impacts of improved use of FF according to principles of SSNM, and the area of farmers applying these practices. The area of farmers that use FF and that use SSNM is in total the same as the area of FF that was observed in the farm survey. The data from the farm survey on area allocated to FF was split up in two groups. One group which uses formula fertilizer, but has not reduced the amounts of fertilizers, and one group which applies fertilizer optimally, according to principles of SSNM (Table 2).

From the survey data the % of farmers that apply FF according to principles of SSNM cannot directly be calculated. Therefore this was estimated based on the amounts of N fertilizer applied. To get the optimal fertilizer application, QUEFTS (Quantitative Evaluation of the Fertility of Tropical Soils; Janssen et al., 1990) calculates in TechnoGIN the needed nutrient inputs for the target yield. The level differs per soil type and is set around the level needed for sandy soils. QUEFTS calculated that 230 kg N/ha for rice is optimal and 150 kg N/ha for rapeseed or wheat is optimal. It was therefore assumed that less than 230 kg N/ha of fertilizer application for rice and less than 150 kg N/ha of rapeseed or wheat is close to optimal. This group is considered to apply FF according to SSNM. The other group that is left, that uses more than 230 kg N/ha for rice and 150 kg N/ha for rapeseed or wheat will be allocated to the group using formula fertilizer according to current average practices (i.e., they use FF, but the practice is not much better than farmers that do not use FF).

According to the farm survey data from 2008, from the farmers that cultivate rice with formula fertilizer, 21.7% used less than 230 kg N/ha (Table 2). For rice with formula fertilizer application and with mechanical transplanting it is 41.8%. For wheat, 31.5% of the farmers used less than 150 kg N/ha, and for rapeseed, 29.2% used less than 150 kg N/ha. From the observed area of crops cultivated with FF, these % are subtracted and allocated to the observed area of crops cultivated with SSNM. Considering all farms and the areas, 71.7% of the farmed area where FF are used is cultivated with FF according to average practices and 28.3% of the farmed area is cultivated with SSNM.

Table 1. Land use types that are defined in TechnoGIN

Abbreviation LUT[1]	Abbreviation crop period 1[2]	Abbreviation crop period 2[2]
RIWH	RIc	WHc
RIRA	RIc	RAc
RI	RIc	
WH	WHc	
RA	RAc	
RIfWHf	RIfc	WHfc
RIfRAf	RIfc	RAfc
WHf	WHfc	
RAf	RAfc	
RImWH	RImc	WHc
RImRA	RImc	RAc
RIm	RImc	
RIfmWHf	RIfmc	WHfc
RIfmRAf	RIfmc	RAfc
RIfm	RIfmc	
RIsWHs	RIssc	WHssc
RIsRAs	RIssc	RAssc
RIs	RIssc	
WHs	WHssc	
RAs	RAssc	
RIsmWHs	RIssmc	WHssc
RIsmRAs	RIssmc	RAssc
RIsm	RIssmc	
FALL	FALL	FALL

[1] RI: rice, WH: wheat, RA: rapeseed, FALL: buffer zone
f: formula fertilizer, m: mechanical transplanting, s: site specific nutrient management
[2] RI: rice, WH: wheat, RA: rapeseed, FALL: bufferzone
c: conventional operations, fc: formula fertilizer, mc: mechanical transplanting, ssc, site specific nutrient management, ssmc: site specific nutrient management and mechanical transplanting, fmc: formula fertilizer and mechanical transplanting

Table 2. Split up of the observed group of farmers using formula fertilizer according the farm survey, in SSNM crops and FF crops. Calculation of the average is based on the number of farms that where using FF in the field survey.

Crop	Percentage of area of farms in the field survey that use FF per crop compared to the total use of FF	Criteria for coming in the SSNM group (kg N/ha)	Farm area below the criteria (%)
Rice	39	230	21.7
Rice with mechanical transplanting	9	230	41.8
Wheat	42	150	31.5
Rapeseed	10	150	29.2
		Average	28.3

The land management units (LMU) that were defined in TechnoGIN are: clay, loam and sand. Only rice cannot be grown on dry land (upland), but is on paddy land (lowland). Wheat and rapeseed are able to grow on dry land and paddy land. Therefore the new defined LMUs are lowland clay, loam and sand and upland clay, loam and sand. The lowland soil types are defined in TechnoGIN as: clay, loam and sand. The upland soil types are defined in

TechnoGIN as: Uclay, Uloam and Usand. On uplands (the dry lands) the yield of rice will be zero, to reproduce the inability of rice to grow on dry lands. The yield for wheat and rapeseed will be the same as on upland, because wheat and rapeseed are able to grow on uplands. The model will not grow rice on upland soil types, because it is not profitable.

In the technology sheet the scenarios are described, for a description of the scenarios see Section 2.5. Several other corrections are made in the inputs provided to TechnoGIN by Kang (2009) to make it more suitable for the Chinese case study. Like the change from one TechnoGIN database to three databases, now every municipality has its own database. This change is made, because the subsidies given to the crops and the input subsidies are different per municipality. Also the subsidy for the use mechanical transplanting machine is different per municipality. Furthermore, a distinction is made between the yields in the different municipalities. More details about the adaptations that are made in TechnoGIN developed by Kang (2009) can be found in Appendix I and the input and outputs from TechnoGIN that are used as input data for FSSIM can be found in Appendix III.

2.2 Farm types

Every municipality has four different farm types (Table 3), this is because different kinds of farm types make different decisions and respond differently to policy options and general trends. The farm type depends on size of the farm and off-farm employment using cluster analysis. Soil types are distinguished within each farm type (Reidsma et al., 2009). Data for the different farm types in 2008 situation was gathered by field surveys and databases.

Table 3. Several characteristics of the four different farm types per municipality

Municipality	Farm type	Total land area (ha)	Area lowland (ha)			Area upland (ha)			% area in the buffer zone	Available family labour (days)	Off-farm income (Yuan)
			Clay	Loam	Sand	Clay	Loam	Sand			
Wuxi	1	0.32	0.17	0.05	0.01	0.06	0.02	0.00	0.5	221	11,744
	2	0.26	0.19	0.01	0.01	0.04	0.00	0.00	1.8	211	52,179
	3	0.25	0.17	0.00	0.08	0.00	0.00	0.00	11.6	188	107,850
	4	2.82	2.06	0.77	0.00	0.00	0.00	0.00	0.0	417	6,000
Changzhou	1	0.30	0.17	0.04	0.10	0.00	0.00	0.00	5.7	242	13,065
	2	0.29	0.12	0.07	0.01	0.05	0.03	0.01	0.5	162	51,194
	3	0.26	0.16	0.00	0.00	0.10	0.00	0.00	0.0	136	136,746
	4	2.26	0.00	1.81	0.34	0.00	0.09	0.02	0.0	400	15,680
Zhenjiang	1	0.31	0.20	0.06	0.02	0.01	0.00	0.00	0.0	286	11,630
	2	0.31	0.16	0.03	0.10	0.01	0.00	0.00	0.0	211	43,097
	3	0.36	0.11	0.00	0.24	0.00	0.00	0.01	0.0	125	136,500
	4	3.39	2.00	0.00	1.39	0.00	0.00	0.00	0.0	625	13,750

From table 3, it can be observed that farm types 1-3 are small farms, while farm type 4 is a relatively large farm. The main difference between farm type 1, 2 and 3 is the increasing off-farm income.

2.3 Indicator selection

To assess impacts on sustainable development, targets should be set and indicators should be selected (Table 4). Economic sustainable development targets in the Chinese case study are increasing the income of rural households, increasing the food production and narrowing the gap between rural income and urban income. Social development targets are to ensure safe drinking water, to balance the supply and demand of food and to ensure air and water quality (Verburg et al., 2008). Environmental targets are to reduce the use of N, P and K by at least 50%, to reduce the pesticide use by 20%, to reach a water quality of level three (the concentration of COD and NH_3-N should be below 20 mg/l and 1.5 mg/l) and to recover the lake view and environment (Verburg et al., 2008). A threshold value below 100 for Biocide residue index (BRI) is safe, between 100 and 200 is permissible and a threshold value above 200 is unsafe (Vasisht et al., 2007). Land use functions (LUFs) are linked to these targets (Table 4). Economic land use functions are physical production (this is land use function one, LUF1), economic production (LUF2) and industry and services (LUF3). Social land use functions are provision of work/livelihood (LUF4), human health (LUF5) and food security (LUF6). Environmental land use functions are abiotic resources (LUF7), biotic resources (LUF8) and ecosystem processes (LUF9) (Reidsma et al, 2008) (Table 4).

To measure the sustainable development, indicators are linked to the land use functions. The main economic target is to increase the production of all products for self sufficiency (Chao et al., 2006 and Lin, 2006), therefore the indicator for LUF1 is crop production (ton/year). Another main economic target is to reduce the rural-urban income gap (Van den Berg et al., 2007), therefore the indicator for LUF2 is net farm income (Yuan/year). For land use function 3, industry and services, the selected indicator is input costs. High input costs represent the stimulation of other business activities (Reidsma et al., 2010). Although farmers want to have as low input costs as possible, for the industry and services it is important that the farmers have high input costs. The high input costs of farmers stimulates the industry and is therefore a positive indicator, because the industry in China is very powerful. If an indicator is a positive indicator it means that if the value of that indicator increases this is a positive change; for negative indicators a increase of that indicator means a negative change. Social targets aim at provision of work to the rural households, healthy environment and ensuring food security (Reidsma et al., 2010). Most farmers can earn more money with working off-farm, because of that the labour used on farm should be as efficient as possible. Therefore the indicator for LUF4 is labour use efficiency in agriculture (Yuan/day) and is calculated by the farm income divided by the on farm used labour. The indicator selector for LUF5 is bio residue index (BRI) and for LUF6 is rice production (ton/year). Rice production and labour use efficiency are a positive indicators and BRI is negative indicator. For ecological indicators the indicator for LUF7 is K:N ration. This is chosen, because the application of N fertilizer compared to K is been too high in the last decades. The area of K-deficient soils is expanding while the fertilizer N use is too high (Chao et al., 2006) The indicator for LUF8 is N input, this indicator is chosen, because it can serve as an indicator of biodiversity loss (Asai, 2009). For improving the water quality it is important that emission of nutrients reduces (Reidsma et al., 2010). For this reason the indicator for LUF9 is nitrogen leaching. LUF7 is a positive indicator and LUF8 and 9 are negative indicators.

Table 4. Economic, social and environmental sustainable development targets, linked to land use functions and indicators

Dimension of sustainability	Sustainable development target	Land use function	Indicator	Unit
Economic	Increasing the income of rural households, increasing the food production and narrowing the gap between rural income and urban income	Physical production	Crop production	Tons/year
		Economic production	Net farm income	Yuan/year
		Industry and services	Input costs	Yuan/year
Social	Ensure safe drinking water, to balance the supply and demand of food and to ensure air and water quality	Provision of work/livelihood	Labour use effiency	Yuan/day
		Human health	Bio residue index	-
		Food security	Rice production	Tons/year
Environmental	Reduce the use of N, P and K by 50%, to reduce the pesticide use by 20%, to reach a water quality of level three and to recover the lake view and environment	Abiotic resources	K:N ratio	-
		Biotic resources	N input	Kg/ha/year
		Ecosystem processes	N leaching	Kg/ha/year

2.4 Bio-economic modeling

2.4.1 Adaptation of FSSIM (Farm System SIMulator)

The bio-economic model FSSIM as developed in the SEAMLESS-project for the European context is adapted such that it is usable for the Taihu Lake basin (Reidsma et al., 2009). TechnoGIN outputs are used as input files for FSSIM instead of FSSIM-AM. FSSIM-MP has been developed within the GAMS (General Algebraic Modelling System) modelling environment. GAMS is a high level modelling system for programming. FSSIM-MP can run inside the whole SEAMLESS-IF system or independently through GAMS by using the input files generated by FSSIM-AM (Louhichi et al., 2007) and in this study through TechnoGIN. GAMS is used to adapt an FSSIM-MP version that is able to assess the Chinese case study of the Taihu lake basin.

One of the most important changes that is made to FSSIM is the definition of the crops. In FSSIM-China the crops are linked to a certain management (Table 1), this is not the case for FSSIM-EU. This means that in the output file the results are displayed for the area allocated to the crops including the used management.

Another change that needed to be made to simulate the Chinese case study correctly is in the premium files. The subsidy structure is much simpler in China than in the EU, and therefore the EU premium files are replaced by new subsidy files. In the Chinese case study subsidy is given for cropping (named subs_crop in FSSIM) and subsidy for inputs (named subs_fert in FSSIM). This subsidy is related to the crop that is cultivated and the area of that crop.

In FSSIM-EU the costs for the future scenario are calculated by the current costs of a rotation times the inflation rate; also the wage in the future is calculated by the current wage times the inflation rate. For FSSIM-China this is not the case. Here the costs and the wage for 2015 are from the input-output files from TechnoGIN. The main difference between the two approaches is that for FSSIM-EU the same inflation rate is used for the wage and for the costs while for FSSIM-China the increase in costs is different per rotation and different from the wage. In TechnoGIN estimations are made on increasing prices using historical time series and extrapolating these towards 2015. Labour costs increase much faster than other costs do. Also for prices of crops, historical time series are used to estimate changes in prices.

FSSIM uses a PMP approach (Positive Mathematical Programming) (more information in section 2.4.2). In FSSIM-EU, the parameter alpha which is used for the PMP approach is defined as 1. In FSSIM-China alpha is coded as a parameter and is related to crops; the parameter that is developed is called alpha_c(gr).

The larger the value of alpha, the less sensitive the model is to price changes. The supply elasticity of the activity level is related to alpha (Kanellopoulos et al., 2010) according to:

$$\eta = \frac{p}{\alpha \cdot |\lambda|}$$

η = price elasticity of the supply level of an activity

λ = shadow price related to the calibration constraint per crop

p = revenues

Not only alpha_c(gr) is added, but also the formula for calculating alpha. The shadow price is already calculated by FSSIM. In case of running for a certain municipality, the correct revenues should be switch on. The revenues are put in a new file, reven.inc. The revenues per municipality are calculated by multiplying the yield with the price and adding the input and the basic subsidy (Table 5).

Table 5. Revenues (Yuan/ha) per crop for Wuxi, Changzhou and Zhenjiang, calculated by FSSIM for the base year 2008

Crop	Wuxi	Changzhou	Zhenjiang
RIc	14,994	14,204	12,879
WHc	9,405	8,126	7,543
RAc	8,507	8,678	7,770
RIfc	14,448	15,165	14,295
WHfc	8,716	8,220	7,747
RAfc	9,509	6,724	7,883
RImc	15,361	14,792	16,343
RIfmc	14,284	14,978	15,695
RIssc	19,732	18,279	18,563
RIssmc	17,932	18,279	18,563
WHssc	10,298	9,975	9,814
RAssc	12,245	10,779	11,359
FALL	6,750	9,000	7,500

The price elasticity is put in a new file, eta.inc. The values for price elasticity for all crops are based on values of whole China (Lin, 2006). For rice the price elasticity is based on the average of early, middle and late rice (Lin, 2006) and is 0.208. The price elasticity for wheat is 0.167 and the price elasticity for rapeseed is 0.326 (Lin, 2006). Based on these values, alpha is calculated per crop and municipality. Many other adaptations have been made for FSSIM-China, which are often related to the link with TechnoGIN, and to simulate outputs. More details about the adaptations that were needed for FSSIM to be suitable for the Chinese case study can be found in Appendix II.

2.4.2 Objective function

GAMS is used to adapt FSSIM-MP for the Chinese case study of the Taihu lake basin. FSSIM is a linear programming model which results in maximizing an objective function considering certain constraints and equations.

Positive Mathematical Programming

The objective function in FSSIM includes a term called PMP and it stands for Positive Mathematical Programming (Equation 1). PMP is a calibration method which will exactly reproduce the base year activity levels (Howitt, 1995). In normal linear programming models the objective function value will always be a corner point of the feasible decision space (Figure 1). Therefore the most optimal point will be the outcome of the objective function and this is simulation behaviour that not realistic. Choosing for the optimal point will lead to a gap between the observed data and the simulated results. The PMP modeling procedure tries to reduce the gap between the observed data and the simulated results of the model (Kanellopoulos et al, 2010).

$U = Z + \text{PMP term}$ (Equ. 1)

Where:
U = farm income with the PMP term included (Yuan/year)
Z = total gross margin (Yuan/year)

With PMP a decreasing marginal gross margin function is included to account for increasing variable costs per unit of the production, because of management capacity, inadequate machinery and to land heterogeneity. Therefore the optimal point of the outcome of the objective function will be reduced. For the assumption of a decreasing marginal gross margin function there is a need to estimate a non-linear costs or a production function that is based on the activity levels of the base year (Kanellopoulos et al, 2010).

PMP procedure

The extended version of the PMP approach is used in FSSIM. This means that the PMP procedure consists of three steps. For phase one and two the idea is to get the information on the shadow prices of the calibration constraints, this is then used for the third step to specify a non-linear objective function such that the observed activity levels are reproduced by the optimal solution of the new programming model without bounds (Heckelei, 2005).

The first step

A linear programming (LP) model (Figure 3) is a model which maximizes an objective function, in this case the total gross margin (Equation 2) and is subjected to a set of resource constraints (for example labour and land) and policy constraints (for example area of bufferzone) (Equation 3) (Heckelei, 2005).

$\text{Max}\{Z = p'x - c'x\}$ (Equ. 2)

Subject to:

$Ax \leq b \; [\pi]$ (Equ. 3)
$x \geq 0$

Where:
p = $n \cdot 1$ vector of the revenues per unit of activity
x = $n \cdot 1$ vector of the activity levels
c = $n \cdot 1$ vector of the costs per unit of activity
A = $n \cdot m$ matrix of the technical coefficients
b = $m \cdot 1$ vector of resource endowments

$\pi = m \cdot 1$ vector associated with the shadow price of the resource constraints

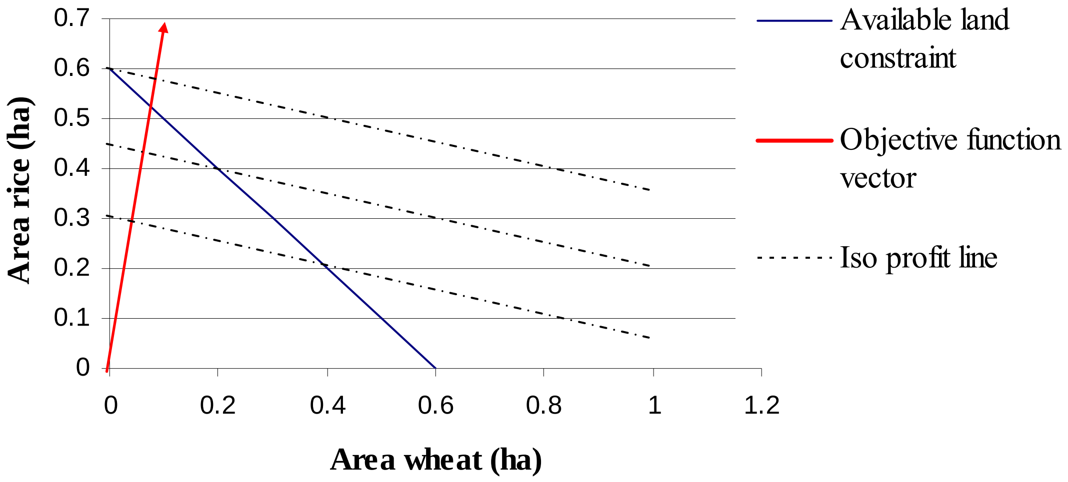

Figure 3. Graphical representation of an example of a LP model. This example presents the objective function vector for gross margin $1 \cdot x_{wheat}+7 \cdot x_{rice}$. The total land constraint is $x_{rice}+x_{wheat} \leq 0.6$. The optimal solution is always a corner point, the corner points for $(x_{wheat},x_{rice})'$ are (0,0), (0,0.6) and (0.6,0). Adding the objective function vector and the iso profit lines, those are lines that are perpendicular on the objective function vector and represent the height of the gross margin. After adding the iso profit lines, it can be seen that the optimal solution for this LP problem is the point $(x_{wheat},x_{rice})'$ is (0,0.6) and has a gross margin of 4.2.

At the first step of the PMP procedure the LP model is extended (Figure 4). It is extended with a set of calibration constraints which fix the simulated crop levels to the observed base year data. Only a small perturbation is allowed to make sure that all binding resource constraints remain binding (equation 5) (Kanellopoulos et al, 2010 and Heckelei, 2005).

$\text{Max}\{Z = p'x - c'x\}$ (Equ. 4)

Subject to:

$Ax \leq b \ [\pi]$
$x \leq (x^0+\varepsilon) \ [\lambda]$ (Equ. 5)
$x \geq 0$

Where:
$x^0 = n \cdot 1$ vector of the observed activity levels
$\varepsilon = n \cdot 1$ vector of a small positive number
λ = shadow price related to the calibration constraint

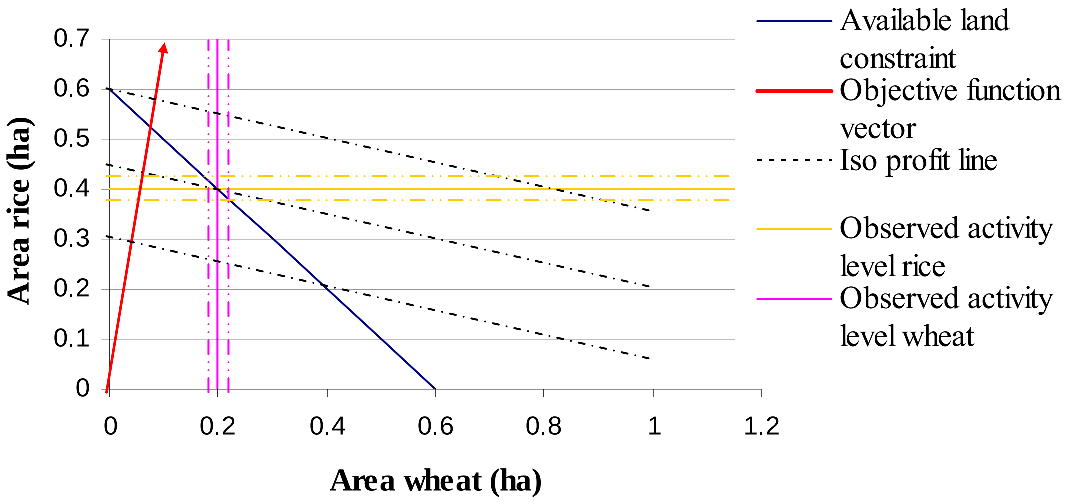

Figure 4. Graphical representation of the extended LP model, with calibration constraints that fit the observed activity level together with a small perturbation. First the outcome of the LP problem was the point (x_{wheat}, x_{rice})' is (0,0.6). After adding the calibration constraints the optimal solution of the LP problem will be the point (x_{wheat}, x_{rice})' is (0.2,0.4) and the gross margin will now be 3.0.

In FSSIM, the shadow price related to the calibration constraints per crop is calculated as follows (Equation 6, 7 and 8):

λ = lower calibration constraint per crop + upper calibration constraint per crop (Equ. 6)

Lower calibration constraint per crop (Figure 4):

$$\sum_{cr,s,t,sys} \sum_{r,pe} X_{cr,s,t,sys} \leq LEVo_{cr} \cdot (1 + 10 \cdot (\frac{1 \cdot 10^{-10}}{LEVLo}) + 1 \cdot 10^{-10}) \quad \text{(Equ. 7)}$$

Where:
X = the level of an agricultural activity in hectare
LEVLo = the observed activity level specified per crop (ha), this is the land area allocated per crop that is observed during the farm survey hold in 2008
cr = crop
s = soil
t = technique
sys = system
r = rotation
pe = period
So $\sum_{s,t,sys} X_{cr,s,t,sys}$ is the crop level

Upper calibration constraint per crop (Figure 4):

$$\sum_{cr,s,t,sys} \sum_{r,pe} X_{cr,s,t,sys} \geq LEVLo \cdot (1 + 20 \cdot (\frac{1 \cdot 10^{-10}}{LEVLo}) + 1 \cdot 10^{-10}) \quad \text{(Equ. 8)}$$

The Second step
The second step of the PMP procedure is the inclusion of a rented land activity (Equation 9). This is incorporated in the model by adding the costs of rented land to the objective function and by replacing the resource constraints of the available land with a flexibility constraint where land is a decision variable. The shadow price of this flexibility constraint and the apparent value of the land are now equal to the average gross margin in the base year. The set

of activities is separated in two groups. One group has a gross margin lower than the average, they will not be restricted. Another group has a gross margin higher than the average, they will be restricted to their observed activity level by the set of calibration constraints of the PMP approach and will set the upper bound (second group). The lower bound will be equal to the observed activity level plus a small positive number (Kanellopoulos et al, 2010).

$\text{Max}\{Z = p'x - c'x - gy\}$ (Equ. 9)

Subject to:

$A^{-}x \le b^{-}\ [\pi^{-}]$
$I'x - y \le 0$
$x \le (x^{0}+\varepsilon)\ [\lambda]$
$x \le (x^{0}-\varepsilon)\ [\lambda']$
$x \ge 0$

Where:
g = average gross margin at the observed level
y = rented land
$A^{-} = (m-1)\cdot n$ matrix of the technical coefficients of resource and policy constraints except from the available land constraint
$b^{-} = (m-1)\cdot 1$ vector of upper bounds of the models constraints
$\pi^{-} = (m-1)\cdot 1$ vector of the shadow prices of the resource and policy constraints except from the available land constraint
$I = n\cdot 1$ vector of ones
$\lambda' = n\cdot 1$ vector of shadow prices of the second set of calibration constraints

Third step
In the third step of the PMP procedure the calibration constraints are taken out. There shadow prices are used for estimation of the parameters of a quadratic cost function such that the model can exactly calibrate the base year data (Equation 10, 11, 12, 13 and 14)(Kanellopoulos et al, 2010).

$C = d'x + 0.5x'Qx$ (Equ. 10)

Were:
$d = n\cdot 1$ vector of parameter related with the linear term
$Q = n\cdot n$ symmetric positive semi-definite matrix of parameters related with the quadratic terms

In FSSIM this is calculated as follows:

$$\text{PMP term} = -\sum_{\text{crops}} d'(\text{if } \text{LEVLo}_{cr} > 0)\cdot \sum_{cr,s,t,sys} X_{cr,s,t,sys} + 0.5\cdot Q\sqrt{\sum_{cr,s,t,sys} X_{cr,s,t,sys}} \qquad \text{(Equ. 11)}$$

$d = \lambda - |\alpha\cdot\lambda|$ (Equ.12)

$$Q = \frac{|\alpha\cdot\lambda|}{\text{LEVLo}_{cr}} \qquad \text{(Equ. 13)}$$

In these functions (Equation 12 and 13) α is the vector that determines the weights of linear and non-linear costs of the activities in the objective function (Equation 14). The larger the value of alpha, the less sensitive the model is to price changes. The supply elasticity of the activity level is related to alpha (Kanellopoulos et al., 2010):

$$\eta = \frac{p}{\alpha \cdot |\lambda|} \qquad \text{(Equ. 14)}$$

Where η is the price elasticity of the supply level of an activity. With this new cost function in the objective value function will be different (Equation 15). Hence the objective value function will change (Figure 5):

$$\text{Max}\{U = p'x - d'x - 0.5x'Qx\} \qquad \text{(Equ. 15)}$$

Subject to:

$Ax \leq b\ [\pi]$

$x \geq 0$

Where $Ax \leq b$, are the model constraints:

$$\sum_{r,s,t,sys} X_{r,s,t,sys} \leq \text{total soil area}$$

Where:

$$\sum_{s,t,sys} X_{r,s,t,sys} = \text{rotation level}$$

$$\sum_{r,s,t,pe,sys} X_{r,s,t,sys} \cdot \text{labour requirement}_{r,s,t,pe\,sys} \leq \text{FLabour} + \text{TLabour}$$

Where:

FLabour = days of family and permanent labour available

TLabour = days of rented temporary labour

$$\sum_{s,t,sys} X_{FALL,s,t,sys} = \%\ \text{in the buffer zone} \cdot \text{total soil area}$$

Where:

FALL = buffer zone

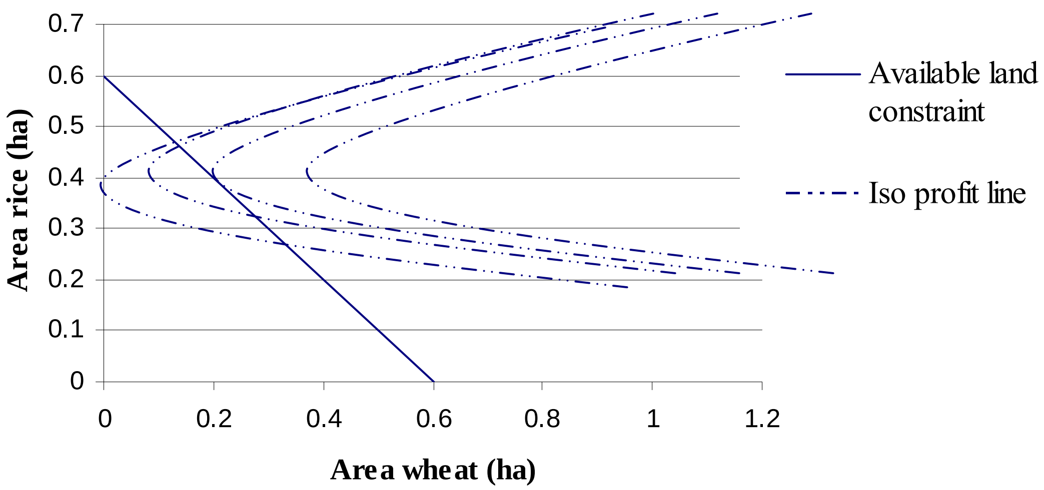

Figure 5. Graphical representation of the last step in the PMP procedure. To find the optimal solution the iso profit lines should be moved until the line does not cross the available land constraint and only toughs the available land constraint. In this example it is the point $(x_{wheat}, x_{rice})'$ is (0.20,0.40)

So in FSSIM the objective function to maximize is the farm income with the PMP term (Equation 15), this is done with the farm income (Equation 2) and the PMP term (Equation 11). The PMP term is calculated with a quadratic costs function (Equation 12, 13 and 14). The PMP procedure tries to reduce the gap between the observed activity levels and the model outcome. For measuring the model performance the PAD (Percentage Absolute Deviation) value is used. This value is defined as the deviation between the simulated activity levels and the observed activity level per unit of actual activity level (Equation 16)(Kanellopoulos et al., 2010). The model performance is fine if the model reproduces the base year activity levels with a PAD value no greater than 15% (Hazell and Norton, 1986).

$$\text{PAD}(\%) = 100 \cdot \frac{\left(\sum_i \left| X_i - X_i^0 \right| \right)}{\sum_i X_i^0} \qquad \text{(Equ. 16)}$$

Where:
i = an activity

The model assumes that the farm income is reduced by the PMP term, which causes a lower farm income. This assumption is made, because the farmer will make more costs due to for example imperfect management skills or inadequate machinery. As the costs introduced by the PMP term are not necessarily needed, it is therefore also interesting to know what the farm income is considering outputs and inputs only. Therefore in FSSIM an equation is included for calculating of the farm income without the PMP term (Equation 17).

Farm income without PMP term (Yuan) = Z (Equ. 17)

The costs of labour increase rapidly. In 2015 the costs of labour have been more than doubled compared to 2008 according to the estimations that are made with the historical time series taken into account. It would be interesting to know what the farm income would be when the costs of hiring labour are subtracted (Equation 18). Then a comparison can be made between 2008 and 2015 and the influence of the high labour costs can be seen.

Farm income without temporary labour costs (Yuan) = $U + \text{wage} \cdot \text{TLabour}$ (Equ. 18)

How much labour is needed to hire (TLabour) depends on how much labour is needed per activity (Equation 19 and 20). If more labour is needed per activity than available family and permanent labour, then the farm household should hire labour (Equation 21).

$$\text{Labour use per ha (days/ha)} = \frac{\sum_{r,s,t,pe,sys} X_{r,s,t,sys} \cdot \text{labour requirement}_{r,s,t,pe,sys}}{\sum_s \text{total land area of the soils}} \qquad \text{(Equ. 19)}$$

$$\text{Total labour use} = \text{Labour use per hectare} \cdot \left(\sum_s \text{total land area of the soils} - \sum_{fgr} \text{LEVLo}_{fgr} \right)$$

(Equ. 20)

Where:
Fgr = crops not represented in the set of rotations
In FSSIM-China there are no crops in the set fgr, so all crops that are represented in the model are in the set of rotations. $\sum_{fgr} \text{LEVLo}_{fgr}$ is zero and therefore not mentioned in the next coming equations, but it is present in FSSIM-China.

$$\text{TLabour} = \left(\sum_{r,s,t,pe,sys} X_{r,s,t,sys} \cdot \text{labour requirement}_{r,s,t,pe\,sys} \right) - \text{FLabour} \qquad \text{(Equ. 21)}$$

The days of family and permanent labour available can be found in FSSIM in the files miscdat.inc or miscdat_change.inc. The days of family and permanent labour available depend on the farm type and region that is chosen.

Due to rapid urbanization in Jiangsu province a lot of farmers get good opportunities for off farm jobs. When the farmer works on the farm it is interesting to see if the farmer will earn more with working on farm or that the farmer can better work off farm. Therefore in the model an equation is included with the costs for family and permanent labour included (Equation 22). When this income is negative the farmer can get a better income when working off farm than on farm. The income per day for the farmers is lower than the wage of the average farm labourer.

Farm income with the costs for permanent and family labour included (Yuan) =
$$\text{U - (total labour use} \cdot \text{wage)} + (\text{wage} \cdot \text{TLabour}) \qquad \text{(Equ. 22)}$$

Several other economic equations are present, which are used to evaluate results. Like the farm income per hectare (Equation 23). This equation is calculated as followed:

$$\text{Income per hectare (Yuan/ha)} = \frac{U}{\sum_{s} \text{total land area of the soils}} \qquad \text{(Equ. 23)}$$

All other farm incomes (equation 17, 18 and 22) are also calculated per hectare by dividing them by the total land area.

The total revenues include the gross production (Equation 25) and the subsidy (Equation 24). In China subsidies can be given for rice, wheat and rapeseed, and for inputs. As this subsidy scheme is simple, it was not added to the premium model in FSSIM-EU, but a new subsidy model was made for FSSIM-China.

$$\text{Subsidy (Yuan)} = \sum_{cr,s,t,sys,payments} X_{cr,s,t,sys} \cdot \text{subsidy}_{cr,payments} \qquad \text{(Equ. 24)}$$

Payments can be crop subsidy and subsidy for inputs.

$$\text{Gross production (Yuan)} = \sum_{cr,prd} \text{sales}_{cr,prd} \cdot \text{price}_{cr,prd} \qquad \text{(Equ. 25)}$$

Where:
prd = crop products

For calculation of the farm income are next to revenues also costs needed to be calculated (Equation 26).

$$\text{Total costs (Yuan)} = \sum_{r,s,t,pe,sys} X_{r,s,t,sys} \cdot \text{costs}_{r,s,t,pe,sys} + \text{wage} \cdot \text{TLabour} \qquad \text{(Equ. 26)}$$

Total costs includes cost for fertilizer, machine rent (for land preparation and for harvesting), mechanical transplanting (MT) machine rent, seeds, biocides and miscellaneous costs.

Total costs with costs for permanent and family labour included(Yuan) =
$$\sum_{r,s,t,pe,sys} X_{r,s,t,sys} \cdot \text{costs}_{r,s,t,pe,sys} + (\text{total labour use} \cdot \text{wage}) \qquad \text{(Equ. 27)}$$

$$\text{Land shadow price (Yuan)} = \frac{\sum_{s} \text{E\_toland.m}_s \cdot \text{total land area of the soils}}{\sum_{s} \text{total land area of the soils}} \qquad \text{(Equ. 28)}$$

Where E_toland.m = the marginal value of the total land constraint

2.4.3 Environmental inputs, outputs and equations

In FSSIM-EU several environmental outputs were programmed. What can be simulated depends on the data available. As in FSSIM-China, TechnoGIN was used to estimate input-output coefficients, everything available from TechnoGIN was used (Appendix III). Adaptations in FSSIM were made in the input file enviro.inc, equations in FSSIM_model.gms, and results produced in FSSIM_results.gms. The following environmental indicators are calculated at farm level by FSSIM:

- Water requirement per crop within each activity (mm/year)
- Surplus of N (kg N/ha/year)
- Surplus of P (kg P/ha/year)
- Surplus of K (kg K/ha/year)
- Run off of N (kg N/ha/year)
- Run off of P (kg P/ha/year)
- Run off of K (kg K/ha/year)
- Leaching of N (kg N/ha/year)
- Leaching of K (kg K/ha/year)
- Biocide residue index (-)
- Volatilization of N (kg N/ha/year)
- Denitrification of N (kg N/ha/year)
- N application (kg N/ha/year)
- P application (kg P/ha/year)
- K application (kg K/ha/year)

All indicators are calculated by taking the results from TechnoGIN at hectare level, multiplying these by the area of an agricultural activity, summing this for all agricultural activities and dividing this by the total land area. For water use at farm level (Equation 29) this implies:

$$\frac{\sum_{r,s,t,pe,sys} X_{r,s,t,sys} \cdot \text{water\_req}_{r,s,t,pe,sys}}{\sum_{s} \text{total land area of the soils}} \qquad \text{(Equ. 29)}$$

Where:
Water_req = water requirement per crop within each activity (mm)

The water use at farm level is the amount of water that is required for all crops on that farm. The water requirement per crop is calculated by TechnoGIN.
Water requirement = actual evapotranspiration + water loss – rainfall – water balance previous period (Ponsioen et al., 2003)

The surplus of N, P and K per activity is calculated by TechnoGIN as the amount of nutrients that remain in the soil per year (Ponsioen et al., 2003).

The long term soil supply of N, P and K refers to the indigenous nutrient content in the soil. For a clay soil the long term soil supply of N is 70 kg N/ha, for loam 60 kg N/ha and for sand 50 kg N/ha (Appendix I).

The total N loss fraction is the sum of the loss fractions by leaching, denitrification and ammonia volatilization (Ponsioen et al., 2003). Run off of N is integrated in leaching, because both N loss via run-off and via leaching will eventually leach into the surface water. The N leaching fraction under aerobic conditions depends on the precipitation and the clay content. Annual rainfall is in the research area between 1010 mm 1400mm. In case of a clay content which is less than 35% the N leaching is dependent on the precipitation between 0.25 (in case of a precipitation which is close to zero) and 0.40 (in case of a precipitation which is 2500mm). In case of a clay content which is between 35% and 55%, then the N leaching is between 0.20 (in case of a precipitation which is close to zero) and 0.30 (in case of a precipitation of 2500mm). For a clay content higher than 55% the N leaching fraction is between 0.15 (in case of a precipitation which is close to zero) and 0.20 (in case of a precipitation of 2500mm). Under anaerobic conditions the N leaching fraction is 0.15 (Kang, 2009).

The volatilization fraction of N under aerobic conditions is 0.12. Under anaerobic conditions the N volatilization fraction is $4 \cdot 10^{-3} \cdot (100 - \%clay)$. The parameters of the N volatilization under anaerobic conditions are calibrated with a recovery fraction between 0.33 and 0.35 (Appendix I). The recovery fraction of available nutrients for crop uptake is calculated as 1 minus the total loss fraction.

The denitrification fraction of N is calculated by: $2.5 \cdot 10^{-3} \cdot \%clay + 1.0 \cdot 10^{-4} \cdot precipitation + 0.1$

The P run-off fraction depends on the %clay, the precipitation and the slope of the land. P run-off fraction = $1.67 \cdot 10^{-4} \cdot \%clay + 1.20 \cdot 10^{-5} \cdot precipitation + 0 \cdot slope$. Parameters are based on outcome of Cao and Zhang (2004) (Appendix I).

The leaching of K also depends under aerobic conditions on the precipitation and the clay content. Under or aerobic conditions with a clay content less than 35% with no precipitation the K leaching fraction is 0.25 and with 2500 mm of precipitation the fraction of leaching is 0.40. When the clay content is between 35% and 55% the leaching fraction will be 0.25 for no precipitation and 0.20 for 2500 mm of precipitation. In case of a clay content which is higher than 55% the leaching fraction will be 0.15 for no precipitation and 0.20 for 2500 mm precipitation. Under anaerobic conditions the K leaching fraction is 0.10 with 0% clay and 0.25 with 100% clay (Appendix I). This is slightly different from the estimations made by Kang (2009).

The Biocide Residue Index calculated by TechnoGIN depends on the biocide used and is calculated as followed:
BRI = biocide (g/ha) · active ingredient fraction (kg/l or kg) · toxicity index · persistence index / 100. A value below 100 for is safe, between 100 and 200 is permissible and a value above 200 is unsafe (Vasisht et al., 2007).

The application of nutrients per activity for the conventional fertilizer managements and for the FF fertilizer managements is based on observed in the farm survey. The fertilizer application for SSNM is calculated with Quantitative Evaluation of the Fertility of Tropical Soils (QUEFTS; Janssen et al., 1990). QUEFTS calculates the crop nutrient uptake for a specific target yield level while using the solver optimization module in Microsoft Excel. The QUEFTS approach used in TechnoGIN calculates the N, P and K uptake with the assumption of a balanced nutrient supply for the selected crop. The calculated uptake of N, P and K is bounded by the maximum dilution and the maximum accumulation of N, P and K in the plant in relation to the yield level (Ponsioen et al., 2006).

2.5 Scenario description

FSSIM-China is programmed such that in each run three scenarios are simulated: base year, baseline and policy. In FSSIM these scenarios are declared in the set scenarios (SIM), and for FSSIM China also in the set systems. The systems in FSSIM EU are production orientations, but these production orientations can be used for the defined scenarios. Production orientations are value driven aims and restriction of the production activity that lead output and input levels (Van Ittersum and Rabbinge, 1997). Every scenario has certain restrictions that the other scenario does not have, like the use of certain technologies and these technologies have a specific input and output.

Every scenario is coupled to a few possible technology options (Figure 6). The base year scenario is coupled to technology levels A, B and C. The baseline scenario is coupled to level D, E and F and the policy scenario is coupled to level G, H and I. In TechnoGIN, agricultural activities are defined as combinations of land use types (LUT), land management units and technologies. A land use type includes one or more crops linked to management (Table 1). In FSSIM the LUTs can be found in the rotation set. In each scenario, the same land use types can be selected, but different technology levels are assumed for different scenarios. Differences in management are partly considered in the crop with management combinations, but can further be adapted by linking this to a different technology level (e.g.

higher yields, or higher nutrient recovery). Hence, in FSSIM in the base year a farmer can for example choose to use level A and/or level B and/or level C.

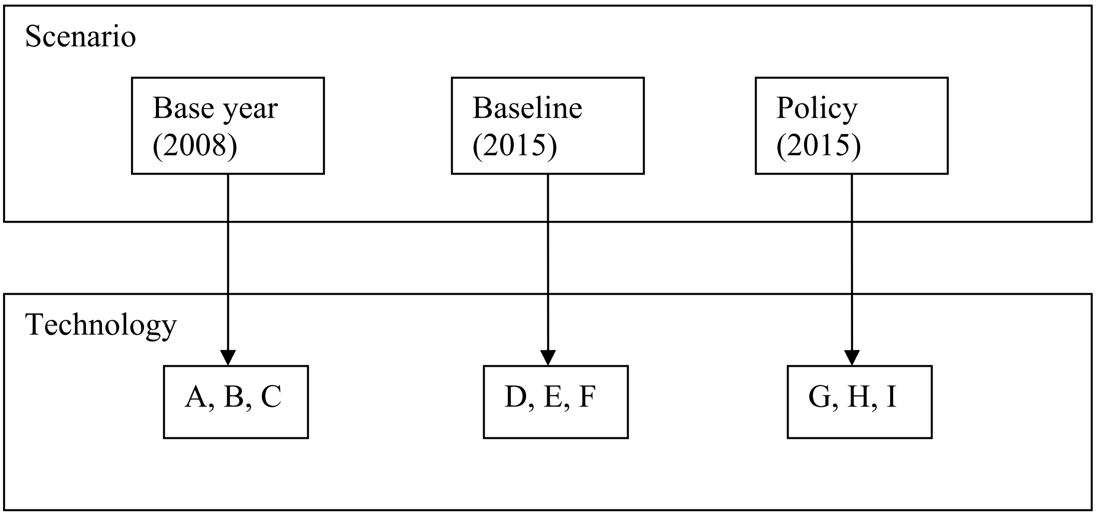

Figure 6. Description of structure of the scenarios

2.5.1 Base year scenario

The base year scenario simulates the situation in 2008. Data for the different farm types in 2008 situation was gathered by field surveys and databases. In this scenario the technology levels are A, B and C.

Level A represents the conventional way of cultivating (Figure 7). In the conventional way of cultivating, mechanical transplanting (MT) of rice is also included; specification of this management is included in a separate crop with management combination. The following land use types (rotations) are linked to this technology: rice-wheat, rice-rapeseed, rice, wheat, rapeseed, riceMT-wheat, riceMT-rapeseed, riceMT and fallow. For the example rice-wheat, this means that in the first period of the year rice is cultivated and in the second period of the year wheat is cultivated.

In TechnoGIN, some values are defined in the technology sheet and other values are defined in the LUT sheet. Some management options should be not the same for every scenario and therefore differ per technology. The conventional way of farming in the base year serves as the reference. With this as the reference, then for example the nutrient recovery in an improved technology can be 1.6 times higher as for technology A for the same crop. Other things should be different per crop and are therefore defined in the crop sheet of TechnoGIN.

Level B represents cultivating with the use of formula fertilizer (FF) application (Figure 7). The only difference with technology A is that no general compound fertilizers are used, but the farmer is restricted to using fertilizers with another formula and another price. Differences in yields and input levels are not defined per technology, but per crop & management combination The following rotations are linked to this technology: riceFF&MT-wheatFF, riceFF&MT-rapeseedFF, riceFF&MT, riceFF-wheatFF, riceFF-rapeseedFF, riceFF, wheatFF and rapeseedFF.

Level C represents cultivating with the use of site specific nutrient management (SSNM) (Figure 7). Instead of applying the current amount of fertilizers, the model simulates how much nutrients are required to obtain the target yield (future system). At the conventional way of farming at technology level A the fertilizer inputs are high. This will lead to low fertilizer N use efficiencies, recoveries will be between 30-35% (Jing, 2007). According to experiments, at optimal fertilizer rates a N recovery of 53-56% can be reached (Jing, 2007). At level C the nutrient recovery is assumed to be in between the current (30-35%) and the optimal (53-56%) (Jing, 2007), which is 1.3 times higher compared to level A. This better crop management will also cost more time, therefore the time needed for management is 15 % higher than for level A and B. In this level the following rotations are included: riceSSNM-wheatSSNM, riceSSNM, wheatSSNM, rapeseedSSNM, riceSSNM&MT-wheatSSNM, riceSSNM&MT-rapeseedSSNM and riceSSNM&MT.

As positive mathematical programming (PMP) is used in FSSIM, the areas of cultivated crops simulated by FSSIM will be calibrated to the observed values. What is observed differs per farm type, but in general at most farm types have the highest percentage of level A and the lowest of level C.

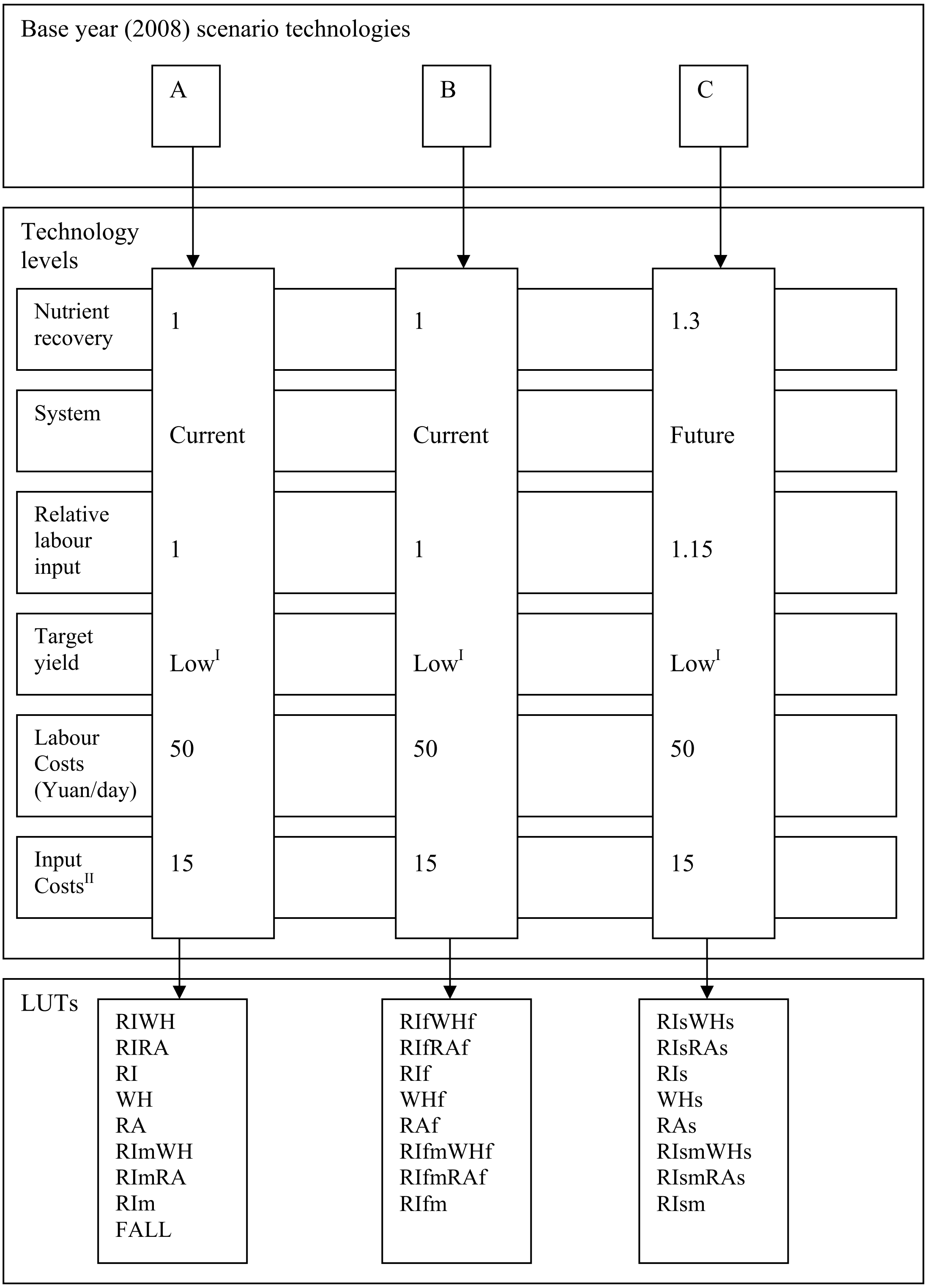

Figure 7. Description of the base year scenario with technologies A, B and C which are coupled to different LUTs and have certain technology levels

[I] Low target yield can be found in Appendix I.

[II] Input costs are the costs for machinery rent for harvesting and land preparation and the machinery rent for the mechanical transplanting machine. The value displayed in this table is a conversion factor and should be multiplied with the rent per hour, which can be found in the crop sheet of TechnoGIN, to get the rent per hectare per day.

In the baseyear the rent for mechanical transplanting is in Wuxi 75 Yuan/mu, in Changzhou 125 Yuan/mu and in Zhenjiang the rent is 100 Yuan/mu (Appendix I). The driver of the MT machine can finish 1 hectare in 1 day. 1 hectare is 15 mu, so the costs per hectare per day are for Wuxi 1125 Yuan, for Changzhou 1875 Yuan and for Zhenjiang 1500 Yuan. The prices in the technology sheet of TechnoGIN are multiplied by the input use of the machine. So for mechanical transplanting is 15 (in the technology sheet, Figure 7) multiplied by 75 (in the crop sheet of the TechnoGIN file of Wuxi) to get the total costs for MT.

2.5.2 Baseline scenario

This scenario represents the business as usual situation as projected for 2015. Average observed trends from 1978 until 2008 are assumed to persist in the future and this will mean increase in crop yield, input costs and output prices (Appendix II).

A driver is needed when renting a MT machine. Expected is that the labour wage increases sharply (Appendix I). The rent is not only dependent on labour costs, but also on seed, gasoline and deprecation costs. Expected is that the rent will increase with 8.05% per year. Therefore the input costs in the technology sheet in TechnoGIN are put on 25.8 instead of 15.

Level D has the same management as level A. This means that the nutrient recovery, biocide use, labour input, water use and the amount of inputs are the same. What is different from the baseline situation compared to the baseyear is that it is assumed for 2015 that the yield will increase and therefore calculation by TechnoGIN will be made with the high yield level (Figure 8). Furthermore the labour costs of 2015 will be used (Appendix I) and the input costs of 2015 (Appendix III) will be used. Level E has the same management as level B and level F has the same management as level C (Figure 8).

Expected is that the areas of the agricultural activities that are chosen will not differ much. Changes in areas of agricultural activities depend on how much the input costs change compared to the prices and yields. How much it will differ depends on the elasticity of area changes to price and yield changes. In the model, the elasticity is determined by alpha. The larger alpha, the less sensitive the model becomes to price changes.

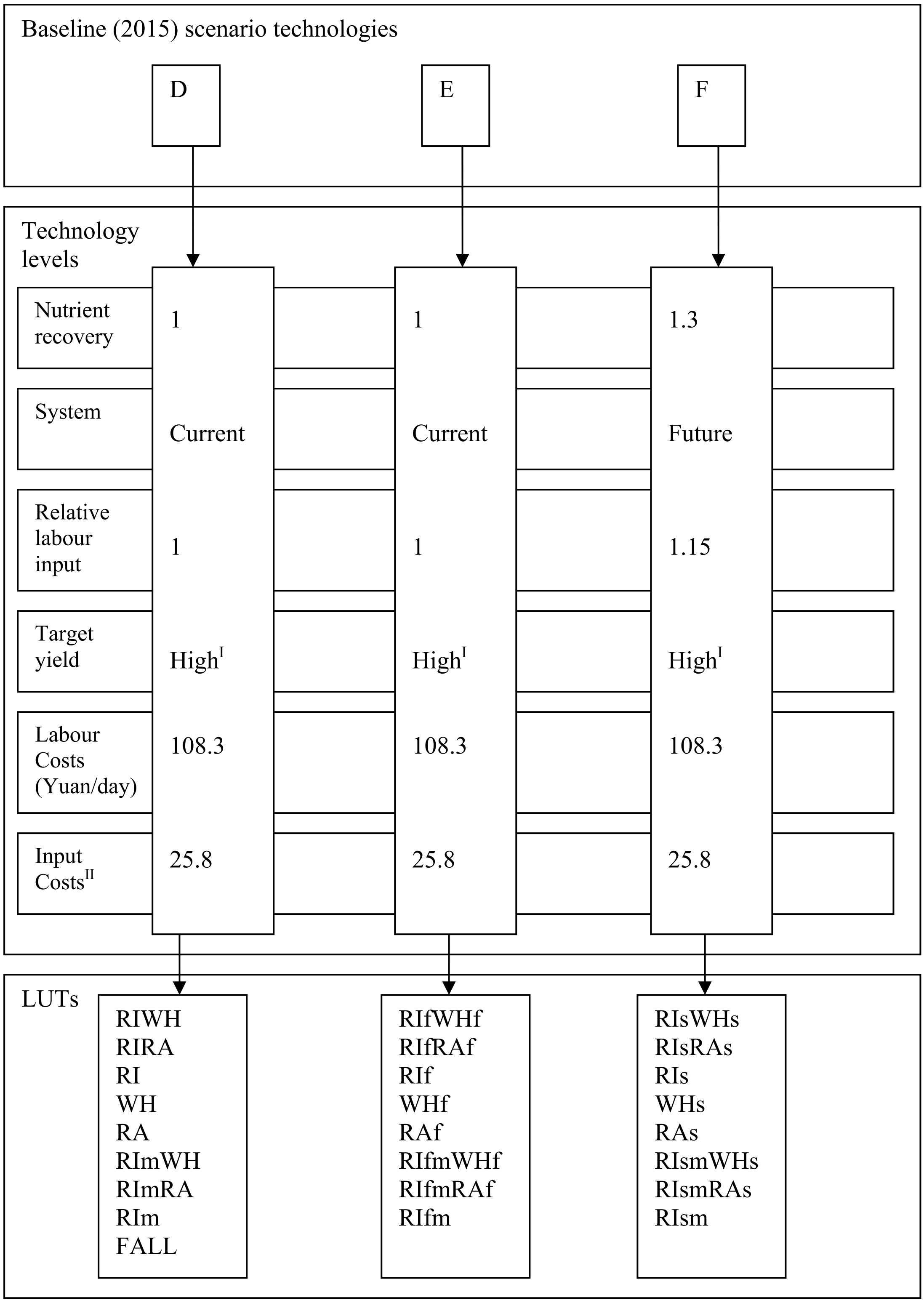

Figure 8. Description of the baseline scenario with technologies D,E and F which are coupled to different LUTs and have certain technology levels

[I] Low target yield can be found in Appendix I.

[II] Input costs are the costs for machinery rent for harvesting and land preparation and the machinery rent for the mechanical transplanting machine. The value displayed in this table is a conversion factor and should be multiplied with the rent per hour, which can be found in the crop sheet of TechnoGIN, to get the rent per hectare per day.

2.5.3 Policy scenario

A policy scenario represents the situation in 2015 as it would become with policy measures. The selected policy measures mainly focus on reducing the environmental outputs.

To be able to assess the impact of a policy, one policy option is assessed per policy scenario. There are three types of policies: 1. command and control, 2. economic instruments and 3. public information and education. The way in which a policy option is introduced in FSSIM depends on the type. A command and control measure is to obligate farmers to reduce the environmental outputs and therefore use site specific nutrient management; no other options are possible. The policy scenario includes then only one level, level I. Level I is then exactly the same as level F of the baseline scenario and no other levels are present.

Another way of introducing policy measures is to make policy measures optional to the farmers. In this case there should be stimulation in the form of economic instruments (e.g subsidies) or public information and training. For example a policy goal can be to stimulate the use of mechanical transplanting. Now only subsidy for buying the machinery is available, subsidy for farmers who rent the machine is not available. In the policy scenario it is a possibility to introduce subsidy for farmers who rent the machinery. Level G, H and I would then be the same as level D, E and F of the baseline situation, only the rent of the machinery for transplanting will be lower (Figure 9).

The costs for renting the MT machine includes costs for seed, depreciation of the machine, depreciation plates, gasoline and labour. Costs for seeds and depreciation are not being subsidized in the policy scenario for stimulating MT. Seed costs are 565 Yuan/ha, the costs for depreciation of the machine is 40 Yuan/ha and for depreciation of the plates the costs are 63 Yuan/ha (Jiangsu Province Government, 2004). To simulate the lowered MT costs the input costs in the technology sheet are lowered, in Figure 9 the costs are lowered from 25.8 to 20. The costs in the technology sheet should be multiplied with the costs in the crop sheet to get the total value for the costs for renting. So the only difference between Figure 8 and 9 is the rent of machinery for transplanting, other input costs stay the same as in the baseline. In Figure 8, which represents the baseline, the rent is 25.8 (in the technology sheet of TechnoGIN) multiplied by 75 (in the crop sheet of TechnoGIN of Wuxi). In Figure 9, which represents the policy scenario of MT stimulation, the rent is 20 (in the technology sheet of TechnoGIN) multiplied by 75 (in the crop sheet of TechnoGIN of Wuxi).

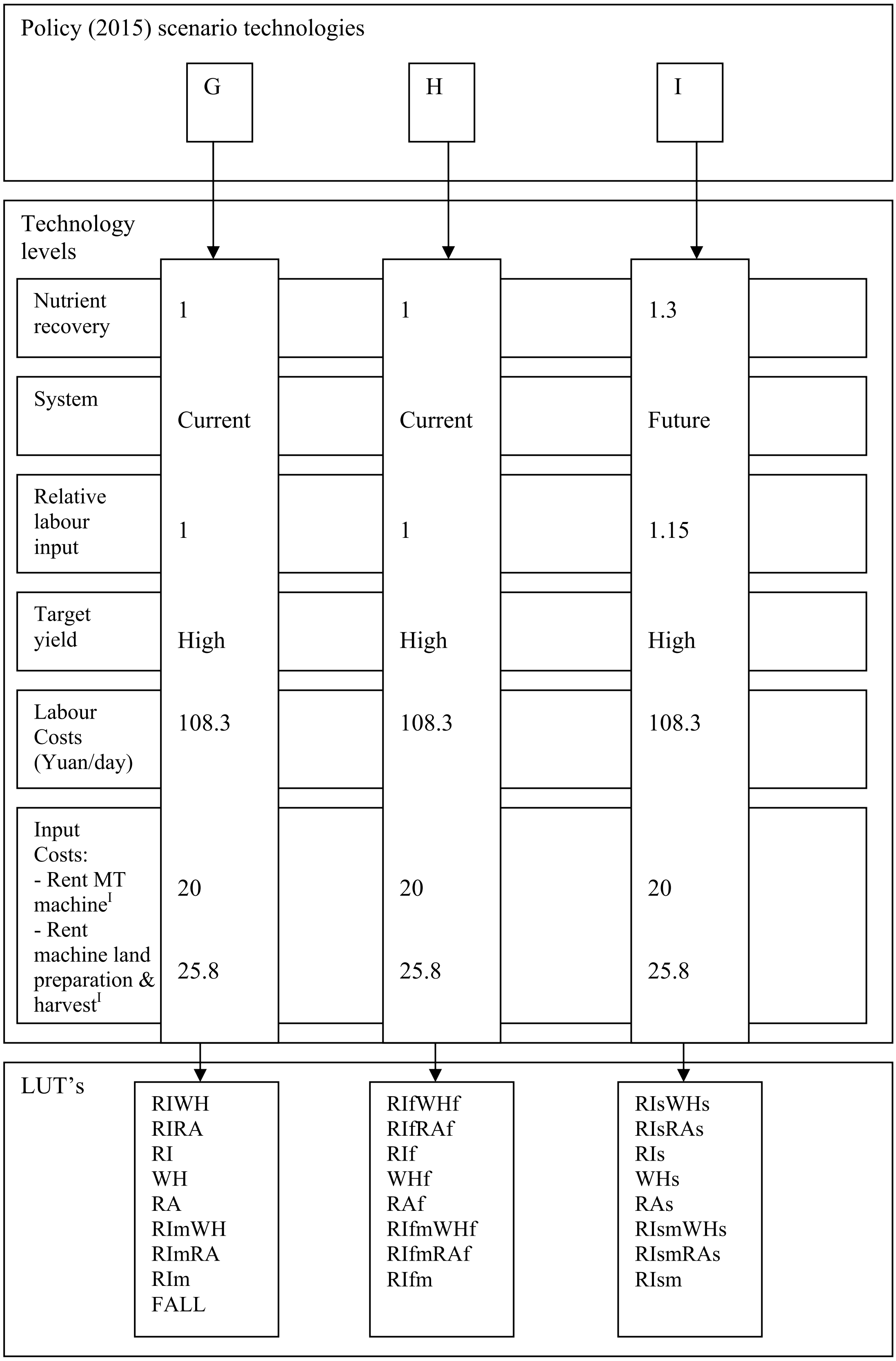

Figure 9. Description of the policy scenario of MT stimulation with technologies G, H and I which are coupled to different LUTs and have certain technology levels

[I] Input costs are the costs for machinery rent for harvesting and land preparation and the machinery rent for the mechanical transplanting machine. The value displayed in this table is a conversion factor and should be multiplied with the rent per hour, which can be found in the crop sheet of TechnoGIN, to get the rent per hectare per day.

It has been argued that for reduction of environmental outputs, the best policy is to give more training and education to farmers to stimulate them to use SSNM and to teach them how to do SSNM better (Che, 2009). When simulating this with TechnoGIN, level G is exactly the same as level D of the baseline and level H will be exactly the same as level E of the baseline (Figure 10). Level I is then the policy option for the stimulation SSNM. Assumed is that the farmers use an optimal fertilizer application, because they are trained to do so. Therefore a nutrient recovery of 53-56% will be reached and this is approximately 1.6 times higher than the assumed nutrient recovery in the base year of 30-35%. Assumed is that the training and education of the farmers will also cause that the highest yield that could be obtained, this is the policy target yield and is higher than the high target yield (Appendix I). The relative labour input for management will be 1.3 times higher than it is in the conventional way of farming (Figure 10), because participating in training of extension services is the main driving force for a good adaptation of SSNM (Che, 2009). The difference between Figure 8 (which represents the baseline) and Figure 10 (which represents the policy scenario of SSNM stimulation) is that for the last level which includes LUTs with SSNM the nutrient recovery is 1.6 instead of 1.3; the relative labour input is 1.6 instead of 1.3 and the target yield is the policy target yield (Appendix I) instead of the high target yield (Appendix I).

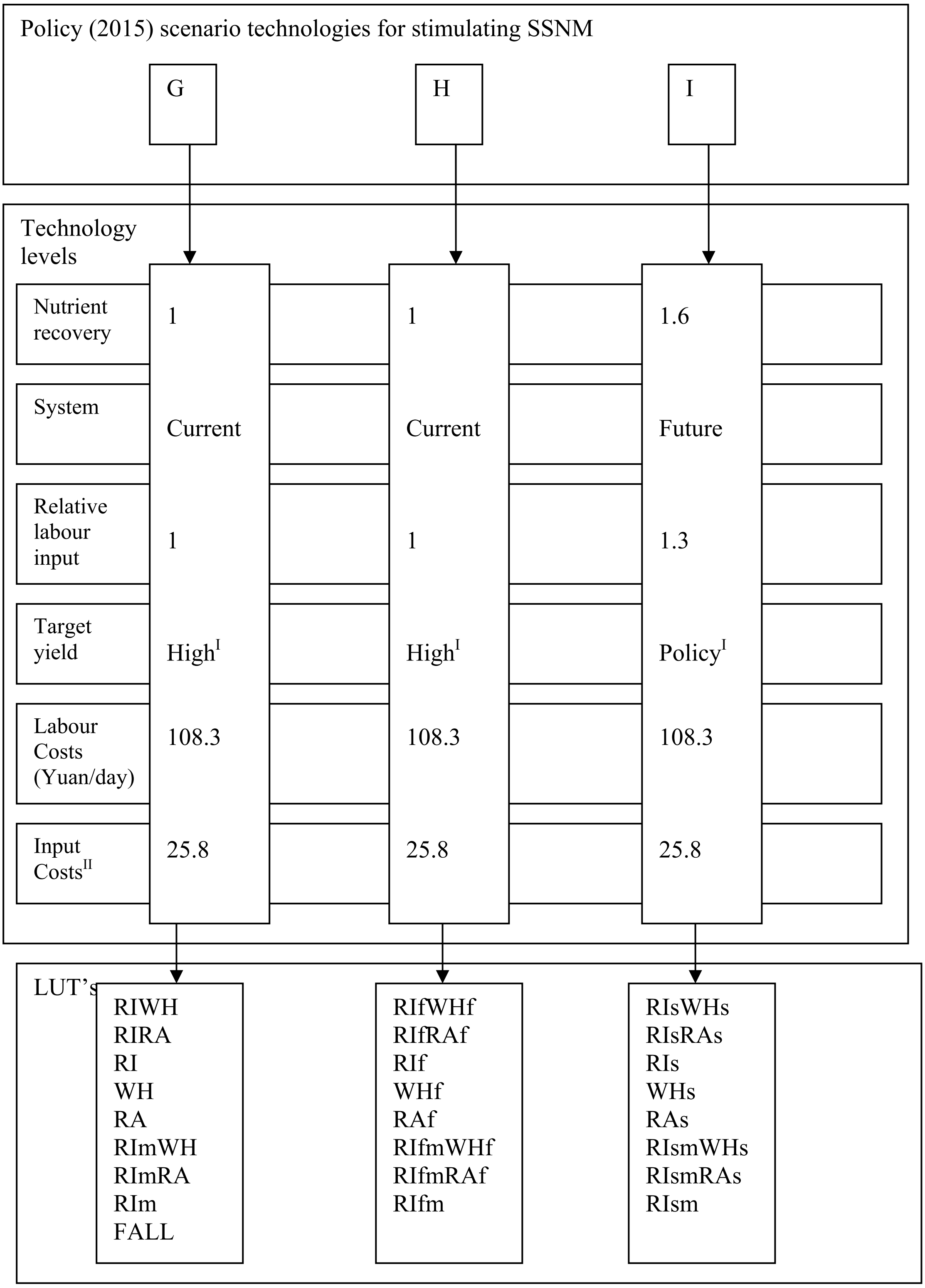

Figure 10. Description of the policy scenario of SSNM stimulation with technologies G, H and I which are coupled to different LUTs and have certain technology levels

[I] High and policy target yields can be found in Appendix I.

[II] Input costs are the costs for machinery rent for harvesting and land preparation and the machinery rent for the mechanical transplanting machine. The value displayed in this table is a conversion factor and should be multiplied with the rent per hour, which can be found in the crop sheet of TechnoGIN, to get the rent per hectare per day.

Most farms are now very small, so therefore the economic benefits derived from better management practices for each household are small (Coa et al., 2006). Another policy option is to stimulate scale enlargement of the farm households. The total cultivated land area constraint would then increase. Also the input premium for growing crops should be increased. When simulating this with TechnoGIN, level G is exactly the same as level D of the baseline and H will be the same as level E and I the same as level F. The only difference is that the total cultivated land area per soil type is increased and that the basic premium for rice, wheat and rapeseed increases at these levels.

In the base year, baseline and policy scenario all policy options are implementing, the use of FF application, SSNM, MT and the buffer zone. SSNM is a better way to reduce the environmental outputs compared to FF application and is therefore stimulated in the policy scenario. In another policy scenario is the stimulation of the use of MT. The area in the buffer zone that farms have will not be stimulated more in the policy scenario than in the base year or baseline scenario, the area in the buffer zone will stay the same for all three scenarios.

More options for modeling the policy scenario are possible, but it depends on the goal of the policy makers what they want to stimulate and how they want to stimulate this.

2.6 Expectations for off-farm income, FF, SSNM and MT use in 2015

FSSIM is a positive model and therefore forecasts the future instead of giving optimal options. Exact calibration of the current situation is ensured, but the reliability of forecasts depends on several factors, of which the elasticity (based on alpha) is of major importance. Two ways of estimating alpha are

i) Using elasticities that have been estimated in econometric studies
ii) Ex-post experiments using data from the past (Kanellopoulos et al., 2010).

The first option has been used in this study, but as crop-level elasticities are different from technology-level elasticities (farmers will keep on growing rice even when prices are low, but changing technology is easier), a sensitivity analysis is needed by changing the parameter alpha, to estimate the forecasting capacity of the model. The farm level data available from 2008 are not available in earlier years, but information is available on the adoption of technologies in the last years. Additional data has been collected on the adoption of technologies from sample farmers, to estimate expected changes. These have been used to evaluate model results, and select a reasonable parameter alpha. Additionally, sensitivity analyses have been performed with labour availability and crop prices, important factors that also influence adoption behaviour.

It is expected that the off-farm income will increase with the same rate as the labour wage. The labour wage is expected to increase with 11.7% per year from 2008 to 2015 (Appendix I). So expected is that the off-farm income will also be more than doubled in 2015 compared to 2008. High off-farm income wages and hence the attractiveness to work off-farm will influence the labour availability on-farm.

Formula fertilizer application started in 2006 in Wuxi and Changzhou. In Zhenjiang it already started in 2005. From the field survey data it is observed that in 2008 in Wuxi 36% of the total area has crops which are cultivated with FF application, for Changzhou this is 11% and for Zhenjiang this is 45%. Assumed is that 28.3% of the FF application users is using SSNM (Table 6).

Expected is that the trend of the use of FF and SSNM will be an S-curve (Shuyi Feng, personal communication and Marra et al., 2003). It is like diffusion of an innovation over time. In the beginning the farmers are cautious about the new technology, they will experiment with the use of FF application on trial basis. In the beginning they seek information on the costs and the value of the new technology. When they have more information they increase their knowledge about the attractiveness of the new technology and they will increase the adaptation (Marra et al., 2003).

With the current use of FF and SSNM (Table 6) and the expectation that the trend will be an S-curve, a logistic function can be developed to calculate the use of FF and SSNM in 2015 (Figure 11,12 and 13 and Table 7). Expected is that not every farmer is changing this fertilizer management, so assumed is that 1% of the total farmers will always use conventional fertilizer management. 28.3% of the farmers in 2008 where observed to use FF are assumed to be using SSNM based on their current fertilizer application. No data about the current and historical use of SSNM is available, therefore still will be assumed that 28.3% of the FF users will use SSNM. Considering data from 2006 and from 2008, it is expected that in all three municipalities according to the logistic curves (Figure 11, 12 and 13) the use of FF and SSNM together will be 99% in 2015, so SSNM will be 28.3% of 99% and FF will be 71.7% of 99% (Table 7).

For MT use similar logistic functions can be developed as for FF and SSNM to get an expectation of the use of MT in 2015. The use of MT machine started in 2004 in Wuxi. First there was a gradual increase in the use of MT machinery, but from 2005 onwards it has developed quite fast. It is expected that there will soon be full mechanization of the rice production in Wuxi and Changzhou. For Zhenjiang the development is also high, but full mechanization is not expected in the short term (Shuyi Feng, personal communication). So expected is that in 2015 in Wuxi and Changzhou there will be 100% use of MT or a bit less (Table 7) (Figure 14 and 15). For all municipalities the trend of the use of MT will probably be an S-curve (Marra et al., 2003). The average use of MT of the farm types in Zhenjiang is in 2008 2% (Table 6), with a logistic curve the use in 2015 will probably be 60% (Table 6 and figure 16). This is based on the assumption that the use of MT in Zhenjiang started also in 2005.

Although it is expected that the management of the farmers will change rapidly from 2008 until 2015 (Figure 11 until 16), the ratio of area of rice, wheat and rapeseed is not expected to change much. Farmers do not change their cropping pattern much, only when they receive subsidy around half of the farmers is then prepared to change the cropping pattern (interviews farmers, May 2010).

Table 6. Percentage use of FF, SSNM and MT for the average of the farm types of Wuxi, Changzhou and Zhenjiang in 2008, based on an additional survey

	Wuxi	Changzhou	Zhenjiang
FF	26	8	32
SSNM	10	3	13
MT	36	44	2

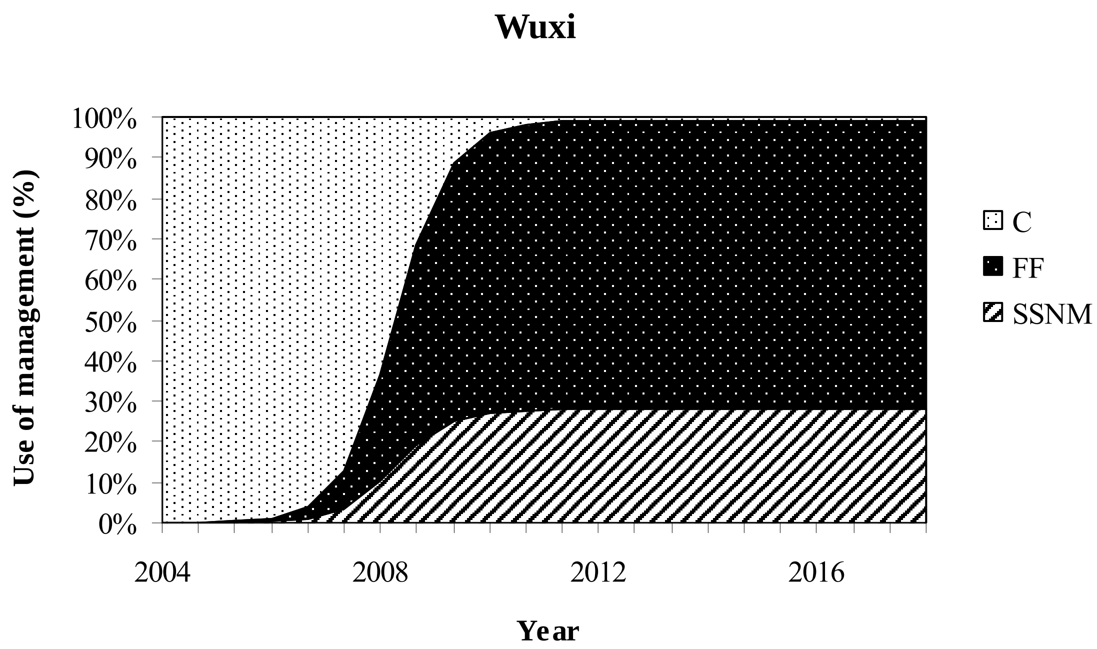

Figure 11. Expected trend of the use of conventional farming, FF application and SSNM in Wuxi. Based on data from 2006 and 2008.

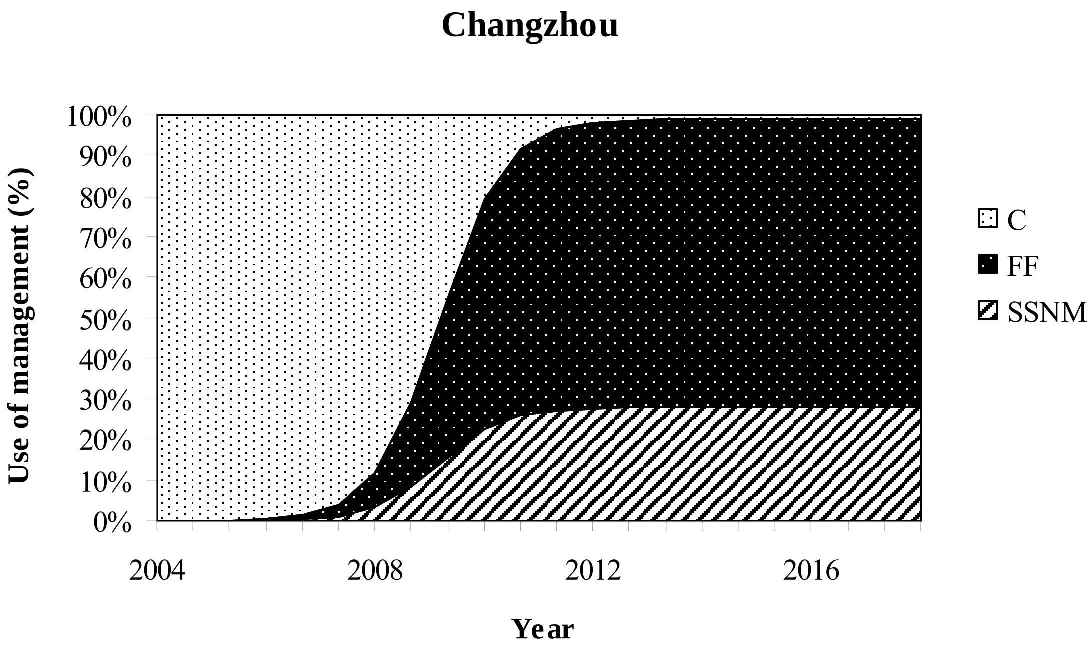

Figure 12. Expected trend of the use of conventional farming, FF application and SSNM in Changzhou. Based on data from 2006 and 2008.

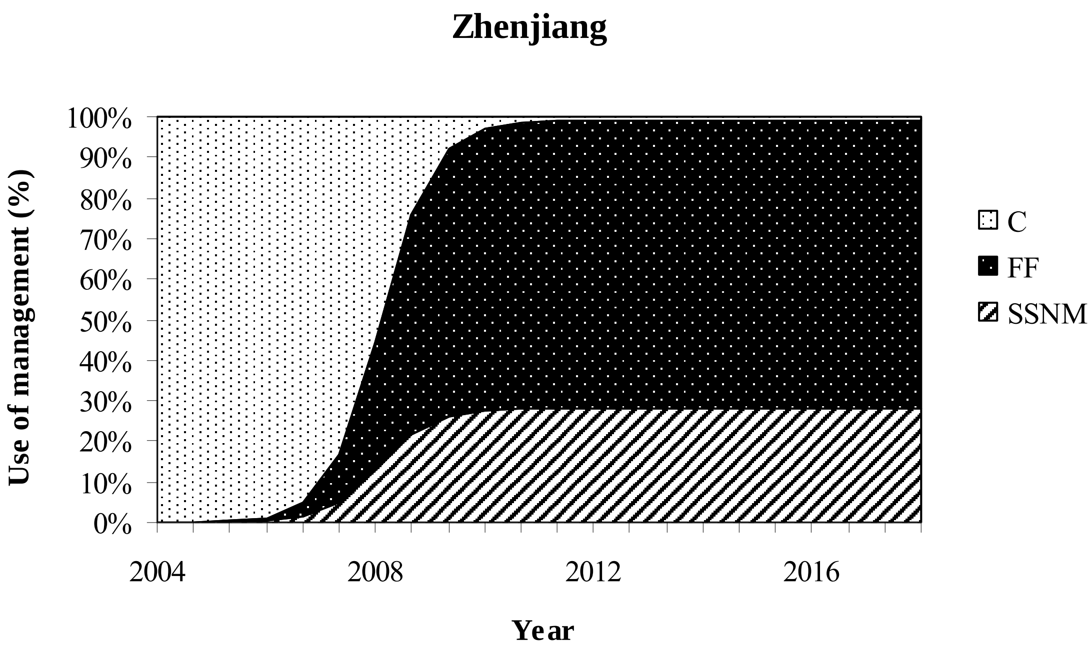

Figure 13. Expected trend of the use of conventional farming, FF application and SSNM in Zhenjiang. Based on data from 2005 and 2008.

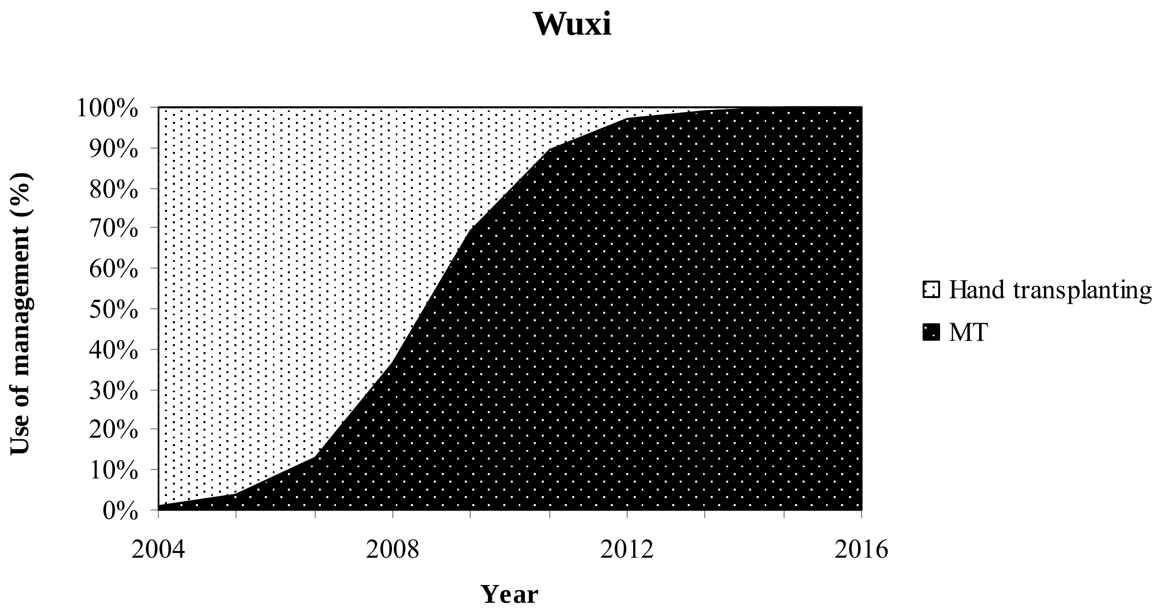

Figure 14. Expected trend of use of MT in Wuxi. Based on data from 2004 and 2008.

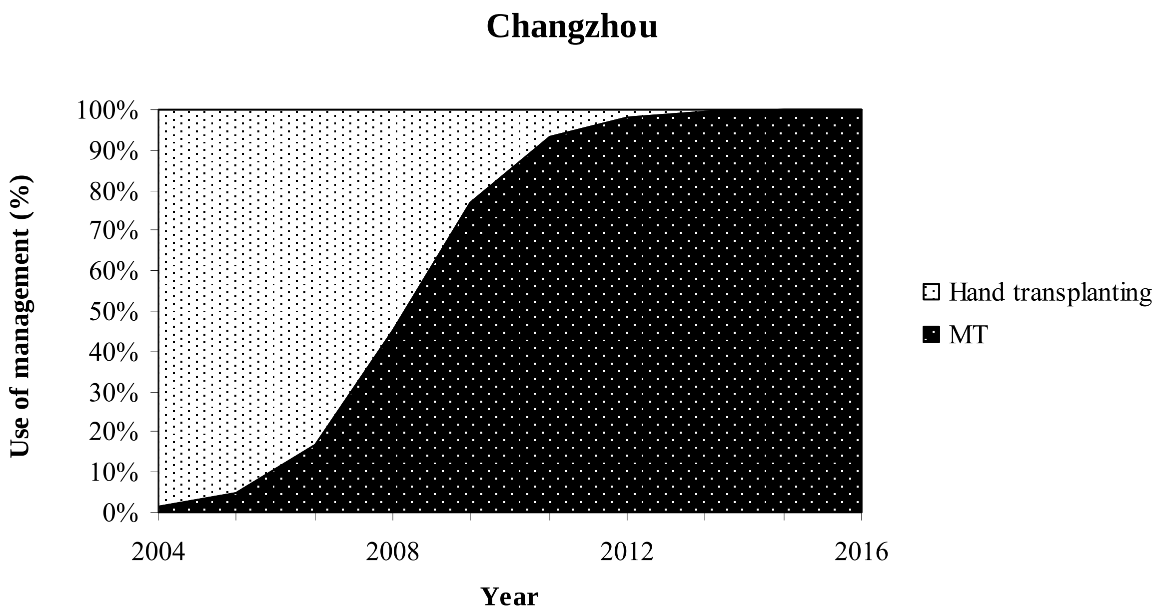

Figure 15. Expected trend of use of MT in Changzhou. Based on data from 2004 and 2008.

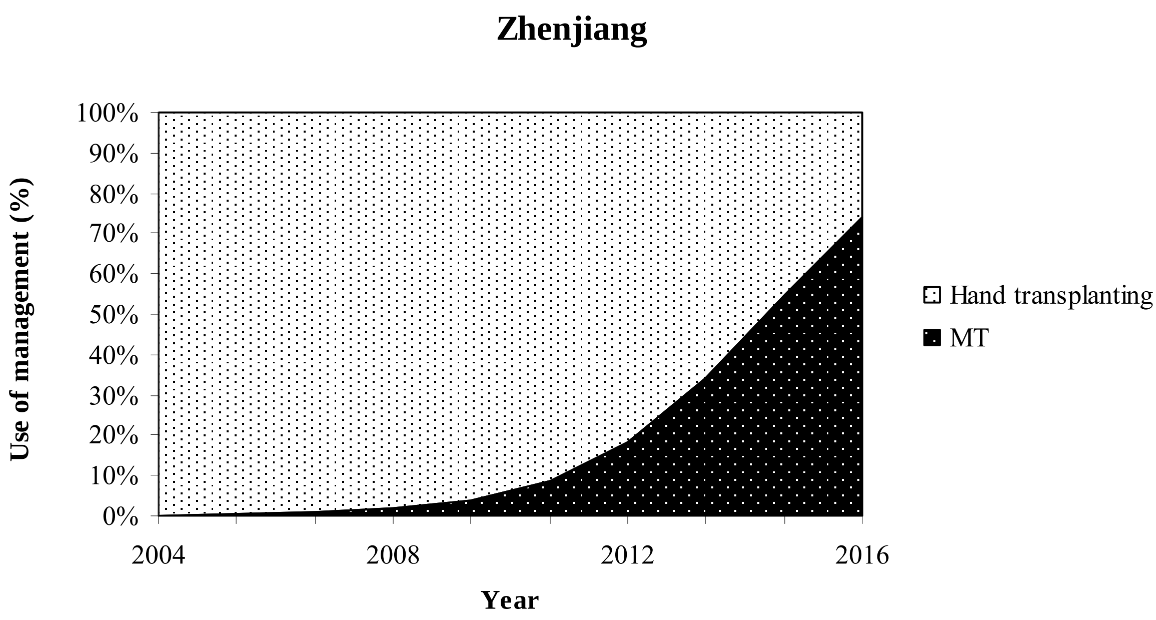

Figure 16. Expected trend of use of MT in Zhenjiang. Based on data from 2004 and 2008.

Table 7. Expected use of FF, SSNM and MT (%) in 2015 for Wuxi, Changzhou and Zhenjiang using logistic functions for adaptation

	Wuxi	Changzhou	Zhenjiang
Equation: FF&SSNM [I]	$\frac{0.99}{1+e^{-1.35t+10}}$	$\frac{0.99}{1+e^{-1.14t+10}}$	$\frac{0.99}{1+e^{-1.40t+10}}$
Equation: MT [II]	$\frac{1}{1+e^{-1.35t+10}}$	$\frac{1}{1+e^{-1.40t+10}}$	$\frac{1}{1+e^{-0.85t+10}}$
% FF use in 2015	71	71	71
% SSNM use in 2015	28	28	28
% MT use in 2015	100	100	60

[I] t_4 = 2006, t_7 = 2008
[II] t_4 = 2004, t_7 = 2008

The outcome of the logistic curve for the expectations towards 2015 for the use of FF application, SSNM and MT is very positive (Figure 11 until 16). Expected is that almost all farmers will either apply FF application or SSNM and that MT is used by almost all farmers. Limitations could exist like for example for the use of MT machine, there is a need for a technical expert (personal communication Shuyi Feng) or that farmers do not have an extension service in their village that provides the MT machine with high subsidy for renting (interview farmers, May 2010).

The estimations that are made for the use of SSNM, FF application and MT use will be used to check the model outcome for the baseline scenario. If the model outcome in the baseline is not quite what is expected, then some parameters should be changed to fit to the expectations.

2.7 Elasticity increase and family and permanent labour reduction

In FSSIM Europe, the alpha (Equation 14) is generally assumed to be 1. In econometric studies, the elasticities of rice, wheat and rapeseed were estimated at 0.208, 0.167 and 0.326 respectively (Lin, 2006). With these elasticities the outcome of the alpha's per crop will be between 8 and 52. For model outputs of the baseline to come close to what is expected, the elasticity of the crops should however be changed. Crops like rice are relatively inelastic, but changing management from conventional to applying formula fertilizer is much more elastic. When the elasticity decreases, the use of FF, MT, conventional and SSNM will not change much compared to the base year. With a low elasticity the value for alpha will be high and this will mean that there is not much change from 2008 to 2015. So to get change, the value of the elasticity should increase.

The main reason that MT is expected to increase and SSNM to have a limited increase, is the labour saving by MT and higher labour use for SSNM. In FSSIM, the costs of hired labour are included in the objective function, but family labour is not. On most farm types, according to the farm survey data, family labour is abundantly available. Nevertheless, as off-farm employment is more profitable, family labour is limited. To include the objective of reducing labour use in the objective function and obtain baseline results as expected, the total available family and permanent labour should be reduced. When the total available family and permanent labour is reached, extra required labour should be hired for a wage. These hired labour costs are included in the objective function; hence lowering the available family labour will increase the adoption of labour use efficient activities. The need to use MT and FF will be higher, because MT saves labour compared to hand transplanting and FF requires less labour than SSNM. So when the family and permanent labour availability decreases the need to use MT and FF is more beneficial compared to conventional and SSNM.

The assumption of lowering the availability of available labour is quite realistic, because saving labour is very important for most of the farmers (interviews farmers May 2010). Most households have enough labour for the work on farm, but rather use the labour for working off farm (interviews farmers May 2010).

2.8 Conclusion of the material and methods

After adaptation of FSSIM-EU to FSSIM-China the model has been runned and fitted to the expected values of 2015 by increasing the elasticity and reducing the family and permanent labour availability. This is done for Wuxi farm type 1. Afterwards a sensitivity analysis is done for Wuxi farm type 1. To check if the model is more sensitive to changes for larger farm types also a sensitivity analysis is done for Zhenjiang farm type 4. The next step is assessing the impact of the policies for several farm types for the three municipalities and to see the influence of the policy options on the environmental, social and economic sustainability indicators. These results will help to make an assessment of the impact of the policies on nutrient pollution and on sustainable development at large at farm type level in the Taihu Basin.

3. Results

The model should give an outcome for the base year almost the same activity levels as the observed activity levels. The model outcome for the base year is fine if the PAD (Percentage Absolute Deviation) value is not above 15% (Hazell and Norton, 1986). For Wuxi farm type 1 the PAD value in the base year is 4.0%; this value is not greater than 15% and the model has therefore a good performance. In section 3.1 will be explained how the model is fitted to get the expected values for the model outcome in the baseline scenario for Wuxi farm type 1. The model outcome for Wuxi farm type 1 for the base year and for the baseline with the activity levels which are closest to what is expected can be found in Section 3.2.

3.1 Modeling the baseline

Results on forecasts for the baseline depend on several factors. The most important are:
1) Elasticity of crop and management area changes
2) Consideration of labour use in the objective function
3) Projected changes in prices of inputs and outputs.
Sensitivity analyses on these factors are therefore performed, to estimate parameter estimates and to evaluate the model structure.

3.1.1 Elasticity and labour availability

When assessing model performance for Wuxi farm type 1, results are if the price elasticity of the supply level of the crops in combination with management increases, the use of FF will decrease, the use of the conventional way (C) will decrease, the use of MT will decrease and the use of SSNM will increase (Figure 17). Wuxi farm type 1 has a total of 0.32 ha and a relatively low off-farm income. Elasticities of rice, wheat and rapeseed of Lin (2006) are used for the crops and multiplied by different values. Although more changes occur with higher elasticities, the change of FF and MT are not yet as expected. Expected was that the use of FF was around 72% and the use of MT was around 100%.

If the price elasticity of the crops is multiplied by 100 and when the family and permanent labour availability is lowered from 221 days to 40 days the model outcome comes closest to what is expected (for Wuxi farm type 1; Figure 18). This multiplication of the elasticity of the crops is very high, but farmers are more prepared to changing their management then to change their cropping pattern, therefore elasticity of crops in combination with the management is much higher than the elasticity of the crops. For the amount of 40 days of family and permanent labour available the conventional fertilizer application is decreased, the use of FF application is increased, the use of SSNM is slightly decreased and the use of MT is increased compared to the base year (Figure 18). With this elasticity alpha will range between 0.08 and 0.5 and the observed labour use in the base year is 64 days.

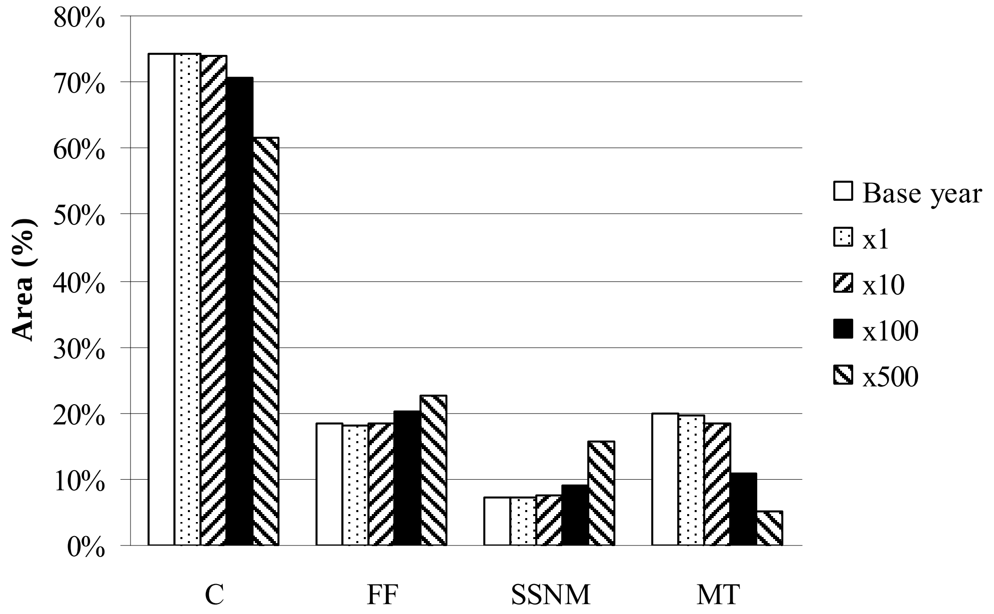

Figure 17. Model outcome of the percentage of the area compared to the total area of different managements for the base year and for the baseline with different multiplications of the elasticities in 2015 for Wuxi farm type 1. Flabour availability is 221.

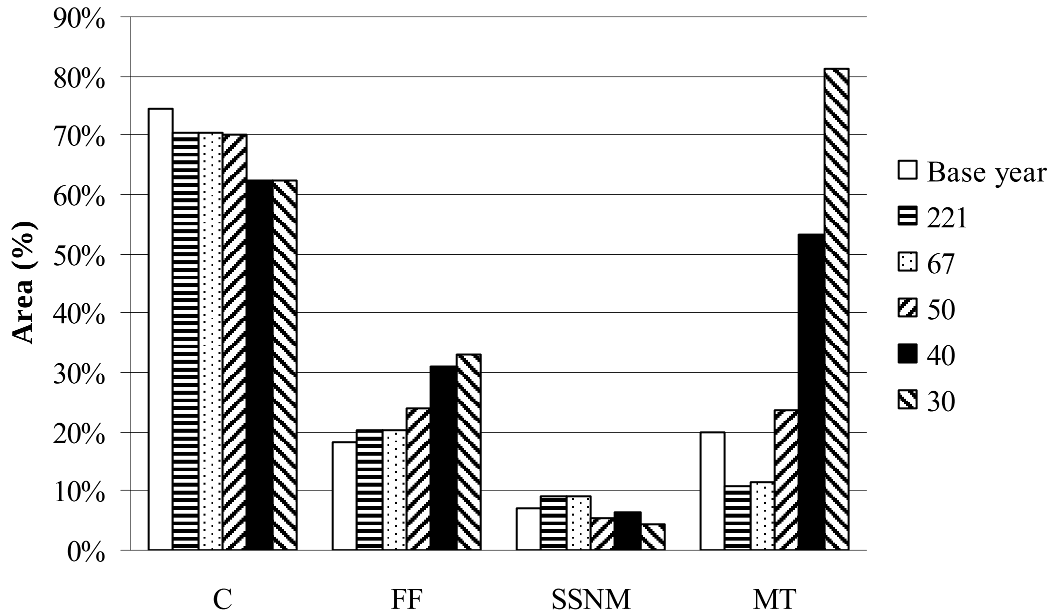

Figure 18. Model outcome of the percentage of the area compared to the total area of different managements for the base year and for the baseline with different availabilities of family and permanent labour in 2015 for Wuxi farm type 1. The observed availability in 2008 is 221, but the model outcome of the use of family and permanent labour is 64 (elasticity of crops is multiplied by 100).

With an elasticity which is multiplied by 100 and an availability of family and permanent labour of 40 for Wuxi farm type 1 in 2015, the use of MT will be 53% (33% increase from 2008 until 2015), the use of FF will be 31% (13% increase), the use of SSNM will be 6% (1% decrease) and the use of conventional farming will be 62% (12% decrease).

3.1.2 Importance of labour use and wage

If the availability of family and permanent labour is lowered to a certain value, the labour that is used according to FSSIM is not more than available. The farm household will not hire labour for working on farm. The costs of labour are higher than the profit that could be gained with cultivating more crops therefore farmers do not hire labour.

In 2015 the expected wage is 108 Yuan/day. Lowering the wage to 36 Yuan/day or lower will result in hiring labour (in the model the price elasticity is multiplied by 100 and the threshold value of family and permanent labour is 40) (Figure 19). In case temporary labour is for free, the use of it will be 29 days (Figure 19), so the maximum labour use will be 69 days in the baseline (compared to 64 days in the base year). With this value almost all land will be in use in every period for cropping (Figure 20). The total land available in Wuxi farm type 1 is 0.32 ha. Hence, when 0.32 ha is not used, this implies that only one of the two seasons is used for cultivation. If labour costs are zero still not all land is used, 0.09 ha will not be used. From that area that is not used 0.06 ha is upland clay. Rice can not be cultivated on upland clay and the yield of wheat and rapeseed is lower on upland clay than on upland loam and upland sand. On upland only wheat and rapeseed can be cultivated. Rice can not grow on upland. There are only rotations which include rice, so for upland soil types only a single crop can be cultivated. Therefore not all land will be used, although there are no costs for hiring labour.

If labour costs are low enough for hiring labour, the farmer will use less MT, less FF application and more conventional fertilizer management (Figure 21). More rice and wheat are cultivated when the labour costs are low (Figure 22).

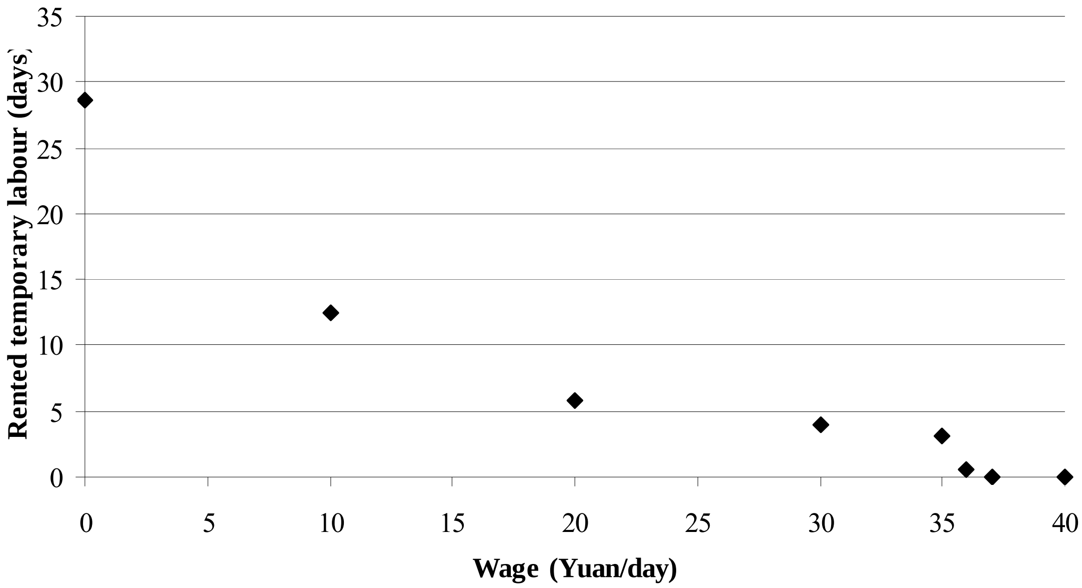

Figure 19. Rented temporary labour (days) for different wages for Wuxi farm type 1 in 2015. Expected wage in 2015 is 108 Yuan/day. (Elasticity of the crops is multiplied by 100 and the threshold value for family and permanent labour is 40 days)

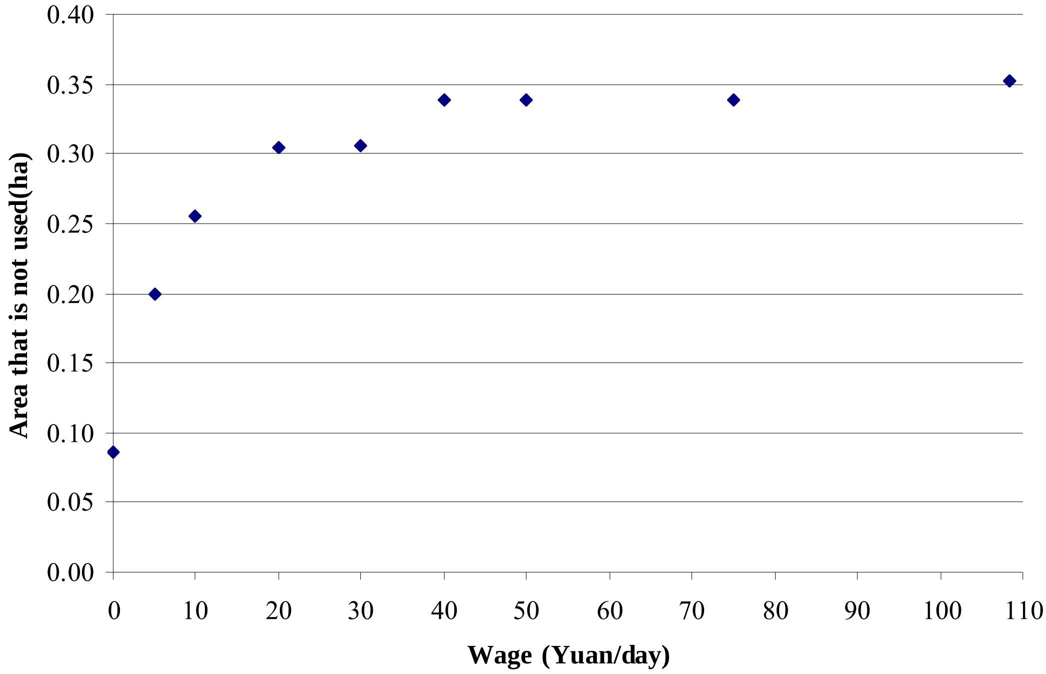

Figure 20. Not used area (ha) for different wages for Wuxi farm type 1 in 2015. Expected wage in 2015 is 108 Yuan/day. Not used area is the sum of the area that is not used in the first and in the second period. (Elasticity of the crops is multiplied by 100 and the threshold value for family and permanent labour is 40 days)

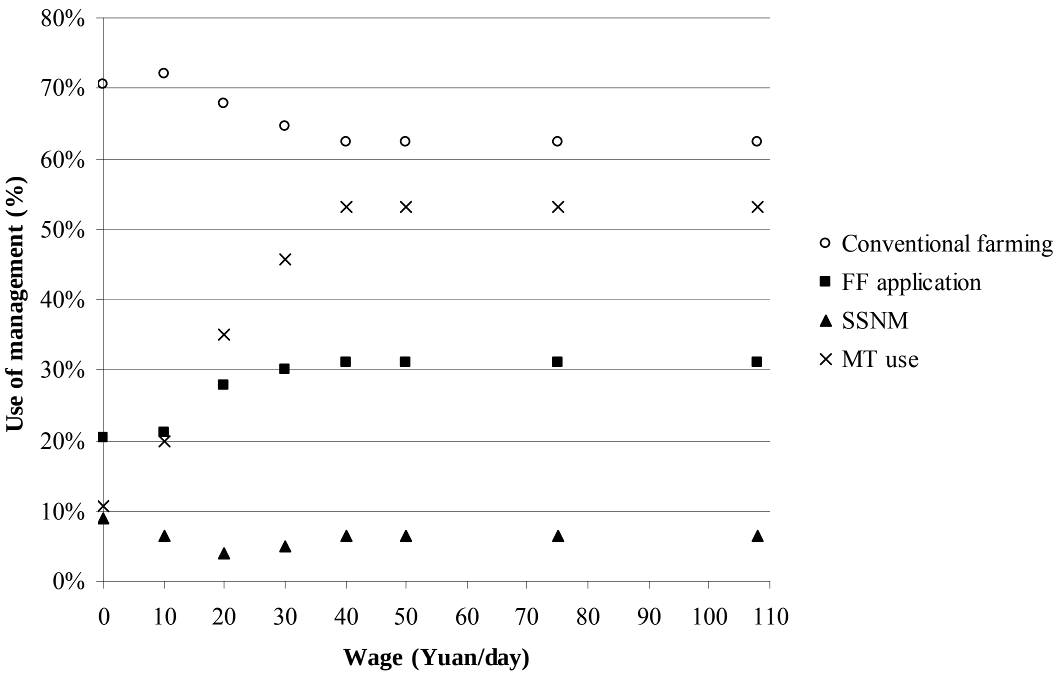

Figure 21. Use of different managements (%) for different wages for Wuxi farm type 1 in 2015. (Elasticity of the crops is multiplied by 100 and the threshold value for family and permanent labour is 40 days). C, FF and SSNM add up to 100%, MT is additional.

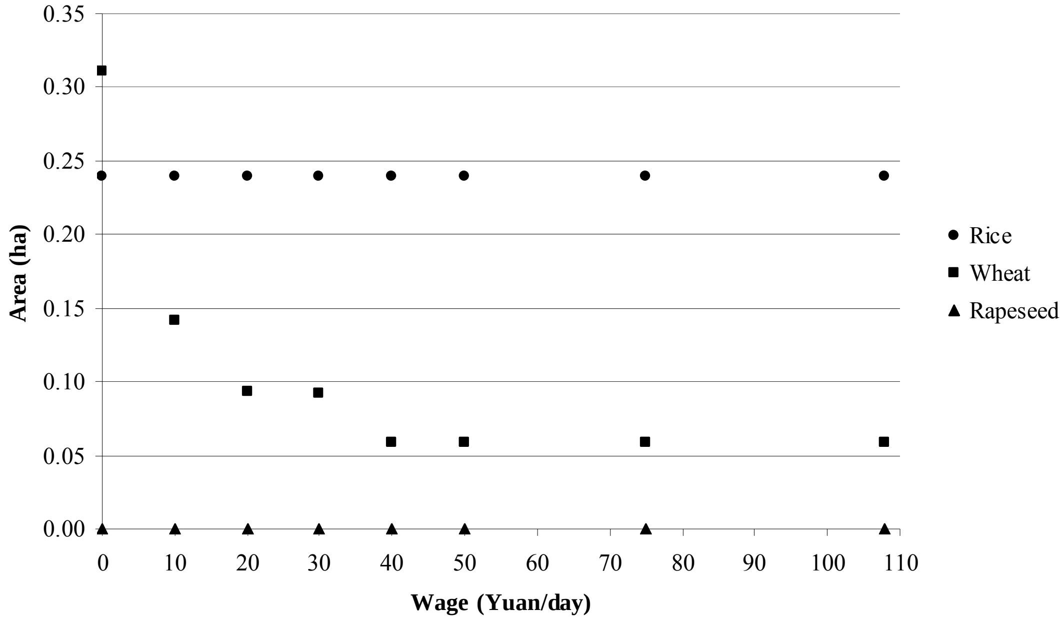

Figure 22. Area of different crops for different wages for Wuxi farm type 1 in 2015. (Elasticity of the crops is multiplied by 100 and the threshold value for family and permanent labour is 40 days)

3.2 Economic and ecological indicators in the baseline for Wuxi farm type 1

Considering the sensitivity analysis as presented above, for the baseline for Wuxi farm type 1 the elasticity was multiplied by 100 and the family and permanent labour restricted to 40 days. This results in a decrease in farm income with 3% from 2008 to 2015, from 2,761 to 2,679 Yuan (Figure 23). The average off farm income of this farm type in 2008 was 11,744 Yuan; hence agricultural income (farm income without PMP term) contributes 21% to total income in the base year. If we assume that the off farm income will increase with the same % as the labour wage for hired labour, the off farm income will be 25,436 Yuan. Agricultural income (farm income without PMP term) is then reduced to 9% of the total income.

If the costs of family and permanent labour are also taken into account then the farm income in the base year will be -415 Yuan and in the baseline there will be an income of -1652 Yuan. This means that working off farm will give more income than working on the farm, assuming that for each hour worked on farm the average labour wage can be earned.

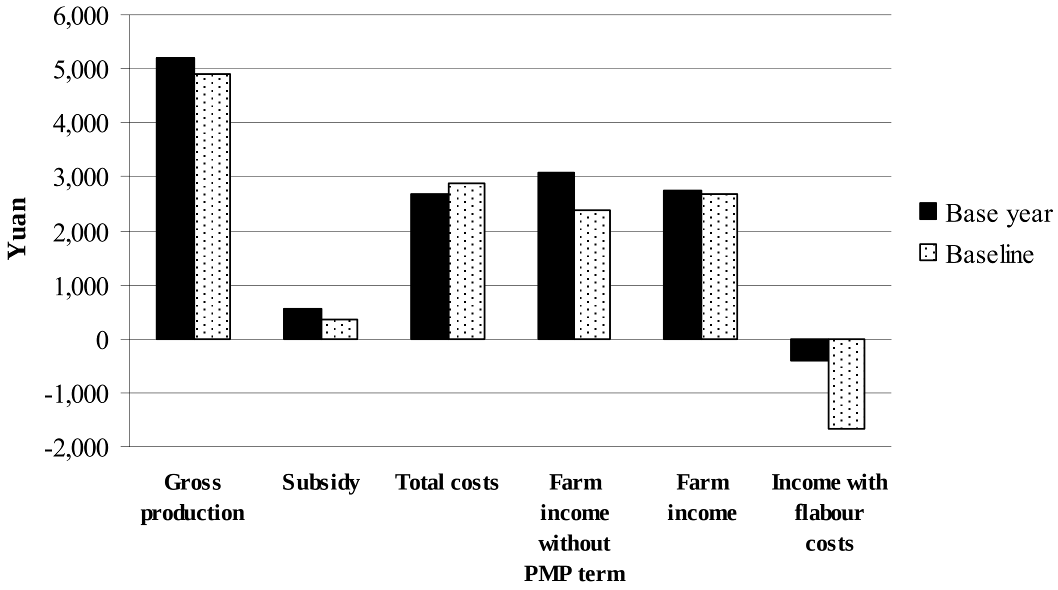

Figure 23. Economic results (Yuan) for Wuxi farm type 1 for the base year and the baseline. Farm income includes the PMP term and does therefore not directly reflect outputs-inputs. Farm income without PMP term does indicate what the farmers earn, i.e. gross production + subsidy – total costs. The income including family and permanent labour costs reflect the opportunity costs of agriculture; when negative labour costs are not covered and off-farm employment will be more attractive.

In the baseline, less crops are cultivated compared to the base year (Figure 24). The total area that is used for cultivation is higher in the base year; in the base year 0.32 ha is used and in the baseline is 0.28 ha used. In the baseline more single crops are cultivated than in the base year (Figure 24). In the first period 0.24 hectare is used in the base year and in the baseline. In the second period 0.23 hectare is used in the base year and 0.06 ha in the baseline. The costs of labour are the limiting factor in the baseline; when the wage is lower more land will be used (Figure 20).

The use of mechanical transplanting will increase with 33% in the baseline compared to the base year. The use of conventional fertilizer application will decrease 11% in the baseline compared to the base year, SSNM will decrease with 1% and FF application will increase with 12% (Figure 25).

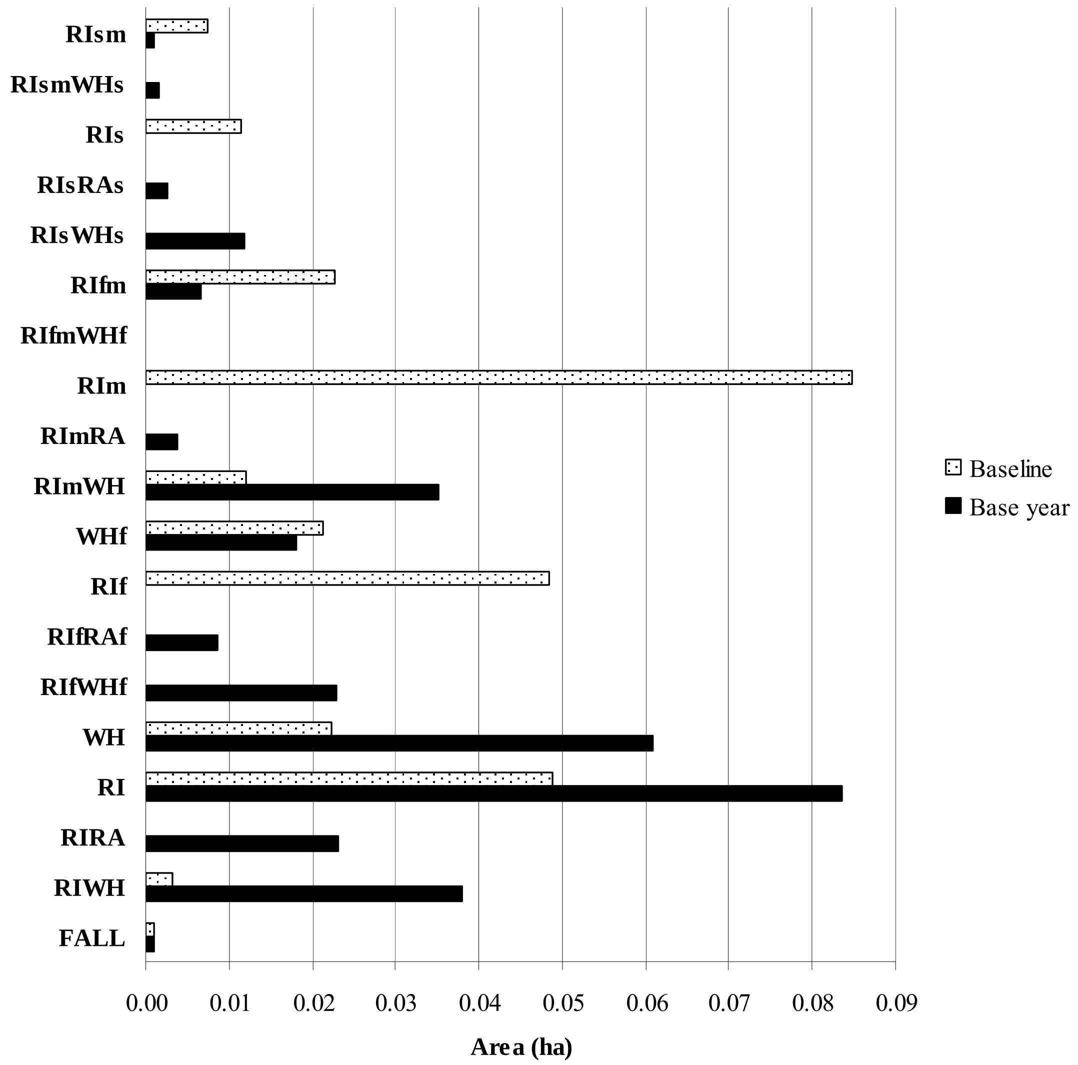

Figure 24. Rotations in the base year and in the baseline for Wuxi farm type 1 (see Table 1 for abbreviations of land use types).

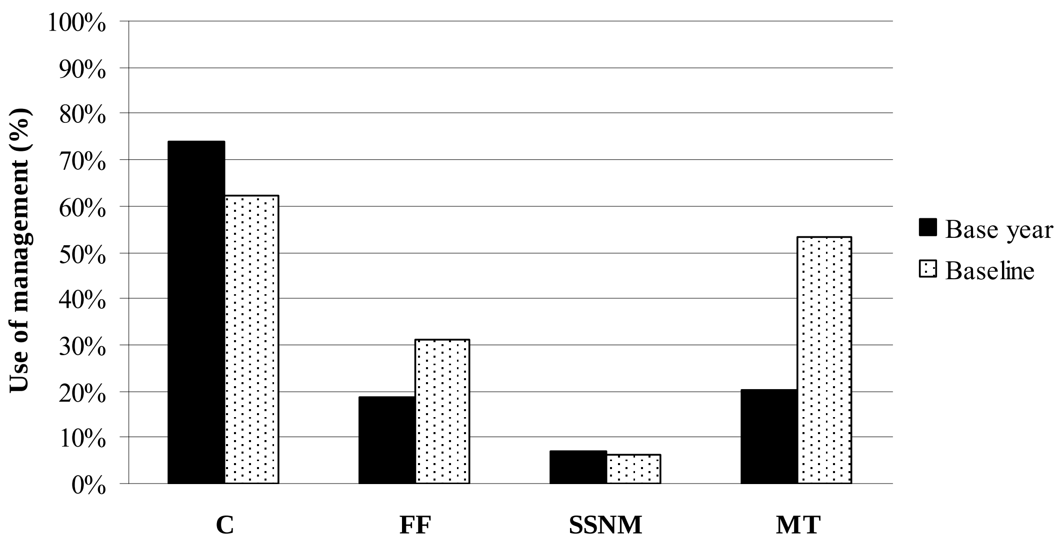

Figure 25. The use of different managements (%) in the base year and baseline for Wuxi farm type 1

The environmental outputs for nitrogen, phosphorus, potassium and the biocide residue index will decrease from 2008 to 2015 (Figure 27, 29, 30 and 31). More single crops are used in the baseline than in the base year, this is one reason for the lower environmental outputs per hectare. Another reason for the lowered environmental outputs is the increase in yield in the baseline compared to the base year while still assuming the same fertilizer gift. The use of N is lowered by 23%, the use of P is lowered by 25% and the use of K is lowered by 17% when going from the base year to the baseline (Figure 26 and 28), due to less conventional fertilizer management and more FF application. Input-output relations per agricultural activity, that form the basis for these results, are included in Appendix III.

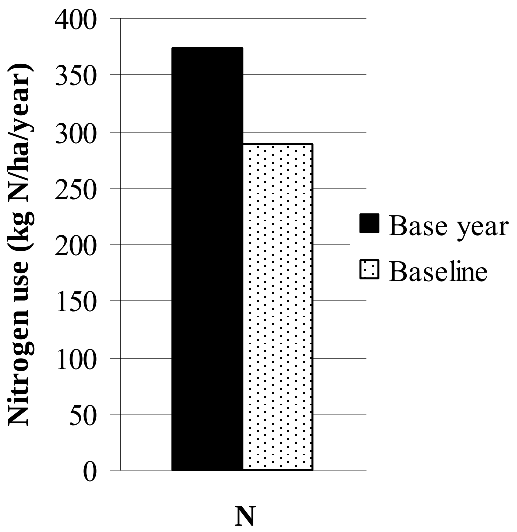

Figure 26. Nitrogen application (kg N/ha/year) in the base year and baseline for Wuxi farm type 1

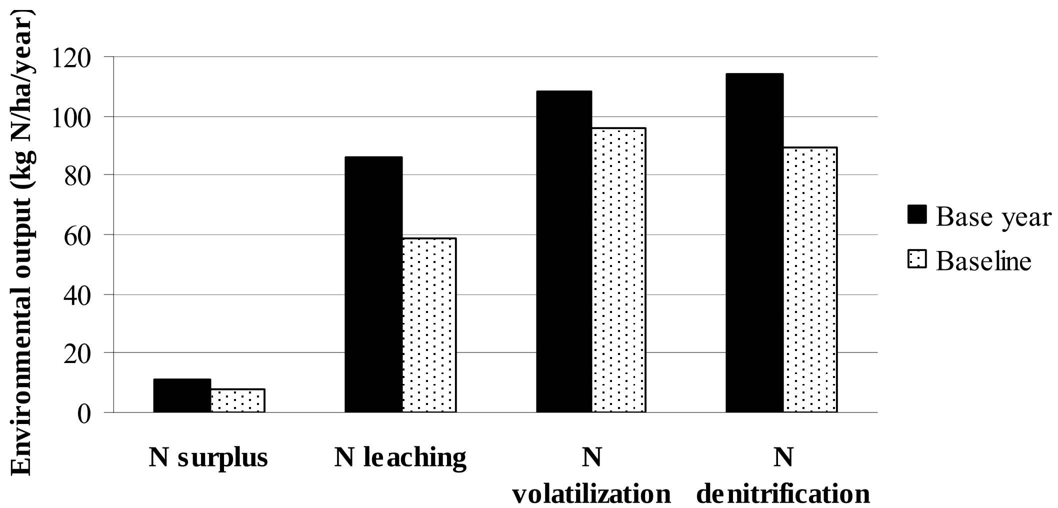

Figure 27. Environmental outputs of nitrogen (kg N/ha/year) for the base year and the baseline for Wuxi farm type 1

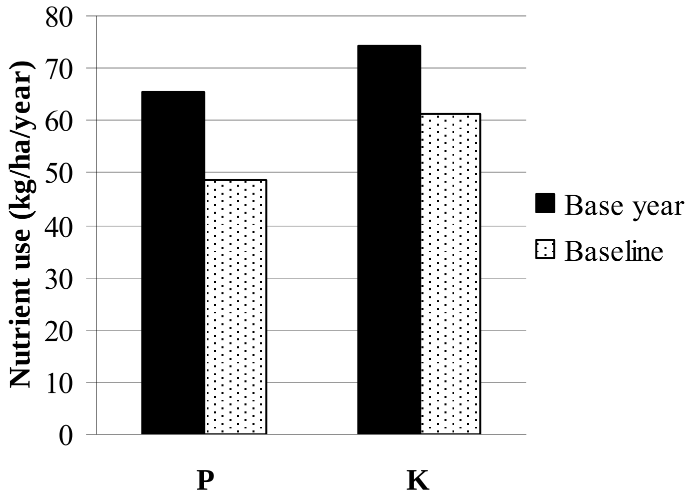

Figure 28. Phosphorus and potassium application (kg /ha/year) in the base year and baseline for Wuxi farm type 1

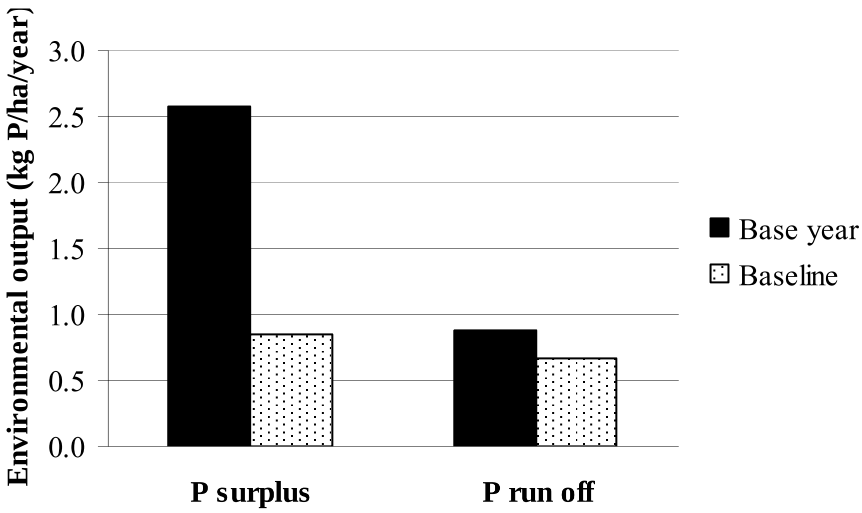

Figure 29. Environmental outputs of phosphorus (kg P/ha/year) for the base year and the baseline for Wuxi farm type 1

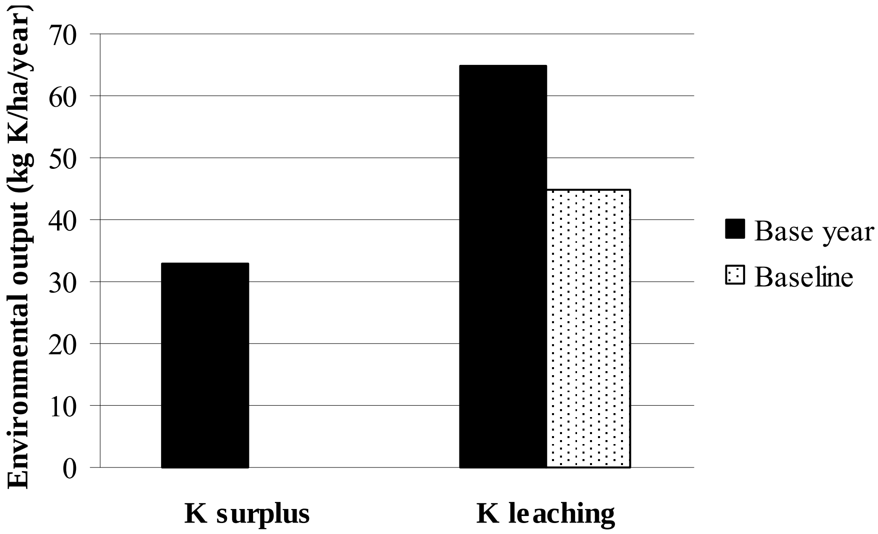

Figure 30. Environmental outputs of potassium (kg K/ha/year) for the base year and the baseline for Wuxi farm type 1

The biocide residue index is declined with 16% in the baseline compared to the base year (Figure 31). Although farmers use less biocides in the baseline the use is still above the threshold value of 200. The biocide use for rice is the highest, the use of MT only reduces the biocide use with 0.5%. Wheat uses less biocides than rice and rapeseed uses less biocides than wheat.

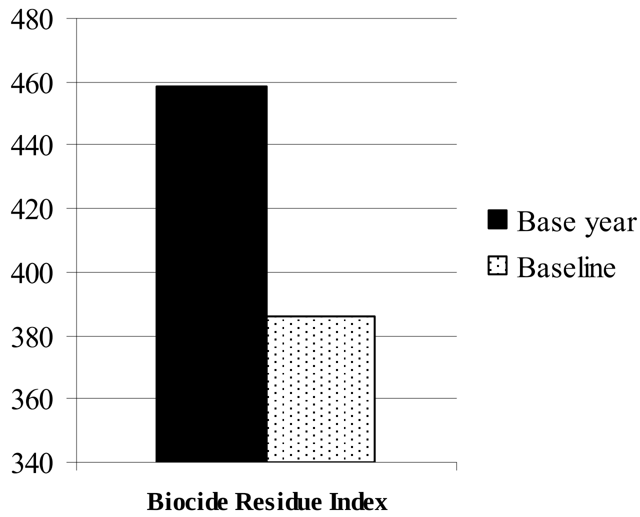

Figure 31. Bio residue index (-) for Wuxi farm type 1 in the base year and baseline

3.3 Price change

The input costs are very high compared to the gross production (Figure 23), the costs are more than half of the gross production. Due to the high costs more single crops are cultivated compared to rotations (Figure 24). Increasing the price received for the crops can have much influence on the cropping pattern.

The model is not very sensitive to the price change of rapeseed. When the price of rapeseed is increased with 50% compared to what is expected for 2015, then the area of rapeseed will be 1% of the total area of crops compared to 0% for the projected price of 3.72

Yuan/ton (Figure 32). When the price of rapeseed is doubled the area of rapeseed is 14% of the total area of crops. A higher price would increase the area, but these prices are unlikely.

The model is more sensitive to price increase of wheat. With a price increase of 20% the area of wheat will increase with 0.04 hectare compared to the model outcome with a price of 1.71 Yuan/ton; When the price increases with 70% the area of wheat will be 0.24 hectare higher as with a price of 1.71 Yuan/ton (Figure 33).

Rice will always be cultivated, unless the price is lower than 0.50 Yuan/ton (Figure 34). A price decrease of 10 or 20% does not change the area of rice (Figure 34).

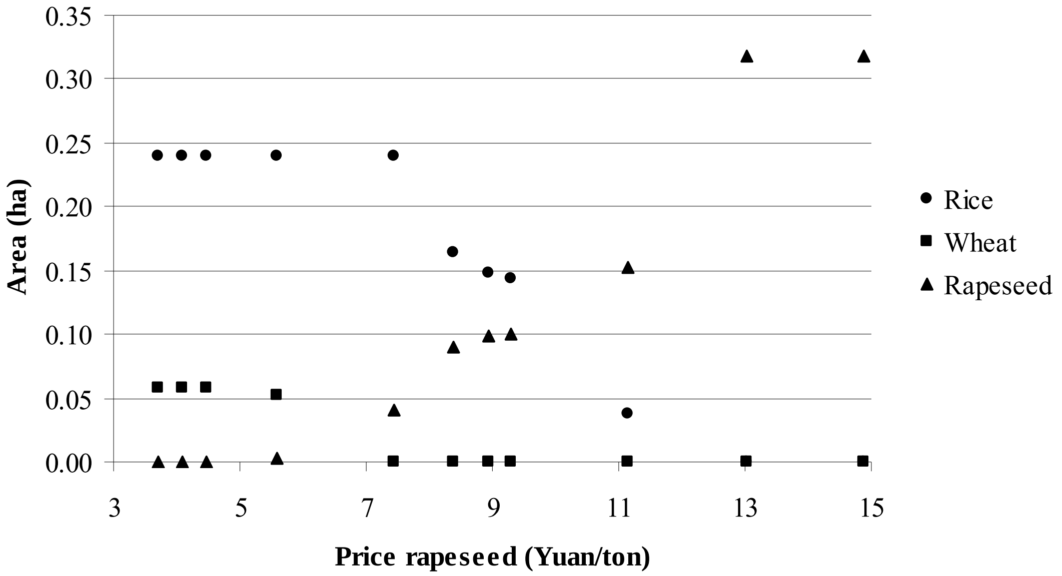

Figure 32. Influence on the area of rice, wheat and rapeseed when the price of rapeseed increases. The expected price of rapeseed in 2015 is 3.72 Yuan/ton.

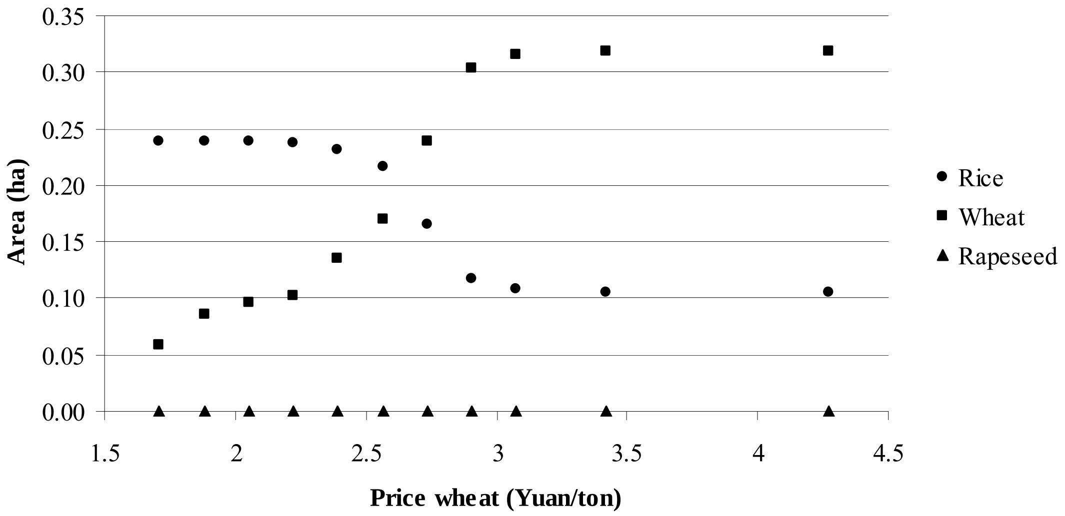

Figure 33. Influence on the area of rice, wheat and rapeseed when the price of wheat increases. The expected price of wheat in 2015 is 1.71 Yuan/ton.

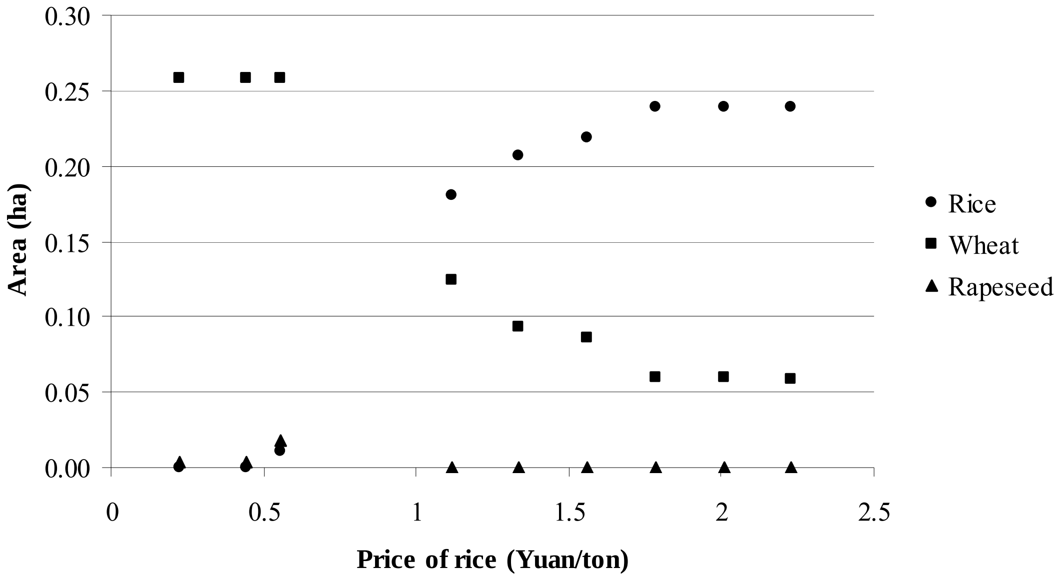

Figure 34. Influence on the area of rice, wheat and rapeseed when the price of rice decreases. The expected price of rice in 2015 is 2.23 Yuan/ton.

3.4 Policy scenario analysis for Wuxi farm type 1, stimulation of SSNM

The first policy scenario is to stimulate the use of SSNM. More education and training will lead to more change of the management of the farmers and therefore it could stimulate the use of SSNM. FSSIM is calibrated such that the model reproduces the observed situation in the base year. The elasticity has an influence on the change of the technology of the farmers to the baseline and the policy scenario. A higher elasticity means that farmers are more prepared to change their technology. So increasing the elasticity will reflect the increase in training and education. In case of only changing the elasticity the percentage area of SSNM from the total area will never be more than 91% (Figure 35).

In the baseline scenario the elasticity of rice, wheat and rapeseed is multiplied by 100 to project the expected outcome in the baseline, with this elasticity in the policy scenario the use of SSNM will be 19%. With an elasticity that is multiplied by 500 instead of 100 already increases the use of SSNM with 34% in the policy scenario. When the elasticity is multiplied by 1000 instead of 100 then the use of SSNM will increase with 44%. The elasticity should be very high to get 91% of the farmers to use SSNM. So a lot of training and education is needed to get a high level of SSNM, because the elasticity increase reflects the increase in training and education. To get a high level of SSNM use and to have still a realistic level of training and education, the elasticity of rice, wheat and rapeseed should be multiplied by 1,000 (Figure 35).

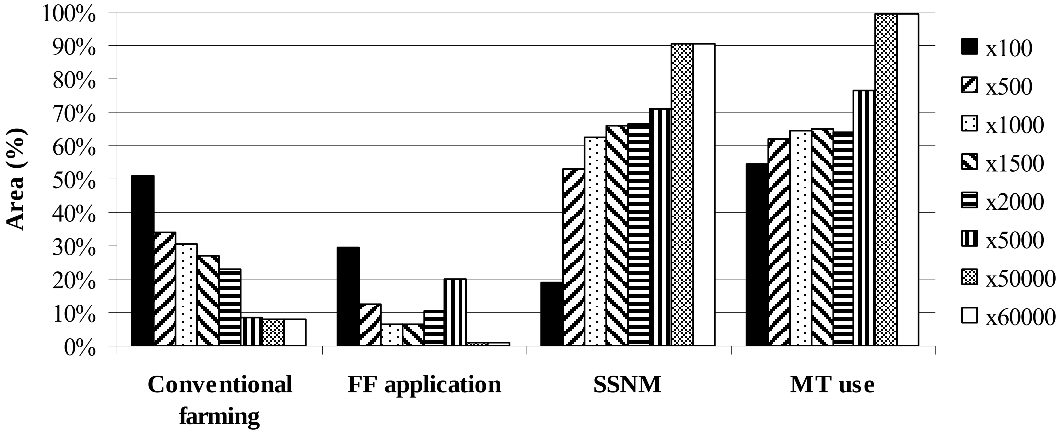

Figure 35. Model outcome of the percentage of the area compared to the total area of different managements with different multiplications of the elasticities in the policy scenario for Wuxi farm type 1. Flabour availability is 40.

So for the baseline the elasticity is multiplied by 100 and for the policy scenario the elasticity is multiplied by 1000, both scenarios have a family and permanent availability of 40 days. This results in an increase of farm income in the policy scenario compared to the base year and baseline, due to higher gross production and lower total costs (Figure 38). Although the farm income is higher the total land that is used is less in the policy scenario (Figure 36). The use of SSNM is 63% of the total area in the policy scenario, this is an increase of 57% compared to the baseline (Figure 37). The use of FF application is 6% and conventional fertilizer management is 31% of the total area in the policy scenario.

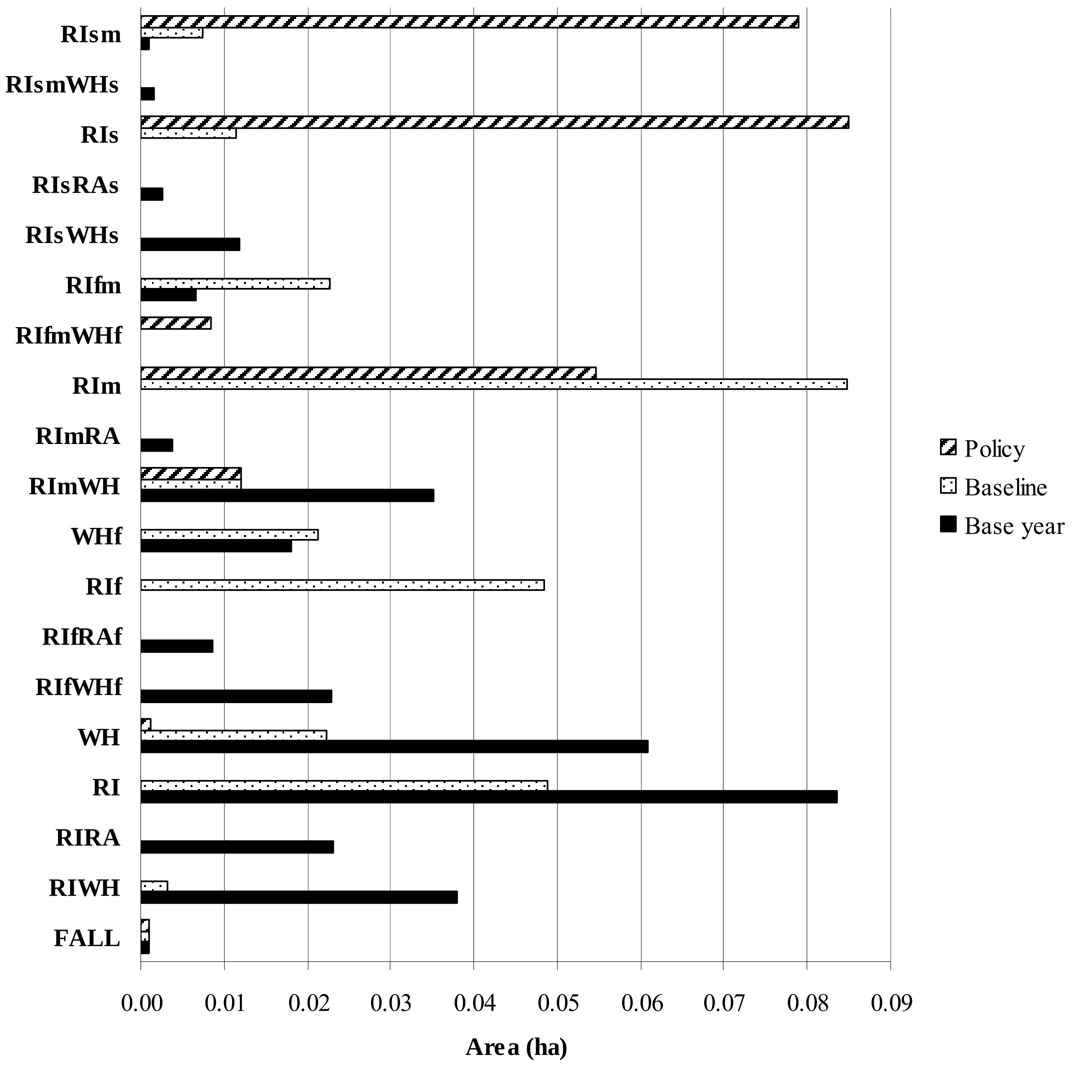

Figure 36. Rotations in the base year, baseline and policy scenario for Wuxi farm type 1

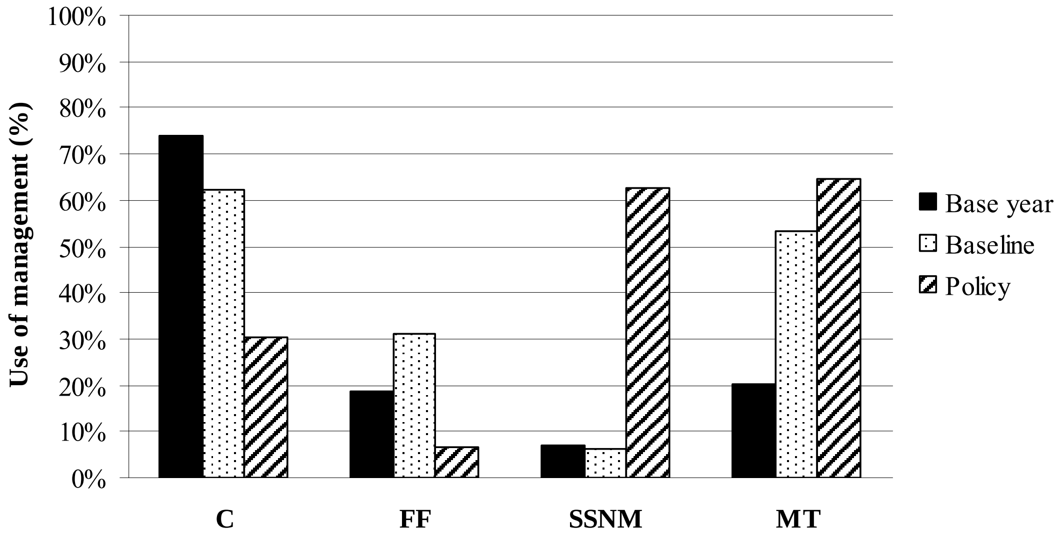

Figure 37. The use of different managements (%) in the base year, baseline and policy scenario for Wuxi farm type 1

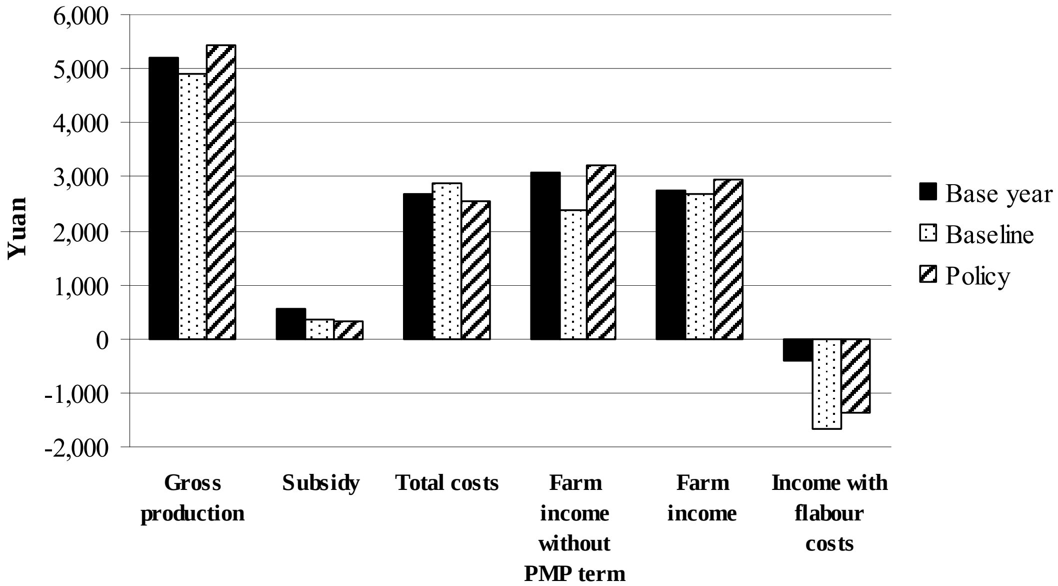

Figure 38. Economic results (Yuan) for Wuxi farm type 1 for the base year, baseline and policy scenario. Farm income includes the PMP term and does therefore not directly reflect outputs-inputs. Farm income without PMP term does indicate what the farmers earn, i.e. gross production + subsidy – total costs. The income including family and permanent labour costs reflect the opportunity costs of agriculture; when negative labour costs are not covered and off-farm employment will be more attractive.

The input of nitrogen and phosphorus decreased in the policy scenario compared to the baseline and base year scenario (Figure 39 and 41). The input of potassium increased in the policy scenario compared to the baseline (Figure 41). All environmental outputs decreased in the policy scenario compared to the base year and baseline scenario (Figure 40, 42, 43 and 44).

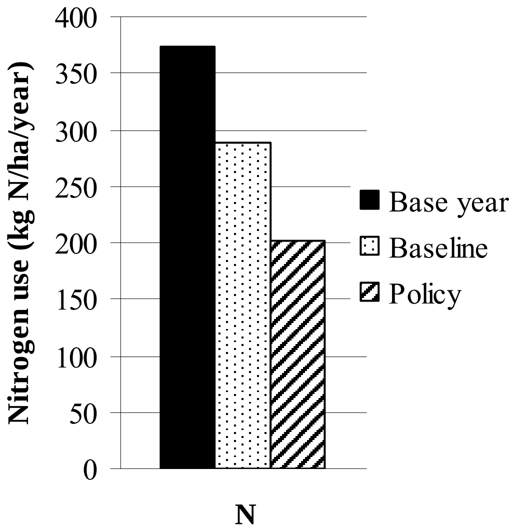

Figure 39. Nitrogen application (kg N/ha/year) in the base year, baseline and policy scenario for Wuxi farm type 1

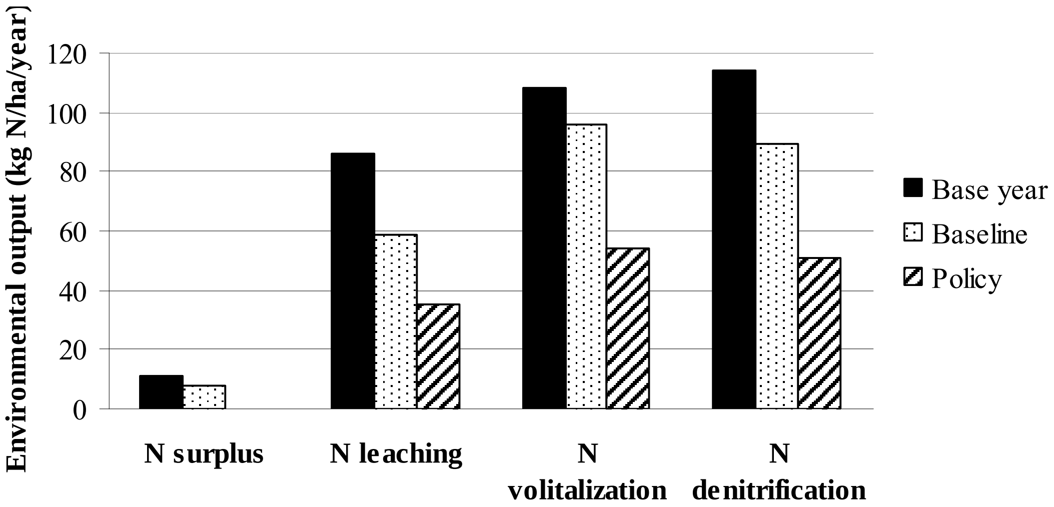

Figure 40. Environmental outputs of nitrogen (kg N/ha/year) for the base year, baseline and policy scenario for Wuxi farm type 1

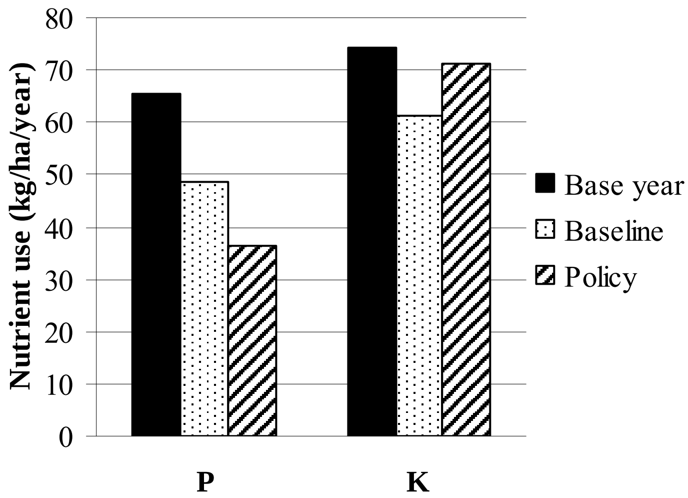

Figure 41. Phosphorus and potassium application (kg /ha/year) in the base year, baseline and policy scenario for Wuxi farm type 1

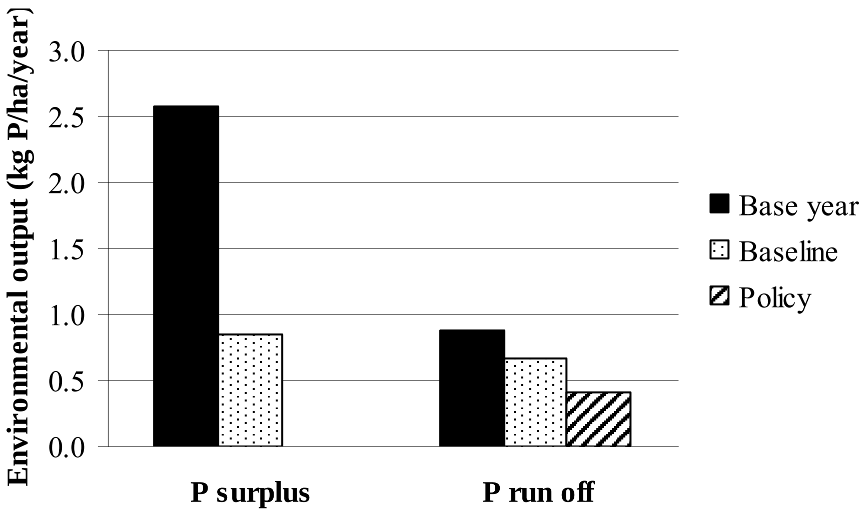

Figure 42. Environmental outputs of phosphorus (kg P/ha/year) for the base year, baseline and policy scenario for Wuxi farm type 1

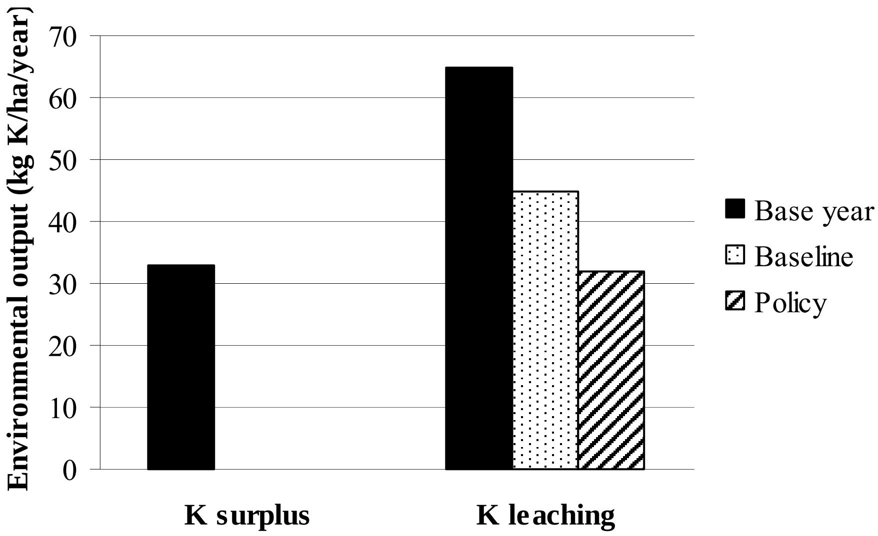

Figure 43. Environmental outputs of potassium (kg K/ha/year) for the base year, baseline and policy scenario for Wuxi farm type 1

Although the BRI is lower in 2015, the values are all still above the threshold value of 200 (Figure 44).

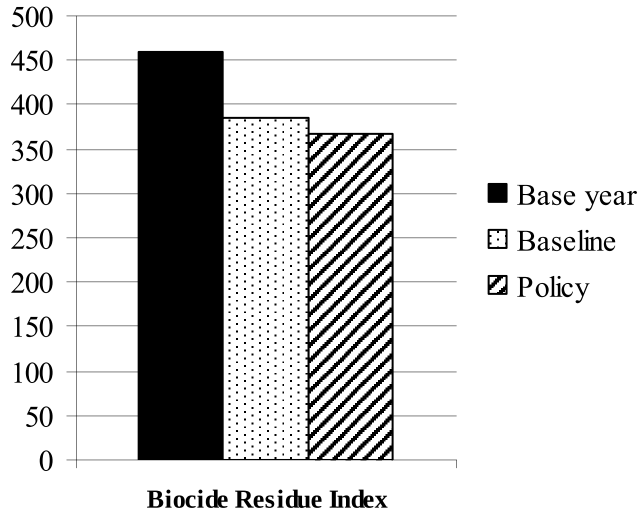

Figure 44. Bio residue index (-) for Wuxi farm type 1 in the base year, baseline and policy scenario

A complementary measure to training and dissemination reflected by an increase in elasticity, is to use economic instruments. Subsidies help to stimulate the use of SSNM (Figure 45 and 46). The input subsidy for the crops is assumed to be 930 Yuan/ha in the baseline.

The best way to stimulate SSNM is to give no input subsidy for cultivating crops other than SSNM. When giving an input subsidy of 930 Yuan/ha for SSNM only, then the use of SSNM is 70%. When giving an input subsidy for SSNM of 2000 Yuan/ha and the other managements in combination with the crop are still 930 Yuan/ha the area of SSNM compared to the total area is 68% (Figure 45). For getting all farmers to use SSNM then the input subsidy for SSNM should be 5000 Yuan/ha or higher and the subsidy for the other managements should be 0 (Figure 46).

If the area of SSNM increases, the area of conventional formula fertilizer management and the area of FF application will decrease. The area of MT will increase slightly (Figure 46).

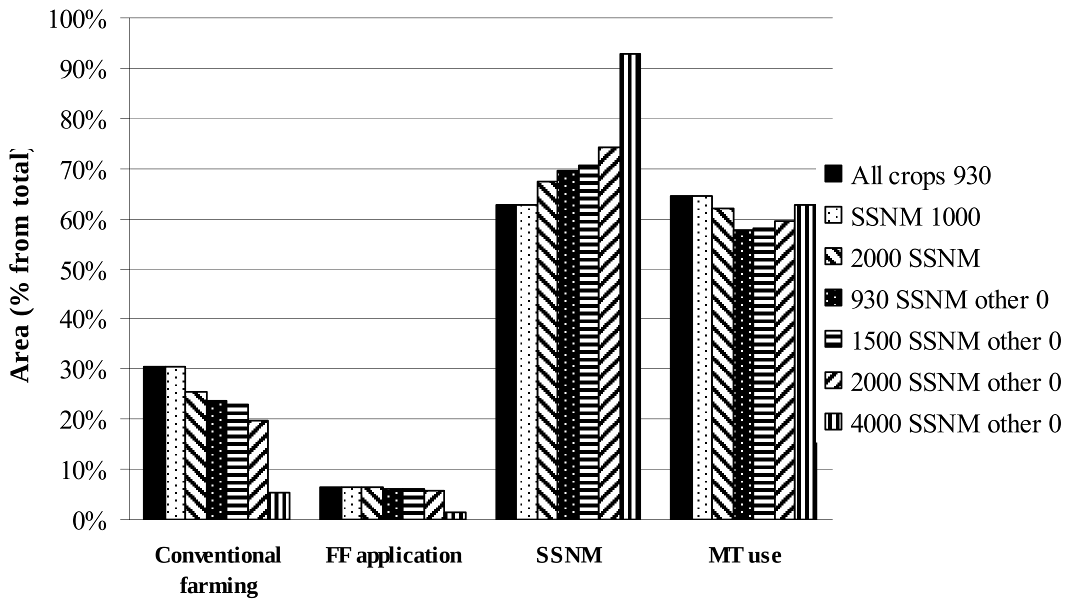

Figure 45. Percentage of use of different managements with different input subsidies with an elasticity of 1000 and a value of Flabour of 40. In the baseline an input subsidy of 930 Yuan/ha for all crops is assumed.

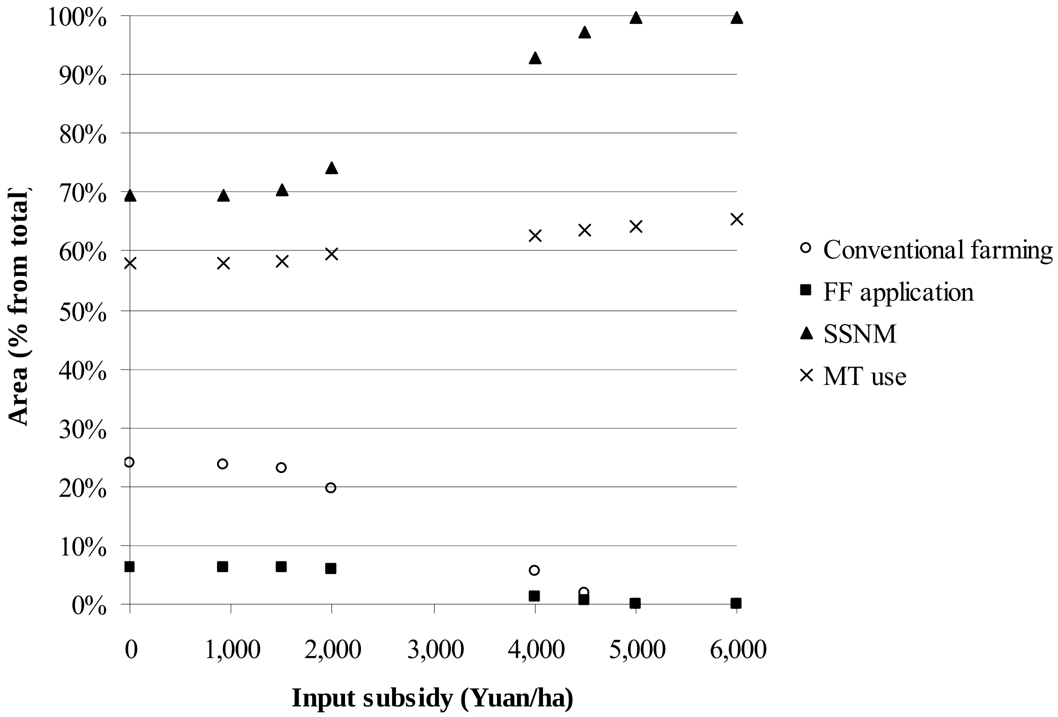

Figure 46. Percentage of use of different managements with different input subsidies for SSNM (input subsidies for other crops is 0) with an elasticity of 1000 and a value of Flabour of 40. In the baseline an input subsidy of 930 Yuan/ha for all crops is assumed.

When more SSNM is used the water use will be higher (Table 8). The higher the use of SSNM the lower the nitrogen application and nitrogen outputs. Potassium application is higher with a higher % of SSNM use, this results in a higher K leaching. Phosphorus application does not change much, and therefore has not much influence on the run-off and surplus of P (Table 8).

Table 8. Different environmental outputs and inputs for the policy scenario with different percentages of use of SSNM

Input subsidy for SSNM (Yuan/ha)	930	1500	4000	6000
Input subsidy for other crops (Yuan/ha)	930	0	0	0
Use of SSNM (%)	63	71	93	100
Environmental results				
Water use (mm)	2,360	2,364	2,411	2,429
N surplus (kg N/ha/year)	0.15	0.16	0.11	0.00
P surplus (kg P/ha/year)	0.00	0.00	0.01	0.00
K surplus (kg K/ha/year)	0.00	0.00	0.00	0.00
P Runoff (kg P/ha/year)	0.41	0.39	0.39	0.39
N leaching (kg N/ha/year)	35	34	28	26
K leaching (kg K/ha/year)	32	30	34	35
N volatilization (kg N/ha/year)	54	53	43	40
N denitrification (kg N/ha/year)	51	49	41	39
Biocide Residue Index (-)	366	359	356	355
Nitrogen application (kg N/ha/year)	202	196	181	177
Phosphorus application (kg P/ha/year)	36	35	36	37
Potassium application (kg K/ha/year)	71	72	86	90

With extra training and education the use of SSNM is 63%. If next to training and education input subsidy of 1500 Yuan/ha is received for cultivation with SSNM is given and no input subsidy for cultivation of crops with an other fertilizer managements, the use of SSNM is 71%. If only an input subsidy of 1500 Yuan/ha for SSNM use and no input subsidy for cultivation of crops with other fertilizer management is received by the farmers (so no training and education, like Figure 46) the use of SSNM is 33% (Figure 47).

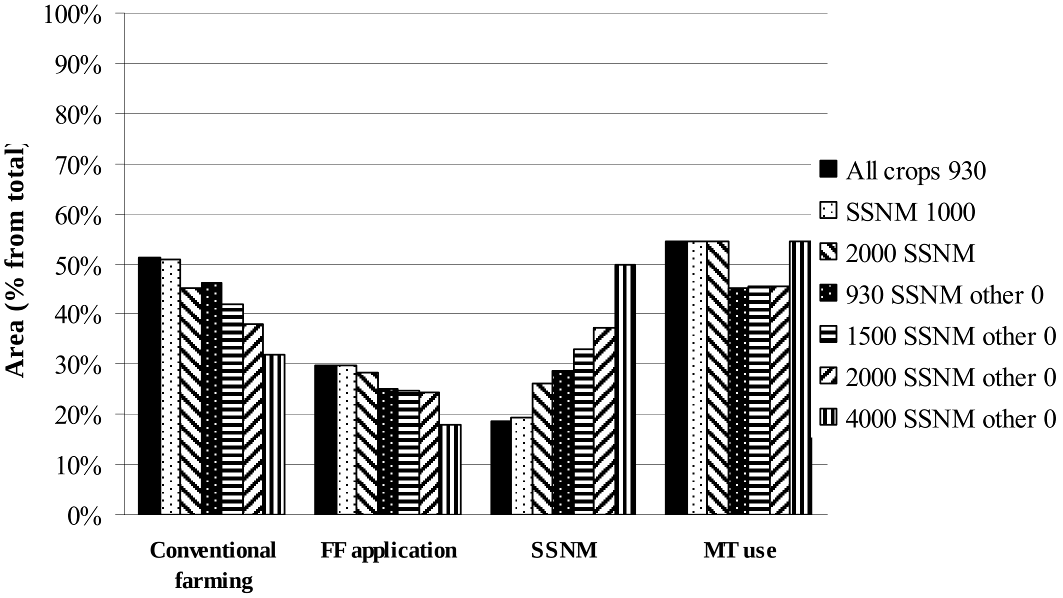

Figure 47. Percentage of use of different managements with different input subsidies with an elasticity of 100 and a value of Flabour of 40. In the baseline an input subsidy of 930 Yuan/ha for all crops is assumed.

With only subsidy given to SSNM the same trend is observed in use of fertilizer managements and MT use compared to subsidy and training and education to stimulate SSNM. If the area of SSNM increases, the area of conventional formula fertilizer management and the area of FF application will decrease. The area of MT will increase (Figure 48).

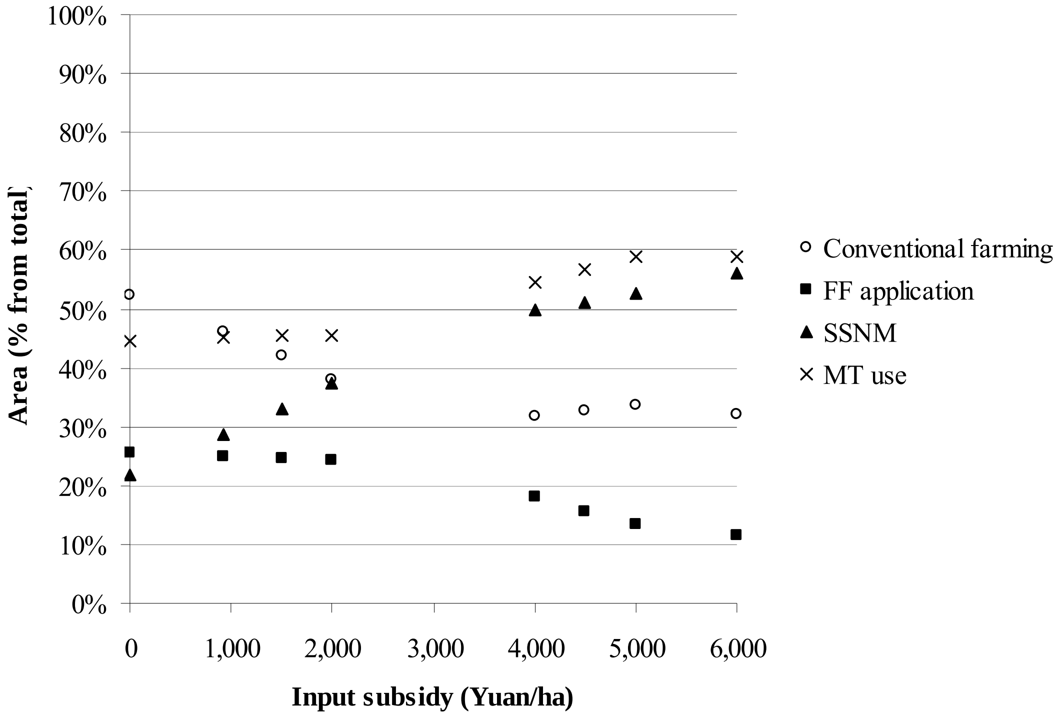

Figure 48. Percentage of use of different managements with different input subsidies for SSNM (input subsidies for other crops is 0) with an elasticity of 100 and a value of Flabour of 40. In the baseline an input subsidy of 930 Yuan/ha for all crops is assumed.

3.5 Policy scenario analysis for Wuxi farm type 1, stimulation of MT

The second policy scenario is to stimulate the use of MT. When only changing the elasticity the percentage area of MT from the total area of rice will never be more than 74% (Figure 19).

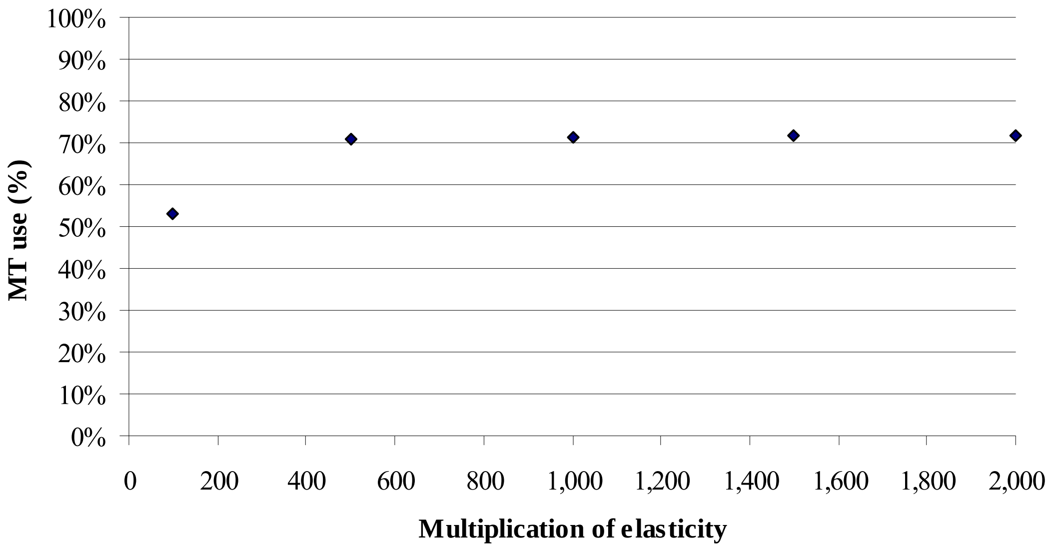

Figure 49. MT use (%) for different elasticities for Wuxi farm type 1

Total MT costs are 1935 Yuan/ha for 2015. Costs for seeds are 565 Yuan/ha and costs for depreciation are 103 Yuan/ha. So the MT rent could be lowered until 668 Yuan/ha.

Lowering the costs of the rent the MT machine will increase the use of it (Figure 50). A combination of increase of the elasticity (so more training and education is given) and decrease of the MT rent will lead to 100% use of MT machine of rice cultivation. Without training and education and only with subsidy the use of MT could be 74% of the total rice cultivation (Figure 50).

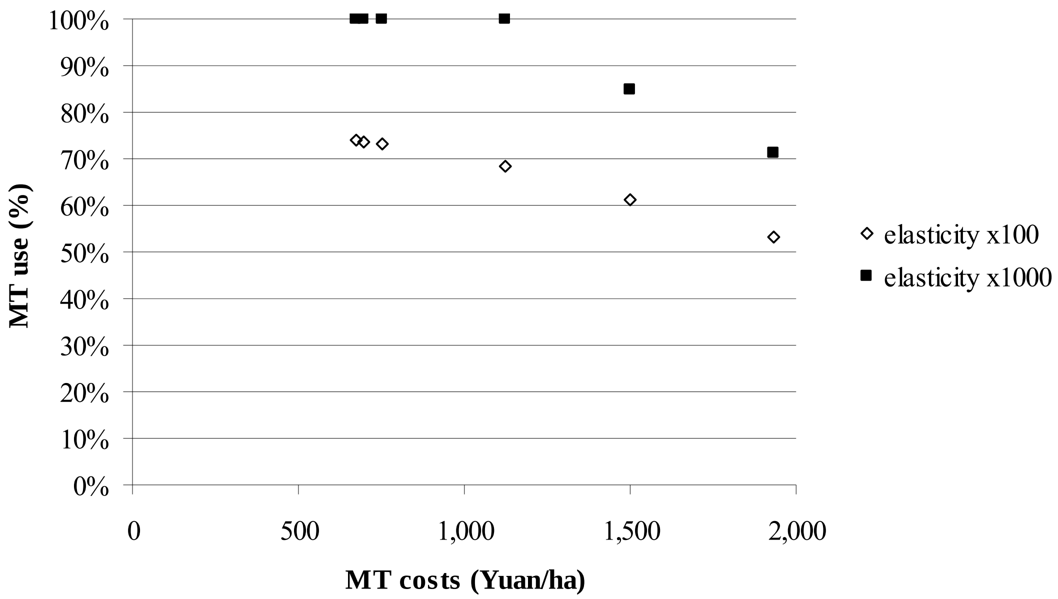

Figure 50. Use of MT (%) for different MT costs (Yuan/ha) for elasticity of rice, wheat and rapeseed multiplied by 100 and by 1000 for Wuxi farm type 1 (Flabour is 40)

The total area of crops stays the same when the MT rent decreases, only more rotations are selected instead of single crops, so the total area with crops in one year is increasing (Figure 51). When the rent of MT decreases more rice with conventional fertilizer management and with MT will be cultivated and more wheat with conventional fertilizer management. Less rice with FF application will be cultivated (Figure 51).

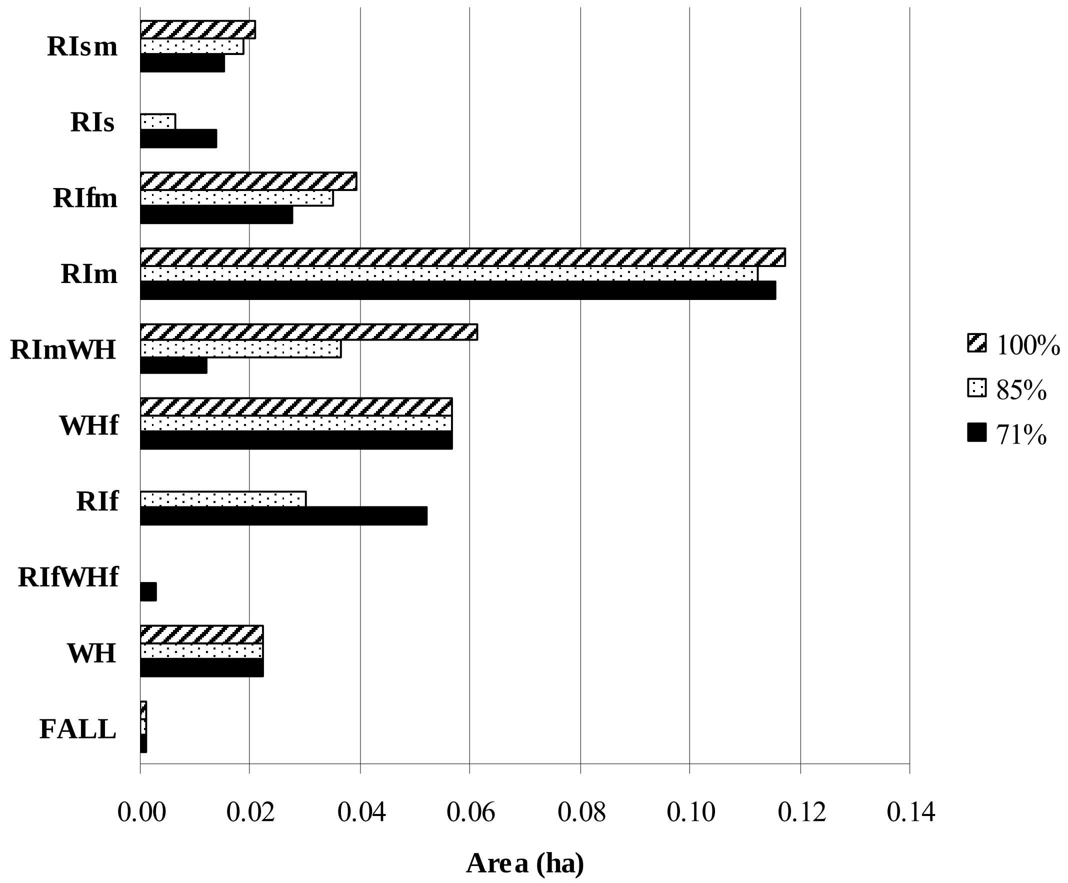

Figure 51. Area of rotations for different percentages of MT use in Wuxi farm type 1. With an elasticity of rice, wheat and rapeseed which is multiplied by 1000 and FLabour value of 40.

The environmental inputs and outputs are increasing when more MT for rice is used (Table 9), this is mainly because the total area that is used is also increasing. The selection of less rice with FF application and the selection of more rice with conventional fertilizer application and mechanical transplanting will increase the fertilizer inputs and therefore also the outputs (Figure 51 and Table 9).

Table 9. Different environmental outputs and inputs for the policy scenario with different percentages of use of MT. With an elasticity of rice, wheat and rapeseed which is multiplied by 1000 and FLabour value of 40.

MT rent (Yuan/ha)	1935	1500	1125
MT use (%)	71	85	100
Environmental results			
Water use (mm)	2200	2215	2235
N surplus (kg N/ha/year)	0.00	0.00	0.42
P surplus (kg P/ha/year)	0.07	0.00	0.00
K surplus (kg K/ha/year)	0.00	1.84	4.12
P Runoff (kg P/ha/year)	0.66	0.69	0.73
N leaching (kg N/ha/year)	59	64	71
K leaching (kg K/ha/year)	53	55	58
N volatilization (kg N/ha/year)	94	96	100
N denitrification (kg N/ha/year)	88	92	97
Biocide Residue Index (-)	404	415	427
Nitrogen application (kg N/ha/year)	284	300	320
Phosphorus application (kg P/ha/year)	49	51	55
Potassium application (kg K/ha/year)	65	65	65

3.6 Policy scenario for Wuxi farm type 1, stimulation of SSNM and MT

The stimulation of MT by extra subsidy leads to decrease in SSNM use and increase in MT use (Figure 52). In case of only stimulating the use of SSNM, the use of SSNM is 63% and the use of MT is 64%. Stimulating SSNM and stimulating the use of MT by a reduction of 435 Yuan/ha on the MT rent, the use of SSNM will be 62% and the use of MT will be 66% (Figure 52).

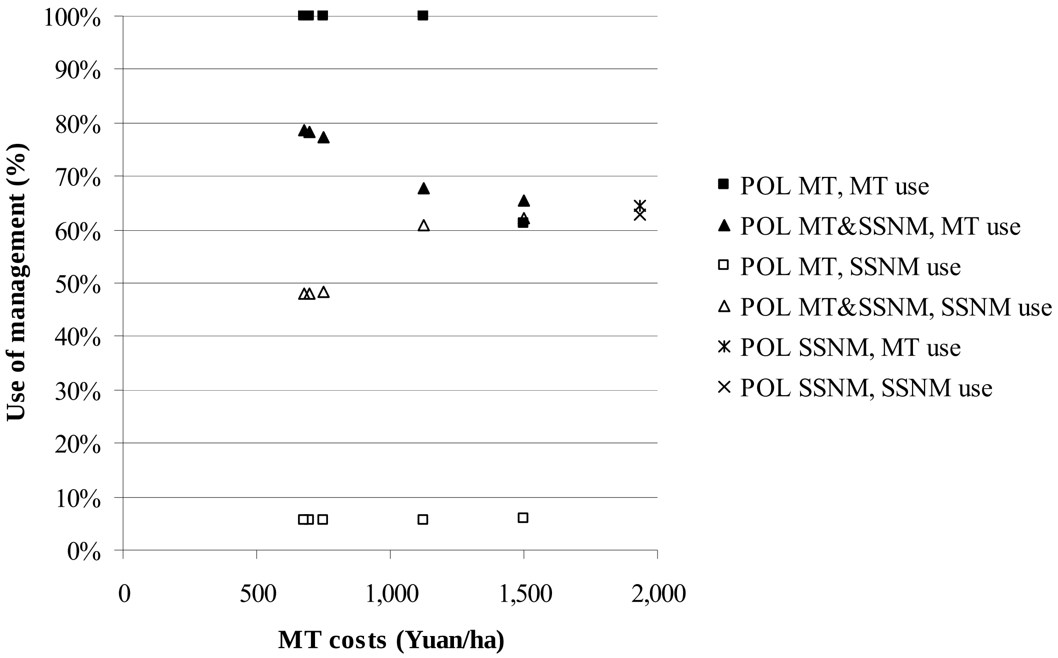

Figure 52. Use of MT (%) and SSNM (%) for different MT costs (Yuan/ha) for policy scenario of MT stimulation, MT stimulation and SSNM stimulation and for the policy scenario of SSNM stimulation. Elasticity of rice, wheat and rapeseed is multiplied by 1000 for Wuxi farm type 1 (Flabour is 40).

3.7 Policy scenario for Wuxi farm type 1, scale enlargement

The third policy scenario is to stimulate scale enlargement. To simulate this scenario the total land area will be increased and the input subsidy will also be increased. In the baseline the family and permanent labour availability is 40 days, because this simulated the closest values to what was expected for 2015. In case of simulating scale enlargement for the policy scenario with a family and permanent labour (Flabour) availability of 40 days the use of FF application and MT increases when the total area increases (Figure 53 and 55). When the total available farm land increases not all land will be used (Figure 56). When the land area is increased the total single crops that are cultivated will first increase when the input subsidy increases and will decrease later and then more rotations are cultivated (Figure 57). In case of a family and permanent availability of 221 days instead of 40 days and a total land area which is two times larger than in the baseline the use of SSNM will increase, the use of FF application will increase a bit, the use of conventional fertilizer management will decrease and the use of MT will decrease a lot (Figure 54). Labour is now less limited and therefore the area that is not used for cultivation is less than with a Flabour availability of 40 days (Figure 56). Also more rotations are cultivated instead of single crops compared to a Flabour availability of 40 days (Figure 57). So for scale enlargement the use of MT is needed if the family and permanent labour availability is limited, if this is not limited the use of MT is not needed so much. In case of using SSNM there should be enough family and permanent labour available otherwise it will not be done.

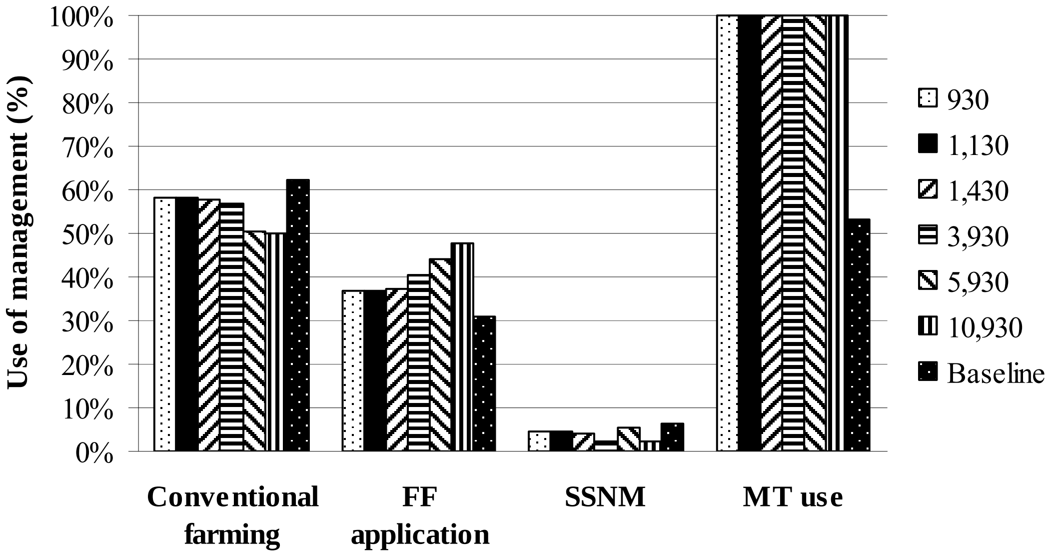

Figure 53. Use of different managements (%) for different input subsidies (Yuan/ha) with two times more land available than in the base year and the baseline (elasticity is multiplied by 1000 in the policy scenario and the Flabour availability is 40 days). In the baseline is the input subsidy 930 Yuan/ha.

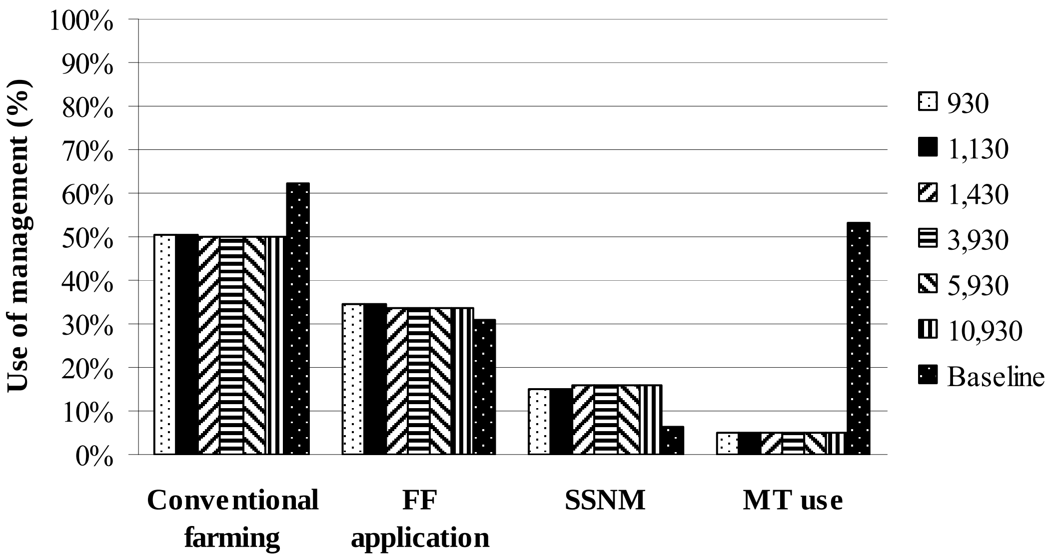

Figure 54. Use of different managements (%) for different input subsidies (Yuan/ha) with two times more land available than in the base year and the baseline (elasticity is multiplied by 1000 in the policy scenario and the Flabour availability is 221 days in the policy scenario and 40 days in the baseline). In the baseline is the input subsidy 930 Yuan/ha.

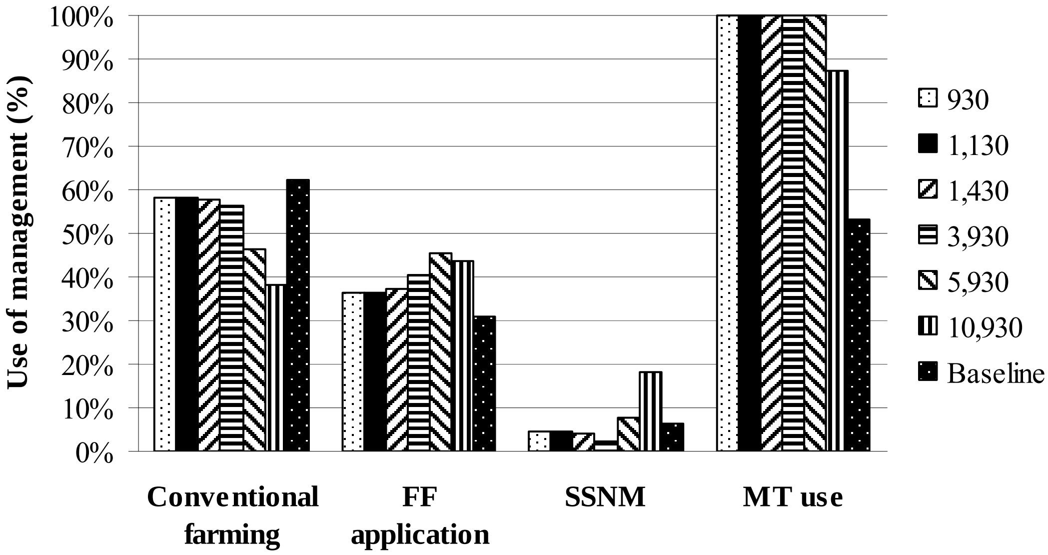

Figure 55. Use of different managements (%) for different input subsidies (Yuan/ha) with three times more land available than in the base year and the baseline (elasticity is multiplied by 1000 in the policy scenario and the Flabour availability is 40 days). In the baseline is the input subsidy 930 Yuan/ha.

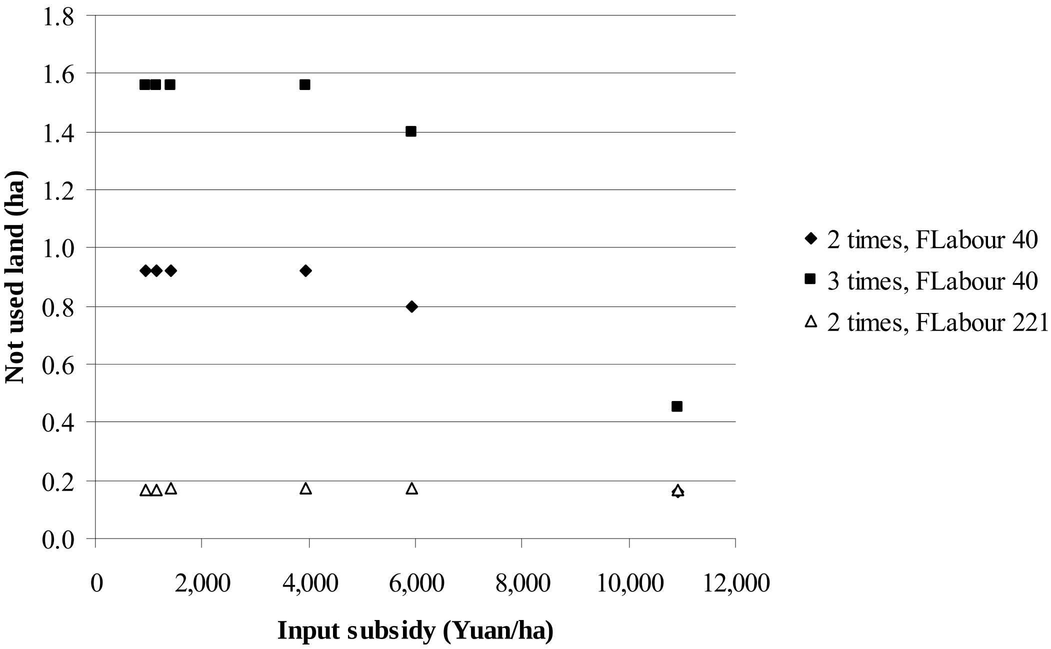

Figure 56. Area that is not used for cultivation of crops (ha) for different input subsidies (Yuan/ha) for a total land area which is two times larger than in the baseline and a total land area which is three times larger than in the baseline and for a family and permanent labour availability (FLabour) of 40 or 221 days.

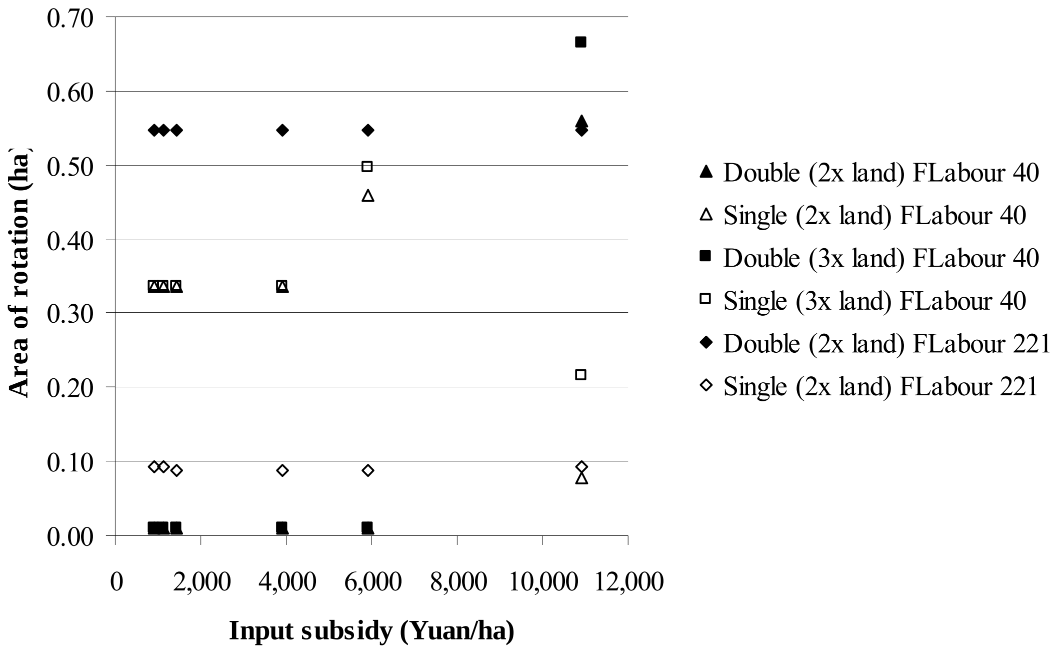

Figure 57. The area of a single crop or a rotation (ha) for two times more land than in the baseline and for three times more land with different input subsidies (Yuan/ha) and for a family and permanent labour availability (FLabour) of 40 or 221 days.

If the Flabour availability is 40 days the N, P and K input will decrease when the total available land increases compared to the baseline, only when the input subsidy is very high the N, P and K input is higher than in the baseline (Figure 58). The inputs and outputs are hectare based, so the decrease in inputs and outputs (Table 10) is mainly caused by a decrease in the use of land.

When the total land area increases only for the high input subsidy the environmental outputs are higher than in the baseline, for all other the environmental outputs except P surplus the outcome is lower than in the baseline for a Flabour availability of 40 days (Figure 59 until 62). If the Flabour availability is 221 days instead of 40 days and the total land available is two times more than in the baseline almost all environmental inputs and outputs are higher than in the baseline (Table 10), only the surplus of N and P are lower in this scenario compared to the baseline. This is mainly due to the more use of land if more labour is available. Due to high costs of renting labour farmers cultivate less land, if labour is higher more land will be used and this leads to more environmental outputs.

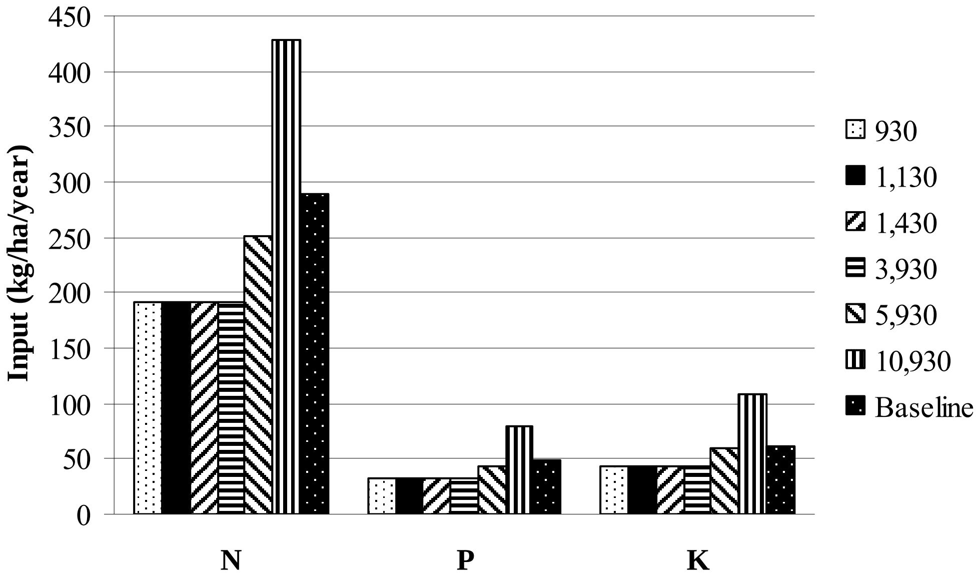

Figure 58. Input of N, P and K (kg/ha/year) for different input subsidies (Yuan/ha) when the total land area is two times larger than in the baseline (elasticity is multiplied by 1000 in the policy scenario and the Flabour availability is 40 days). In the baseline is the input subsidy 930 Yuan/ha.

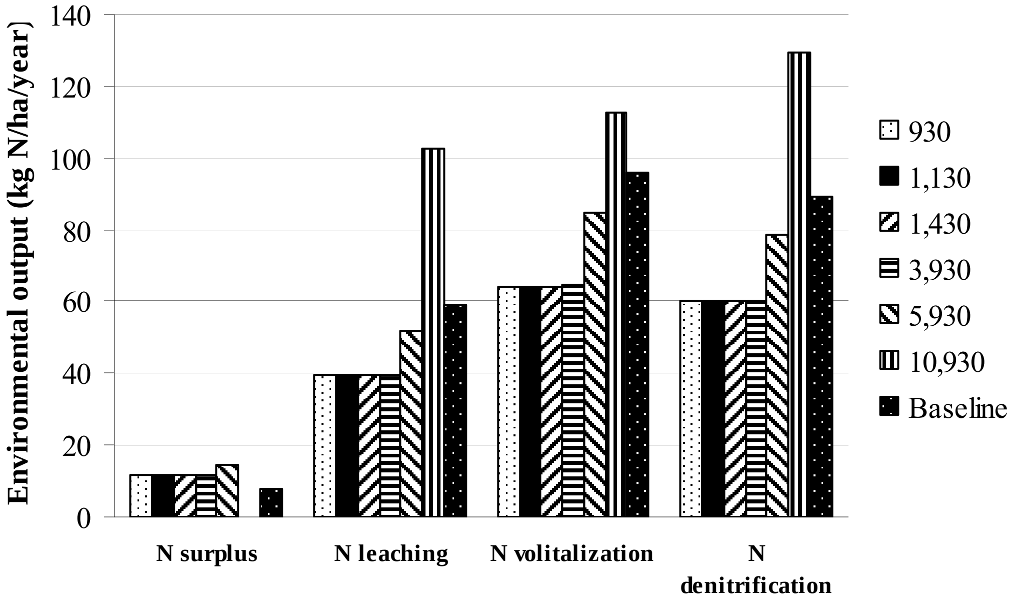

Figure 59. Different environmental outputs (kg N/ha/year) for different input subsidies (Yuan/ha) when the total land area is two times larger than in the baseline (elasticity is multiplied by 1000 in the policy scenario and the Flabour availability is 40 days). In the baseline is the input subsidy 930 Yuan/ha.

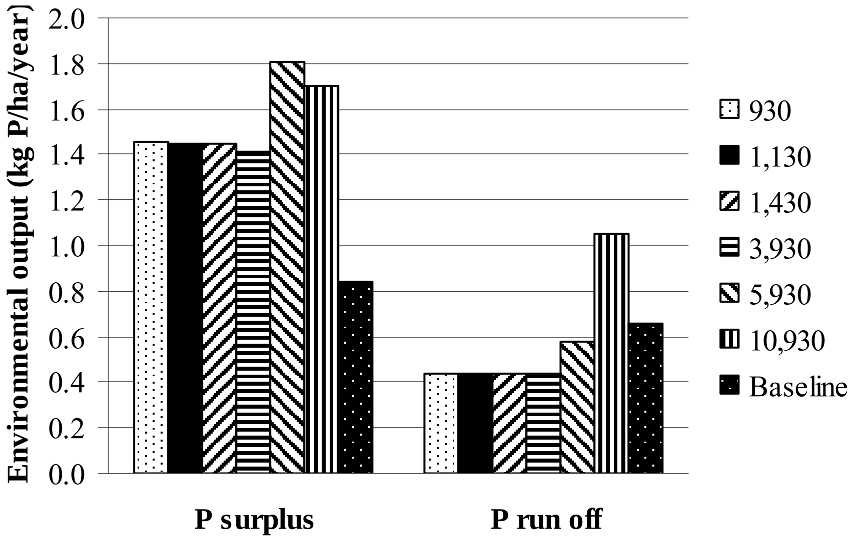

Figure 60. Different environmental outputs (kg P/ha/year) for different input subsidies (Yuan/ha) when the total land area is two times larger than in the baseline (elasticity is multiplied by 1000 in the policy scenario and the Flabour availability is 40 days). In the baseline is the input subsidy 930 Yuan/ha.

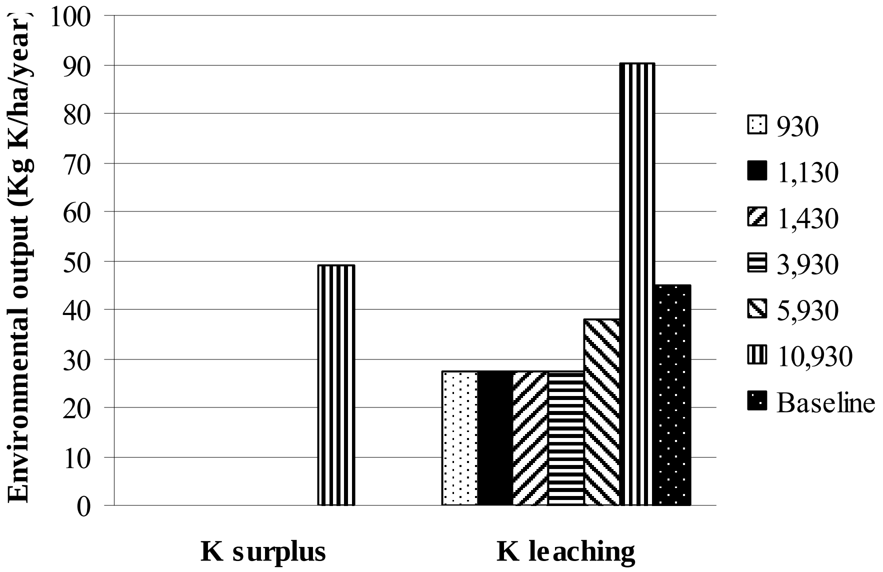

Figure 61. Different environmental outputs (kg K/ha/year) for different input subsidies (Yuan/ha) when the total land area is two times larger than in the baseline (elasticity is multiplied by 1000 in the policy scenario and the Flabour availability is 40 days). In the baseline is the input subsidy 930 Yuan/ha.

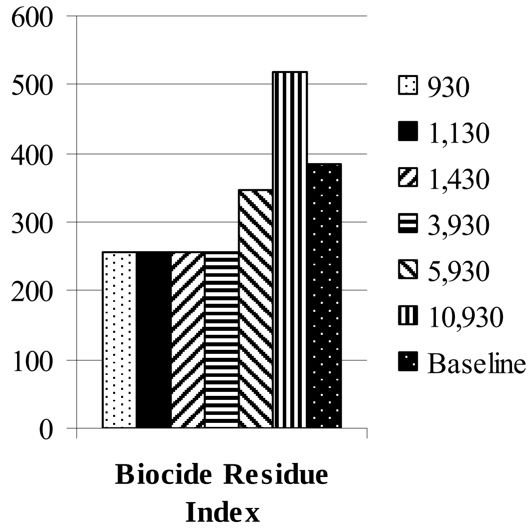

Figure 62. Biocide residue index for different input subsidies (Yuan/ha) when the total land area is two times larger than in the baseline (elasticity is multiplied by 1000 in the policy scenario and the Flabour availability is 40 days). In the baseline is the input subsidy 930 Yuan/ha.

Table 10. Different environmental outputs and inputs for the policy scenario with different total land areas and different availability of family and permanent labour with an input subsidy of 930 Yuan/ha.

Scenario	Baseline	Policy	Policy	Policy
Multiplication of total land area	1	2	3	2
Family and permanent labour available	40	40	40	221
Environmental results				
Water use (mm)	2,169	1,494	997	2609
N surplus (kg N/ha/year)	8	12	8	0
P surplus (kg P/ha/year)	0.8	1.5	1.0	0
K surplus (kg K/ha/year)	0	0	0	42
P Runoff (kg P/ha/year)	0.7	0.4	0.3	0.9
N leaching (kg N/ha/year)	59	39	26	93
K leaching (kg K/ha/year)	45	27	18	82
N volatilization (kg N/ha/year)	96	64	43	103
N denitrification (kg N/ha/year)	89	60	40	118
Biocide Residue Index (-)	386	256	171	518
Nitrogen application (kg N/ha/year)	289	191	127	400
Phosphorus application (kg P/ha/year)	49	33	22	75
Potassium application (kg K/ha/year)	60	43	29	90

3.8 Model outcome of Wuxi farm type 2 for base year, baseline and policy scenario with SSNM stimulation

In case of running the model for Wuxi farm type 2 the PAD value is 2.88%. Wuxi farm type 2 has a similar size as Wuxi farm type 1, but has a higher off-farm income (Table 3). For Wuxi farm type 1 the elasticity of rice, wheat and rapeseed is multiplied by 100 for the baseline scenario for the policy scenario it is multiplied by 1000. This will also be done for all other farm types.

With this elasticity the agricultural income (farm income without PMP term) in the base year is 2,614 Yuan (Figure 65). The off-farm income for Wuxi farm type 2 is 52,179 Yuan. So the agriculture income is 5% of the total income. For Wuxi farm type 1 the agriculture income was 21% of the total income (Figure 56). This means that the off farm income is more important for Wuxi farm type 2 than for Wuxi farm type 1. The total available family and permanent labour days for Wuxi farm type 1 is 221 days. To simulate the limitation of the Flabour days the % of agriculture income from the total income will be taken of the Flabour availability. For Wuxi farm type 1 this means 0.21 times 221 and the outcome will be that 46 days of Flabour is limiting. For Wuxi farm type 1 a Flabour availability of 40 is chosen so this value is below the limiting level. For Wuxi farm type 2 the limiting level is 0.05 times 212 and this will lead to a limiting level of 10 days of Flabour availability. In the base year are 53 days of family and permanent labour used. So in the base year more labour is used compared to the limited labour days for the baseline and policy scenario. Considering the increasing wages, it can be assumed that towards 2015 labour will become more limiting in agriculture. Although 10 days may be very low, it represents the high competitiveness of other sectors.

In case of taken the costs of family and permanent income into account the farm income will be -304 Yuan in the base year, -178 Yuan in the baseline and -166 Yuan in the policy scenario. This means that in all scenarios could be earned more with working off-farm compared to working on-farm.

In the base year the area that is not used for cultivation of crops in both periods is 0.10 ha, in the baseline 0.42 ha is not used and in the policy scenario 0.43 ha is not used during two periods (Figure 63). In the base year the use of MT machine is 25% of the farmers who cultivate rice, in the baseline and policy scenario every farmer who is cultivating rice is using the machine. In the base year 69% of the farmers uses the conventional fertilizer application, while in the baseline 43% uses conventional fertilizer application and in the policy scenario 21%. The use of FF application is in the base year 22%, in the baseline it is 43% and in the policy scenario the use of FF application is 3%. 8% of the farmers in the base year is using SSNM, in the baseline 9% is using SSNM and in the policy scenario 70% (Figure 64).

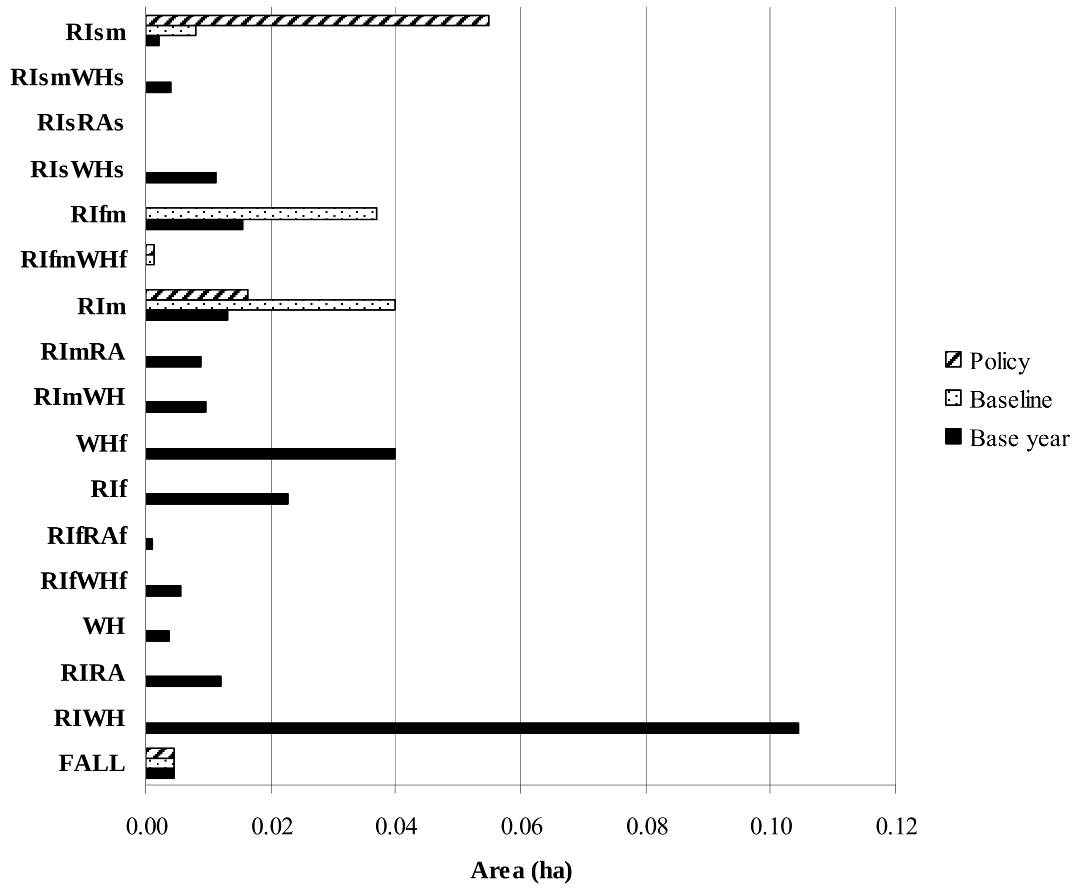

Figure 63. Rotations in the base year, baseline and policy scenario for Wuxi farm type 2

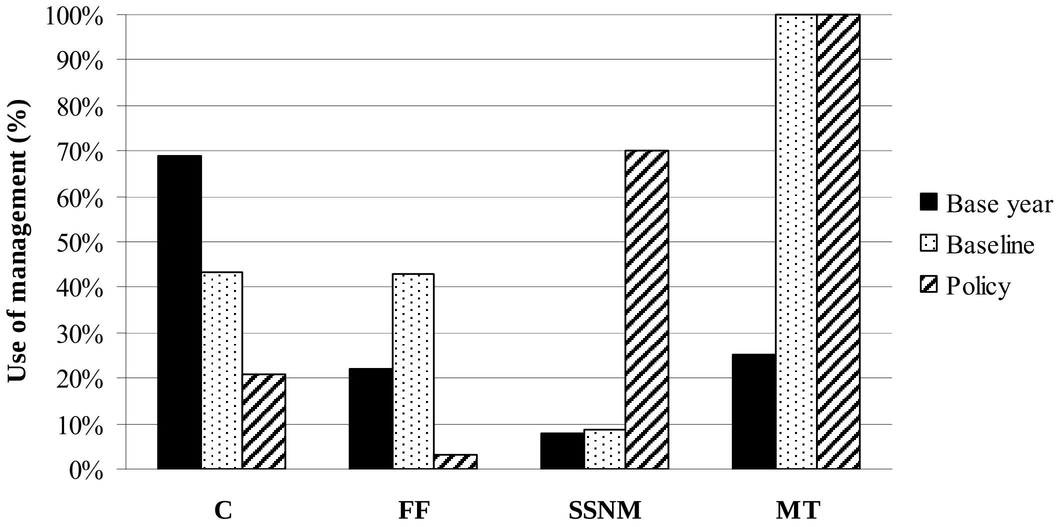

Figure 64. The use of different managements (%) in the base year, baseline and policy scenario for Wuxi farm type 2

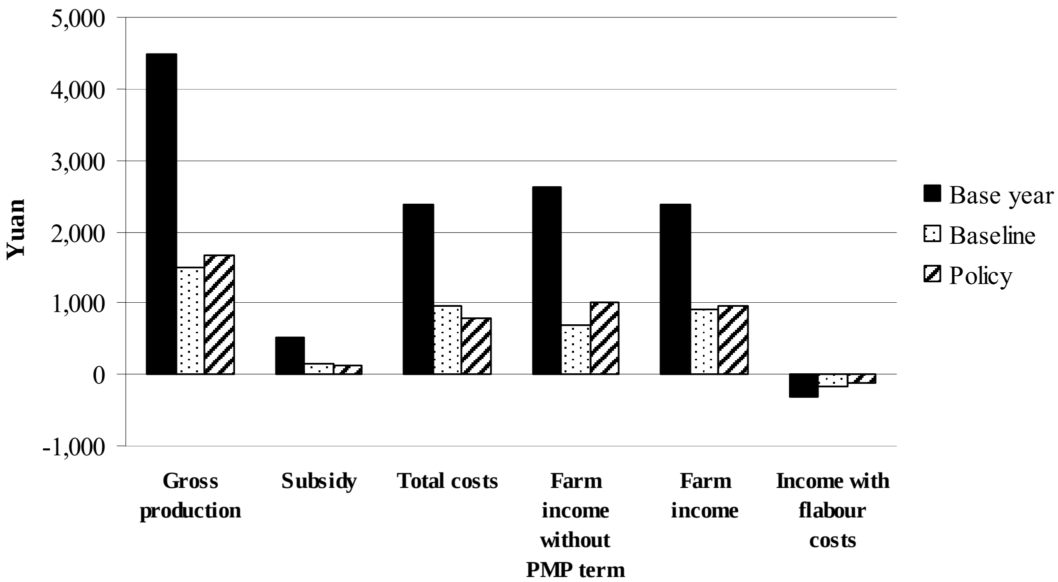

Figure 65. Economic results (Yuan) for Wuxi farm type 2 for the base year, baseline and policy scenario. Farm income includes the PMP term and does therefore not directly reflect outputs-inputs. Farm income without PMP term does indicate what the farmers earn, i.e. gross production + subsidy – total costs. The income including family and permanent labour costs reflect the opportunity costs of agriculture; when negative labour costs are not covered and off-farm employment will be more attractive.

The environmental inputs are in 2015 much lower than in 2008 (Figure 66 and 68). The use of potassium is a bit higher in the policy scenario compared to the baseline (Figure 68). The environmental outputs are in the base year the highest, in the baseline the environmental outputs reduce much compared to the base year and in the policy scenario the environmental outputs are a bit lower than in the baseline (Figure 67 and 69).

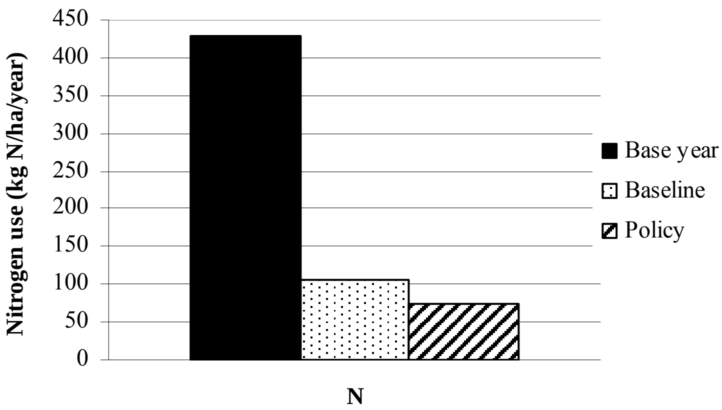

Figure 66. Nitrogen application (kg N/ha/year) in the base year, baseline and policy scenario for Wuxi farm type 2

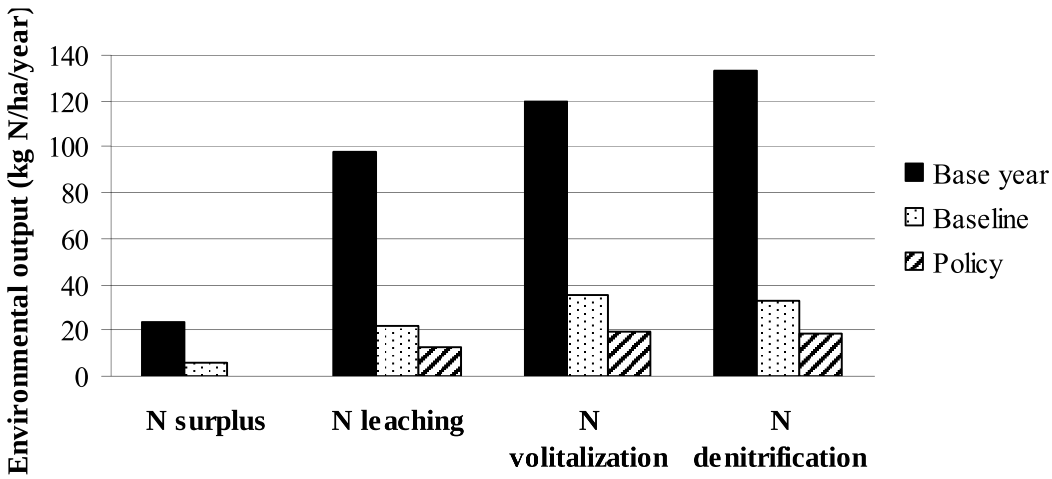

Figure 67. Environmental outputs of nitrogen (kg N/ha/year) for the base year, baseline and policy scenario for Wuxi farm type 2

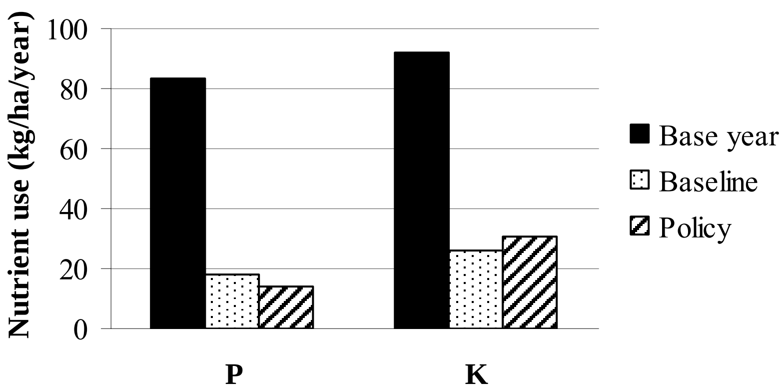

Figure 68. Phosphorus and potassium application (kg /ha/year) in the base year, baseline and policy scenario for Wuxi farm type 2

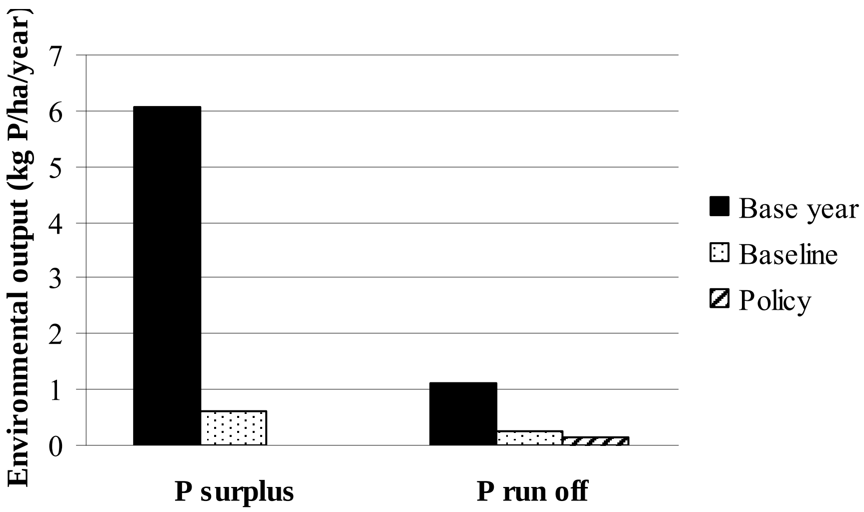

Figure 69. Environmental outputs of phosphorus (kg P/ha/year) for the base year, baseline and policy scenario for Wuxi farm type 2

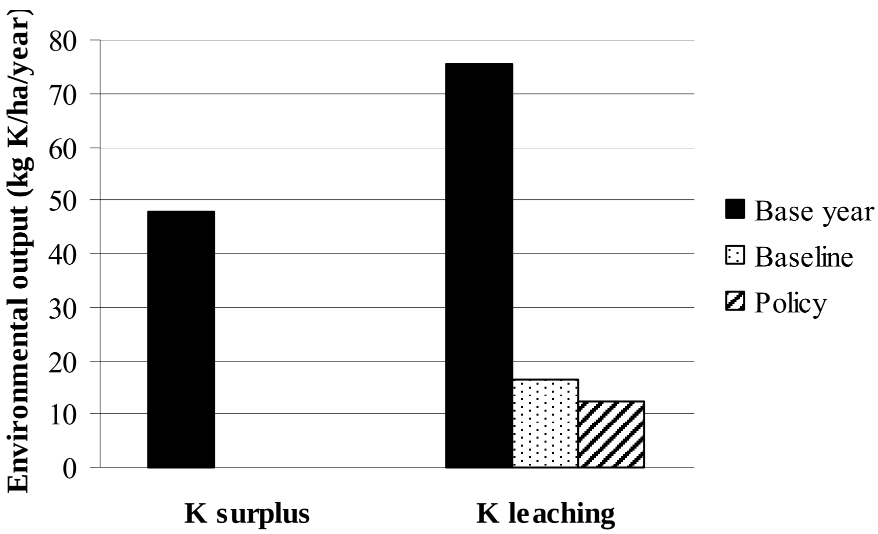

Figure 70. Environmental outputs of potassium (kg K/ha/year) for the base year, baseline and policy scenario for Wuxi farm type 2

In 2008 the BRI is above the threshold value of 200, in 2015 the BRI is between 100 and 200 and is therefore permissible (Figure 71).

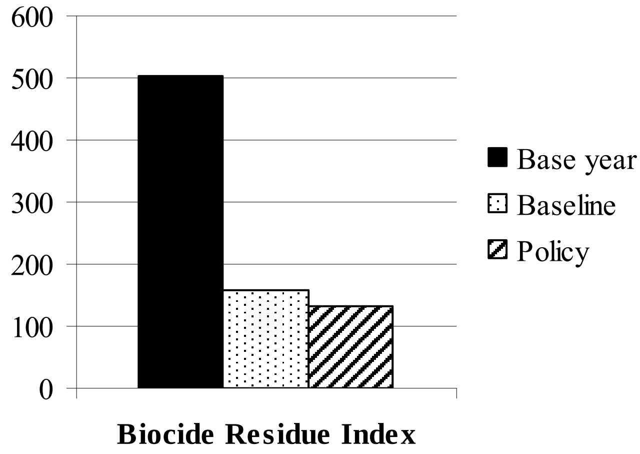

Figure 71. Bio residue index (-) for Wuxi farm type 2 in the base year, baseline and policy scenario

3.9 Model outcome of Wuxi farm type 3 for base year, baseline and policy scenario with SSNM stimulation

In case of running the model for Wuxi farm type 3 the PAD value for the base year is 1.121%. Wuxi farm type 3 has a comparable total area as Wuxi farm type 1 and 2, but the off-farm income is much higher for Wuxi farm type 3 than for Wuxi farm type 1 and 2. In the base year the farm income without PMP term is 2,737 Yuan (Figure 74), the off-farm income is 107,850 Yuan. So the agriculture income is 2% of the total income. This means that 2% of 188 days, 5 days will be the available Flabour in the baseline and in the policy scenario.

In the base year the farm income with the costs for family and permanent labour taken into account is -409 Yuan, in the baseline the farm income with Flabour costs taken into account is 362 Yuan and in the policy scenario it is 349 Yuan (Figure 74). So in 2008 more could be earned with working off-farm compared to working on-farm and in 2015 could be earned more with working on-farm compared to working off-farm. In the baseline and policy scenario there is rent of temporary labour of 2 days (Figure 74).

In 2008 0.02 ha of the total available land is not used for cultivation of crops in both periods, while in 2015 0.36 ha of land is not used for cultivation of crops (Figure 72). In the baseline and policy scenario the same rotations are chosen (Figure 72). The use of MT machine for rice is in the base year, baseline and policy scenario 0%. The use of conventional fertilizer management is in the base year 43%, in the baseline 73% and in the policy scenario also 73% (Figure 73). The use of FF application is in the base year 36% and in the baseline and policy scenario the use of FF application is 0% (Figure 73). The use of SSNM is in the base year 14%, in the baseline and policy scenario it is 0% (Figure 73).

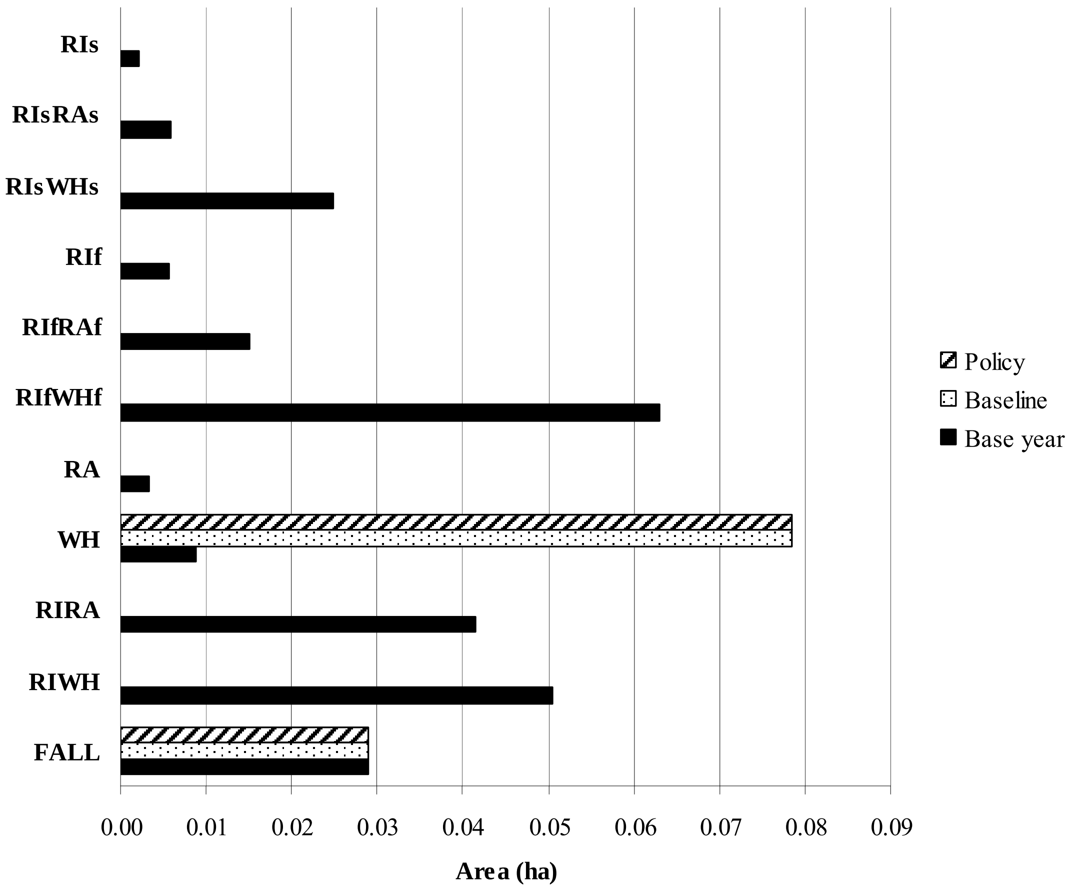

Figure 72. Rotations in the base year, baseline and policy scenario for Wuxi farm type 3

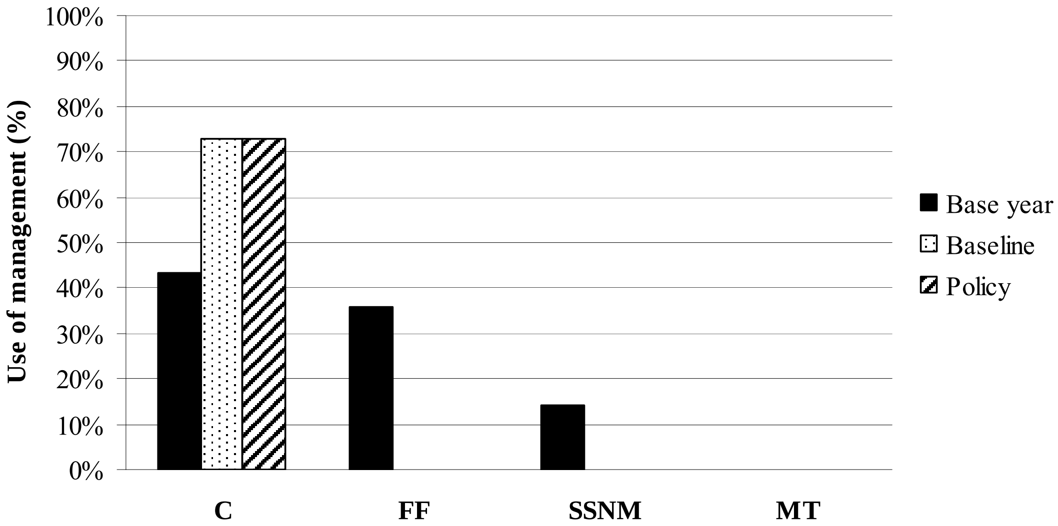

Figure 73. The use of different managements (%) in the base year, baseline and policy scenario for Wuxi farm type 3

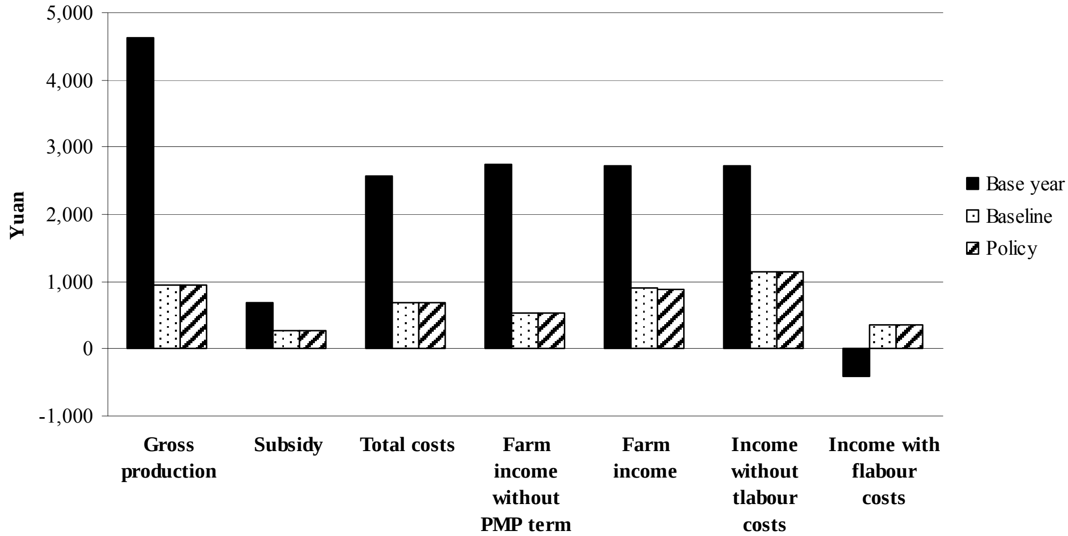

Figure 74. Economic results (Yuan) for Wuxi farm type 3 for the base year, baseline and policy scenario. Farm income includes the PMP term and does therefore not directly reflect outputs-inputs. Farm income without PMP term does indicate what the farmers earn, i.e. gross production + subsidy – total costs. The income without the temporary labour costs, flabour is put on a lower value for the baseline and policy scenario so normally hiring labour is not needed. The income including family and permanent labour costs reflect the opportunity costs of agriculture; when negative labour costs are not covered and off-farm employment will be more attractive.

The environmental inputs and outputs are much higher in 2008 as in 2015 (Figure 75 and 77). The environmental inputs and outputs in the baseline are the same as in the policy scenario (Figure 75 until 80).

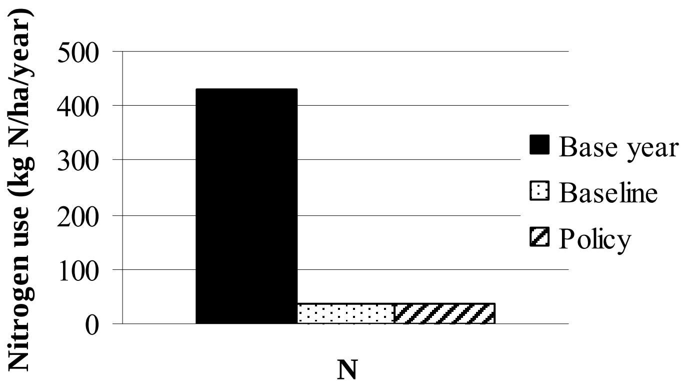

Figure 75. Nitrogen application (kg N/ha/year) in the base year, baseline and policy scenario for Wuxi farm type 3

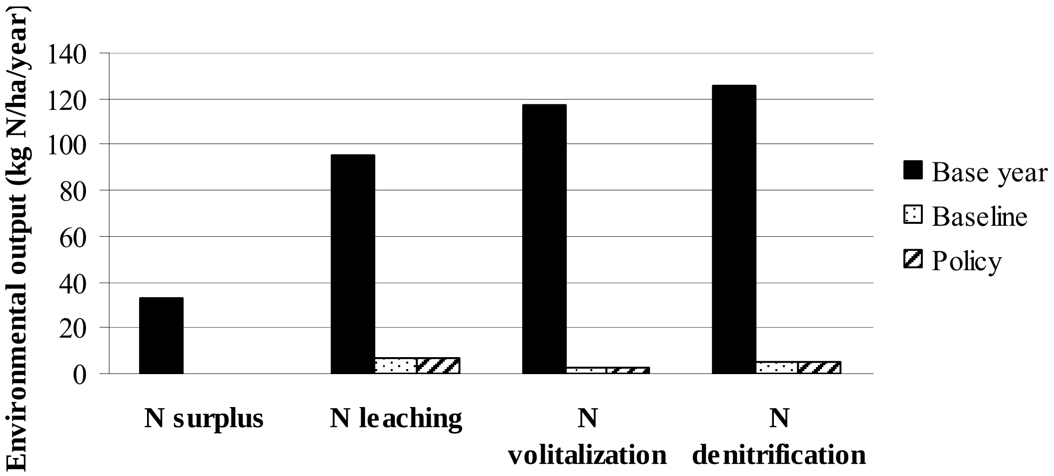

Figure 76. Environmental outputs of nitrogen (kg N/ha/year) for the base year, baseline and policy scenario for Wuxi farm type 3

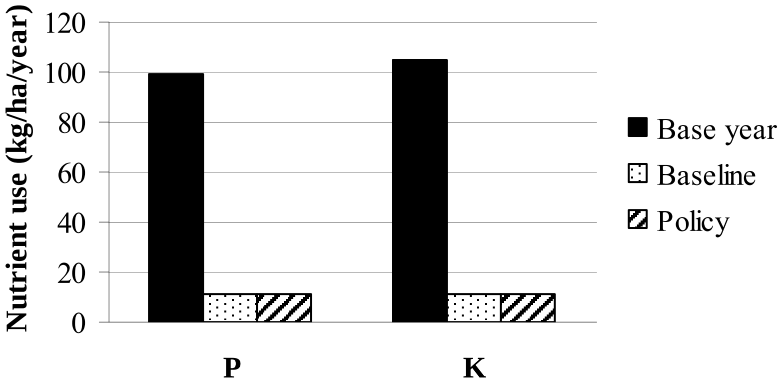

Figure 77. Phosphorus and potassium application (kg /ha/year) in the base year, baseline and policy scenario for Wuxi farm type 3

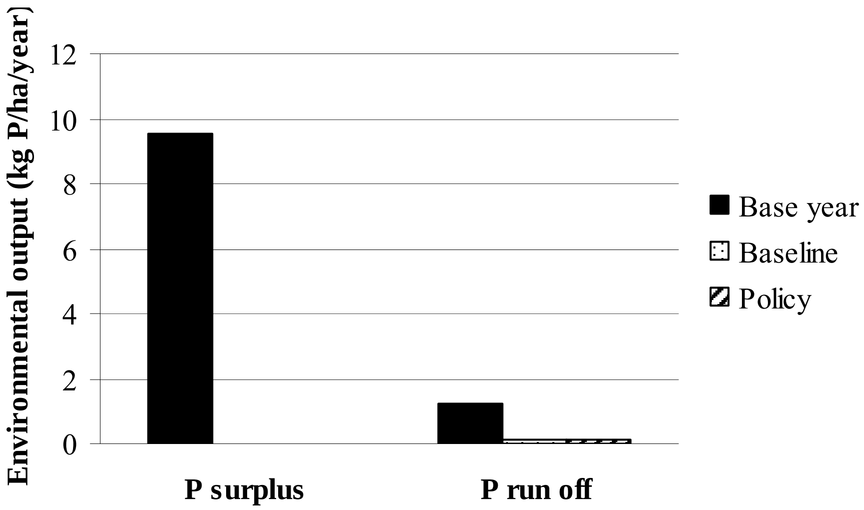

Figure 78. Environmental outputs of phosphorus (kg P/ha/year) for the base year, baseline and policy scenario for Wuxi farm type 3

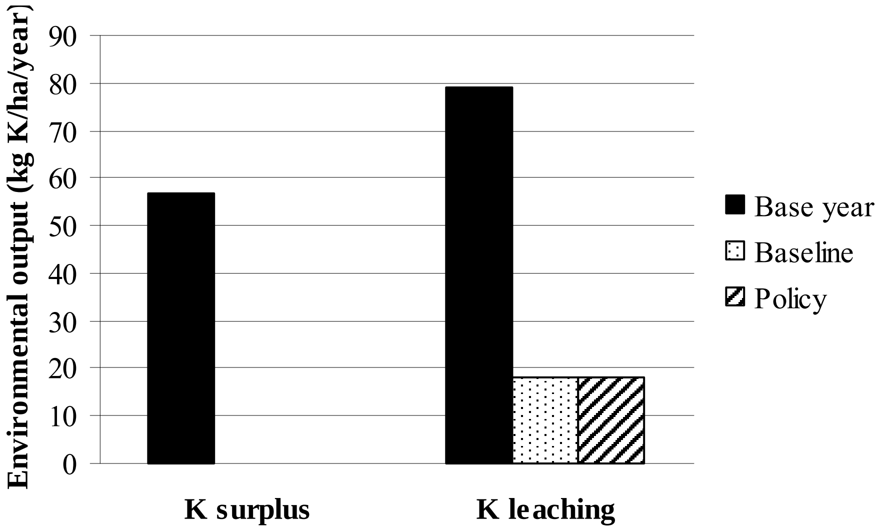

Figure 79. Environmental outputs of potassium (kg K/ha/year) for the base year, baseline and policy scenario for Wuxi farm type 3

In 2008 the BRI is above the threshold value of 200 (Figure 80). In 2015 the BRI is below 100 and is therefore safe (Figure 80).

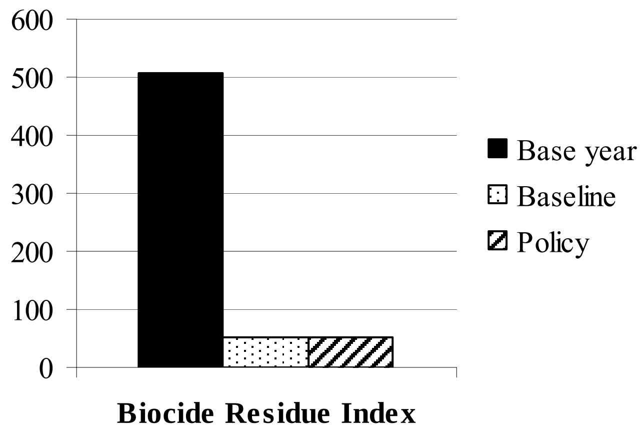

Figure 80. Bio residue index (-) for Wuxi farm type 3 in the base year, baseline and policy scenario

In the base year are 62 days of family and permanent labour used. For other farm types the formula for the limitation of Flabour availability seem to work quite well, but in this case the Flabour availability of 5 days seems to be too low. In the base year is 96% of the total land area used for the cultivation of crops while in the baseline and policy scenario only 27% of the total land area is used and 12% of that is used for the buffer zone. So very high percentage of land is not used in the baseline and policy scenario compared to the base year due to the too high limitation of Flabour availability. Labour limitation in the baseline and policy scenario is also the cause of the low use of SSNM.

3.10 Model outcome of Wuxi farm type 4 for base year, baseline and policy scenario with SSNM stimulation

Wuxi farm type 4 has a large total area compared to Wuxi farm type 1, 2 and 3, but the off-farm income is low compared to Wuxi farm type 1, 2 and 3. In the base year the farm income without PMP term is 17,478 Yuan (Figure 83), the off-farm income is 6,000 Yuan. So the agriculture income is 74% of the total income. This means that 74% of 417 days, 310 days will be the available Flabour in the baseline and in the policy scenario. In case of running the model for the base year for Wuxi farm type 4 the PAD value is 0.20%.

In the base year 0.09 ha is not used for cultivation of crops, in the baseline this is 2.29 ha and in the policy scenario this is 2.42 ha (Figure 81). So even with a lot of family and permanent available the cultivation of crops seems to be not profitable enough. In the base year only rice with MT is cultivated so in the baseline and policy scenario still all rice will be cultivated with MT. In the baseline only crops are cultivated with conventional fertilizer application, no use of FF application and of SSNM. In the policy scenario 25% of the crops is cultivated with SSNM and still no crops are cultivated with FF application (Figure 82).

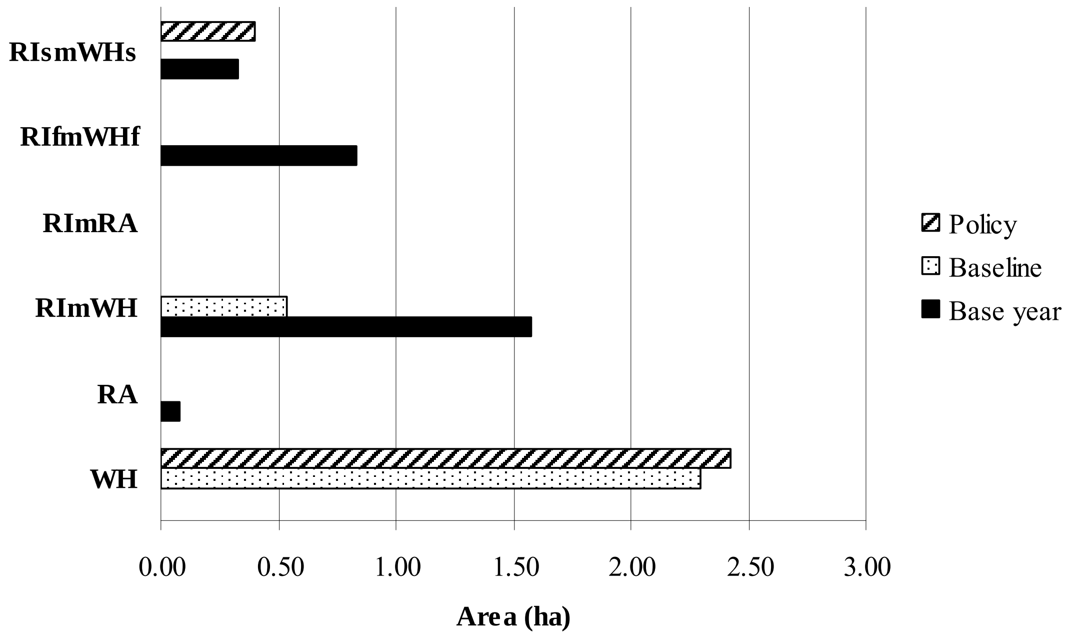

Figure 81. Rotations in the base year, baseline and policy scenario for Wuxi farm type 4

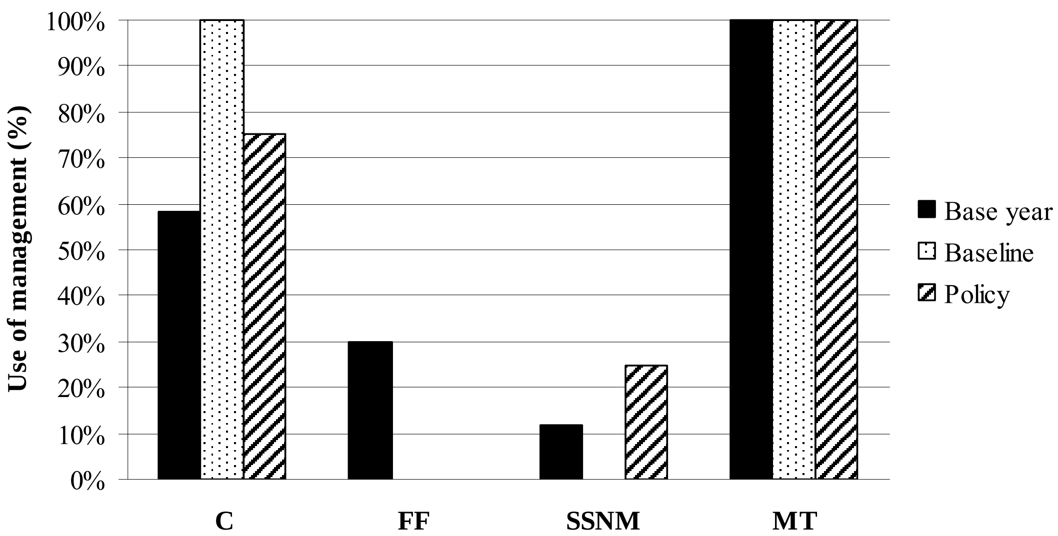

Figure 82. The use of different managements (%) in the base year, baseline and policy scenario for Wuxi farm type 4

The farm income is higher in 2015 than in 2008. In the base year temporary labour is hired, in case of subtracting these costs then the farm income is higher in the base year. If the costs of family and permanent labour are taken into account the income is higher in 2008 than in 2015. The income with Flabour taken into account is in all scenarios still positive (Figure 83), so with working on-farm could be earned more than with working off-farm. In the base year scenario 74% of which is earned by subsidy and gross production is for the costs, in the baseline 57% of the total revenues is for the costs and in the policy scenario 52% is for the costs. Due to the high costs in the base year the income is lower. The costs are higher in the base year due to rent of labour, in the baseline and policy scenario no temporary labour is rented.

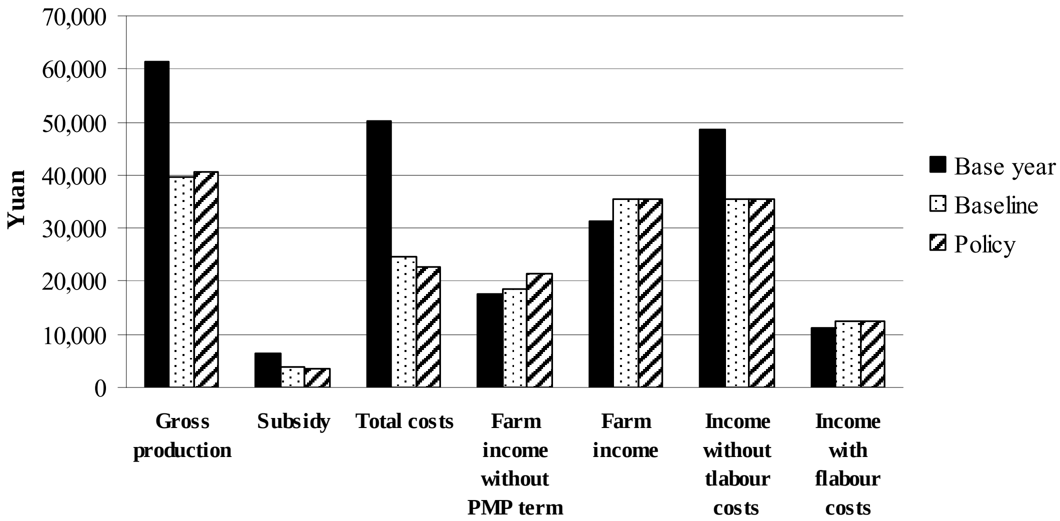

Figure 83. Economic results (Yuan) for Wuxi farm type 4 for the base year, the baseline and policy scenario. Farm income includes the PMP term and does therefore not directly reflect outputs-inputs. Farm income without PMP term does indicate what the farmers earn, i.e. gross production + subsidy – total costs. The income without the temporary labour costs, flabour is put on a lower value for the baseline and policy scenario so normally hiring labour is not needed. The income including family and permanent labour costs reflect the opportunity costs of agriculture; when negative labour costs are not covered and off-farm employment will be more attractive.

All nutrient inputs and outputs are reduced in the baseline compared to the base year (Figure 84 until 89). Nitrogen en phosphorus inputs are reduced in the policy scenario compared to the baseline (Figure 84 and 85), potassium input is slightly increased in the policy scenario compared to the baseline scenario (Figure 86). Nitrogen and phosphorus outputs are reduced in the policy scenario compared to the baseline scenario (Figure 85 and 87). Potassium surplus is reduced in the policy scenario, but potassium leaching is slightly increased compared to the baseline scenario (Figure 88).

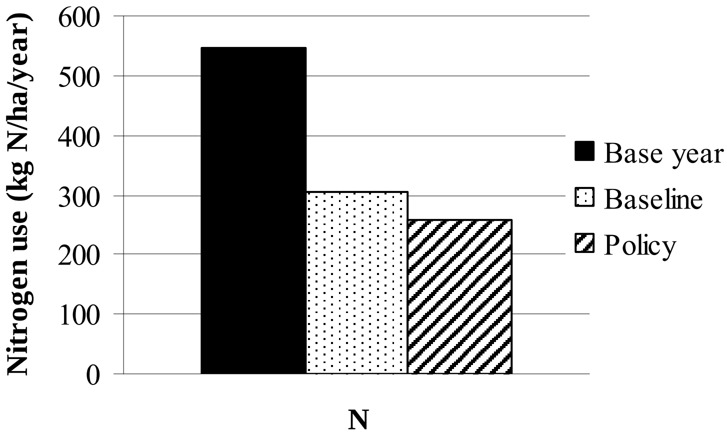

Figure 84. Nitrogen application (kg N/ha/year) in the base year, baseline and policy scenario for Wuxi farm type 4

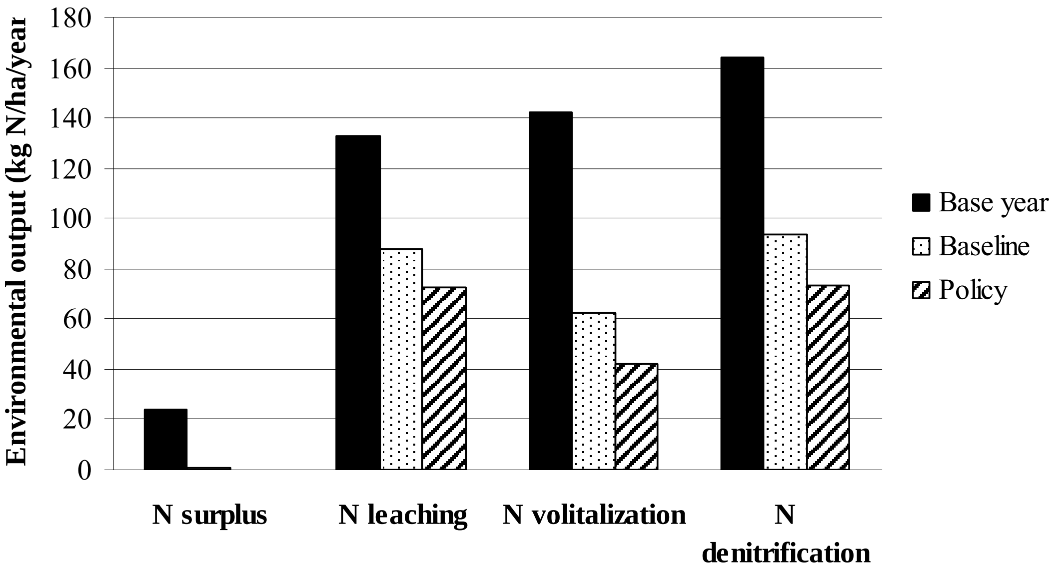

Figure 85. Environmental outputs of nitrogen (kg N/ha/year) for the base year, baseline and policy scenario for Wuxi farm type 4

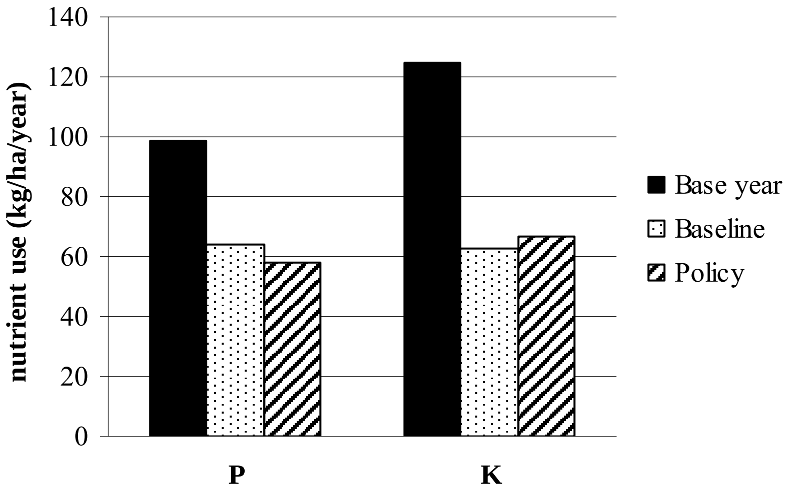

Figure 86. Phosphorus and potassium application (kg /ha/year) in the base year, baseline and policy scenario for Wuxi farm type 4

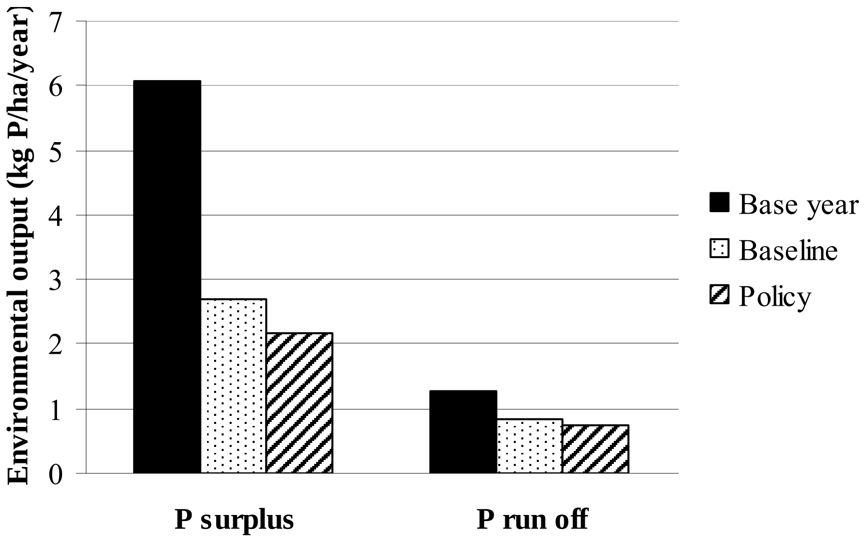

Figure 87. Environmental outputs of phosphorus (kg P/ha/year) for the base year, baseline and policy scenario for Wuxi farm type 4

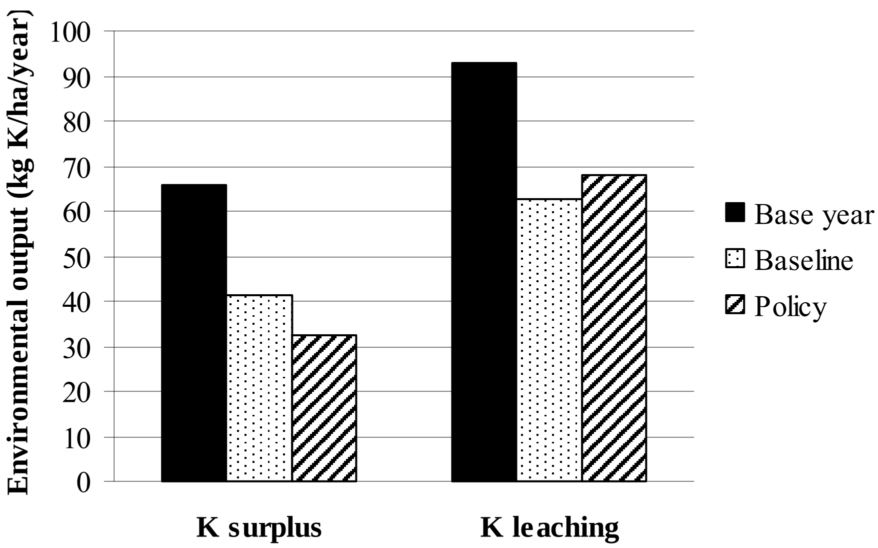

Figure 88. Environmental outputs of potassium (kg K/ha/year) for the base year, baseline and policy scenario for Wuxi farm type 4

Biocide residue index is slightly decreased in the policy scenario compared to the baseline scenario (Figure 89). Although the BRI is lower in 2015, the values are all still above the threshold value of 200.

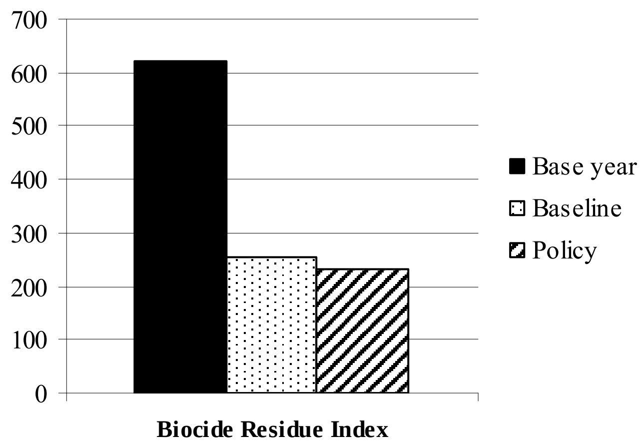

Figure 89. Bio residue index (-) for Wuxi farm type 4 in the base year, baseline and policy scenario

3.11 Model outcome of Changzhou farm type 1 for base year, baseline and policy scenario with SSNM stimulation

In the base year the farm income without PMP term is 3352 Yuan (Figure 92), the off-farm income is 13065 Yuan. So the agriculture income is 20% of the total income. This means that 20% of 242 days, 49 days will be the available Flabour in the baseline and in the policy scenario. In case of running the model for Changzhou farm type 1 the PAD value is 7.9%.

In the base year most of the area is used for cropping; only 0.01 ha is not used in the second period. In the baseline 0.23 ha is not used and in the policy scenario 0.19 ha of land is not used (Figure 90). The area of rice will stay the same when going from the base year to the baseline and to the policy scenario. The area of wheat changes, more wheat is cultivated in the base year scenario than in the baseline. In the policy scenario more wheat is cultivated than in the baseline, but not more than in the base year (Figure 90).

The policy scenario has 42% more SSNM than the baseline, FF application reduces with 16% and conventional fertilizer management reduces with 26% (Figure 91). In the policy scenario 37% more MT is used compared to the baseline scenario. Comparing the policy scenario with the base year then the % of use of SSNM is increased with 43% in the policy scenario, FF application is reduced with 10%, conventional fertilizer management with 35% reduced and MT is increased with 33% (Figure 91).

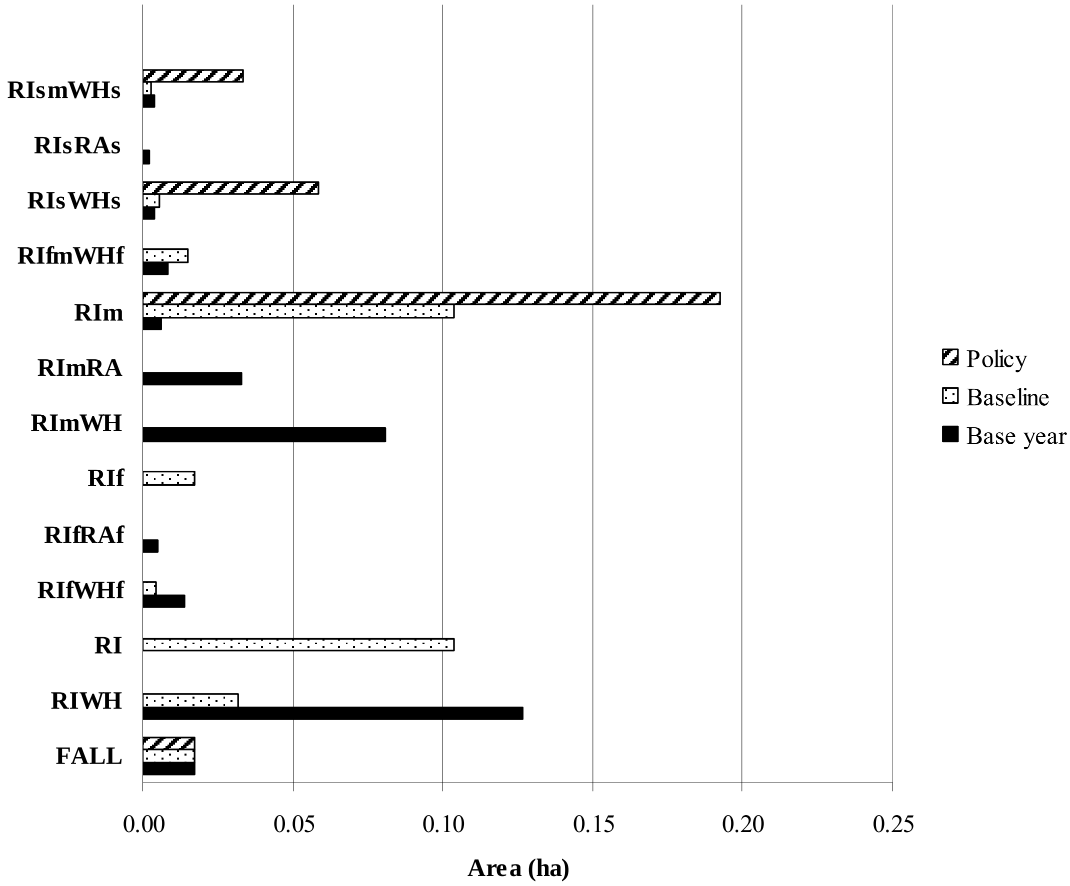

Figure 90. Rotations in the base year, baseline and policy scenario for Changzhou farm type 1

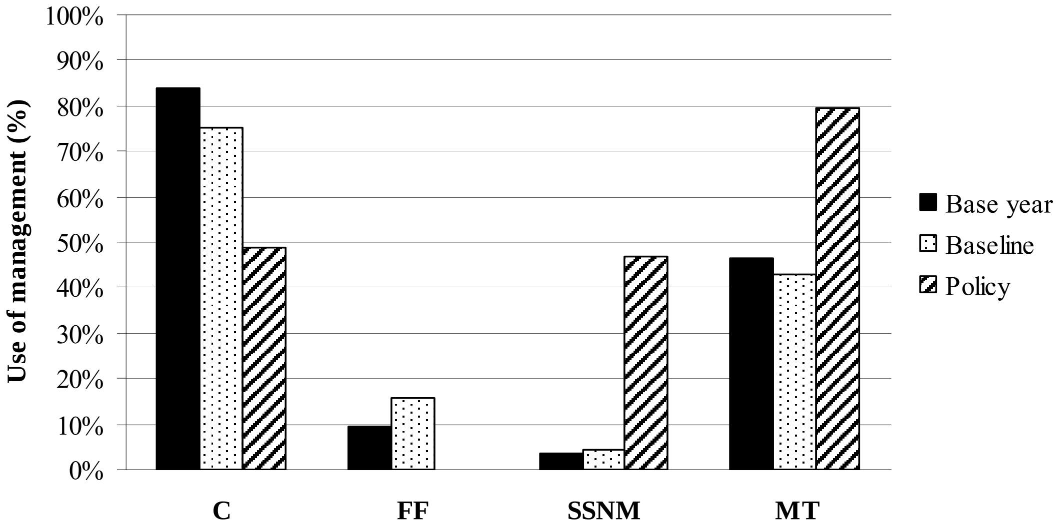

Figure 91. The use of different managements (%) in the base year, baseline and policy scenario for Changzhou farm type 1

Although less area is used in the baseline and policy scenario compared to the base year, the farm income is almost the same in all three scenarios (Figure 92). Due to the high wage in 2015 the farm income with the costs of family and permanent labour taken into account will be much lower than in 2008 (Figure 92). The income with Flabour is negative in 2015 (Figure 92), so with working off-farm can be earned more than with working on-farm.

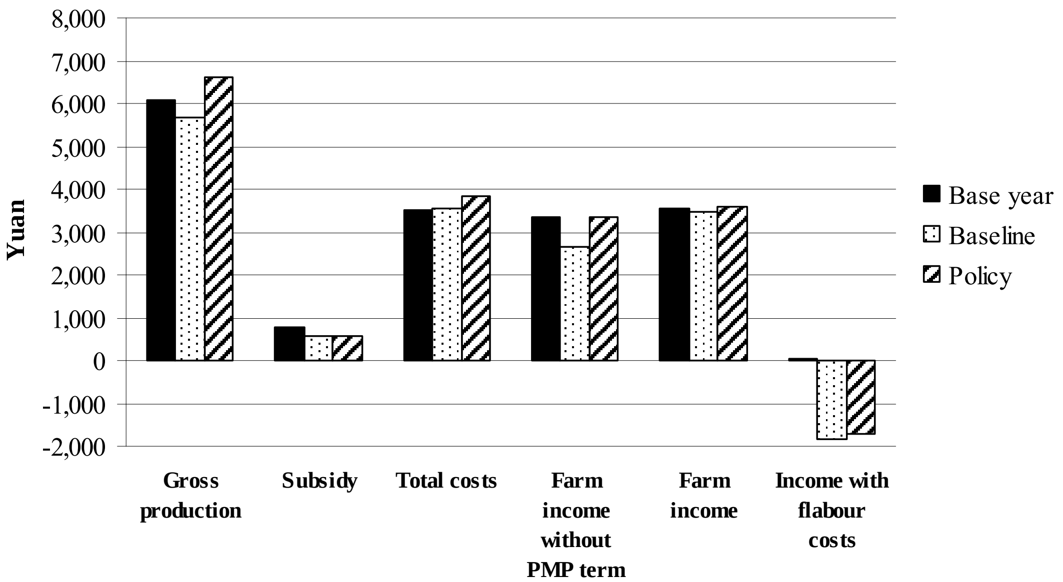

Figure 92. Economic results (Yuan) for Changzhou farm type 1 for the base year, the baseline and policy scenario. Farm income includes the PMP term and does therefore not directly reflect outputs-inputs. Farm income without PMP term does indicate what the farmers earn, i.e. gross production + subsidy – total costs. The income including family and permanent labour costs reflect the opportunity costs of agriculture; when negative labour costs are not covered and off-farm employment will be more attractive.

N and P input is reduced in the baseline compared to the base year and also in the policy scenario compared to the base year and baseline (Figure 93 and 95). The reduction in N and P input leads to reduction in N and P outputs (Figure 94 and 96). The use of K is reduced in the baseline compared to the base year (Figure 95). Only the input of K is higher in the policy scenario compared to the baseline, but not higher compared to the base year (Figure 95). The surplus of K will be completely reduced in the policy scenario, but the leaching of K increases in the policy scenario compared to the baseline, but not compared to the base year (Figure 97).

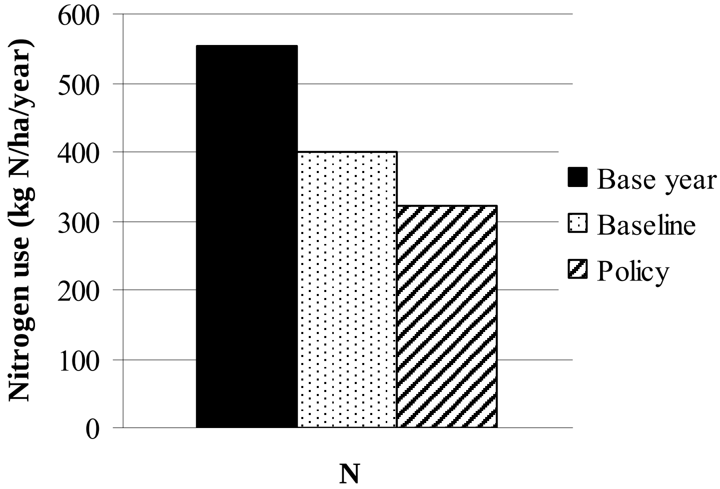

Figure 93. Nitrogen application (kg N/ha/year) in the base year, baseline and policy scenario for Changzhou farm type 1

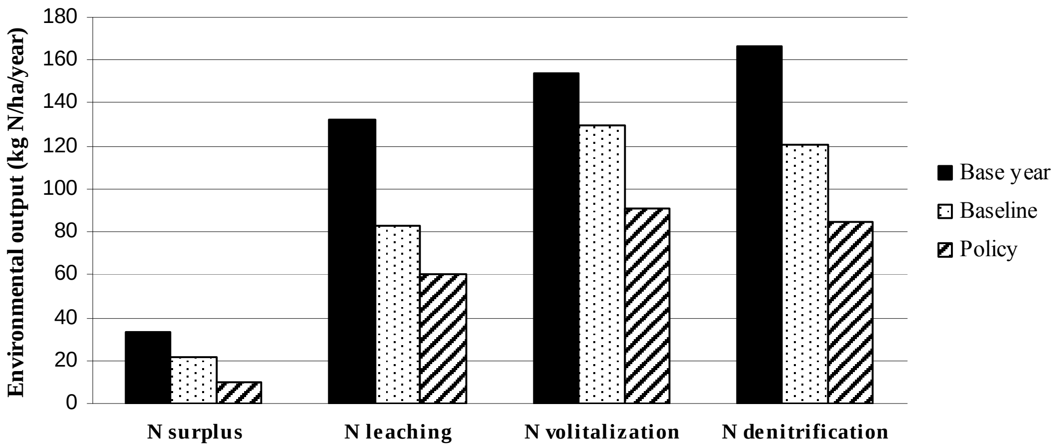

Figure 94. Environmental outputs of nitrogen (kg N/ha/year) for the base year, baseline and policy scenario for Changzhou farm type 1

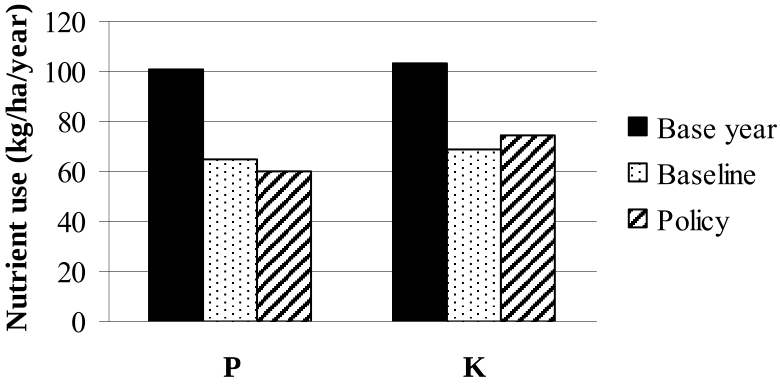

Figure 95. Phosphorus and potassium application (kg /ha/year) in the base year, baseline and policy scenario for Changzhou farm type 1

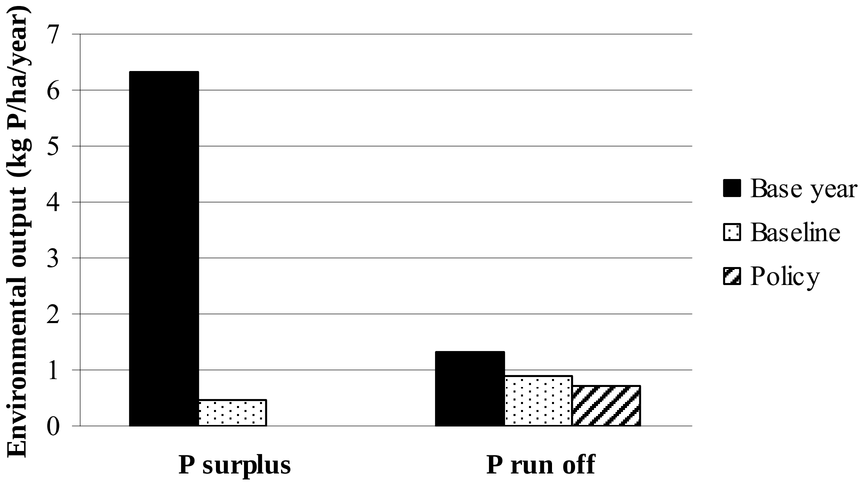

Figure 96. Environmental outputs of phosphorus (kg P/ha/year) for the base year, baseline and policy scenario for Changzhou farm type 1

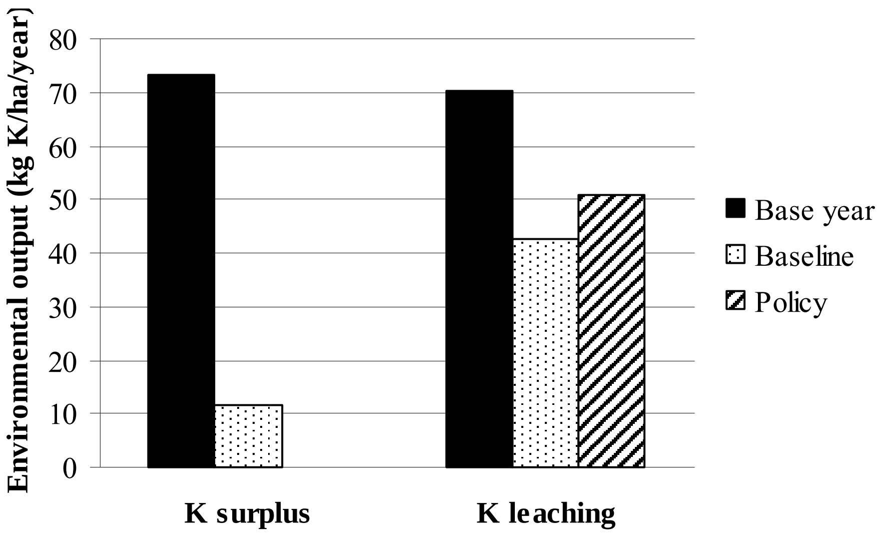

Figure 97. Environmental outputs of potassium (kg K/ha/year) for the base year, baseline and policy scenario for Changzhou farm type 1

The BRI is in the base year higher than in the baseline and policy scenario, in the policy scenario the BRI is higher than in the baseline (Figure 98). In all three scenarios the BRI is above the threshold value.

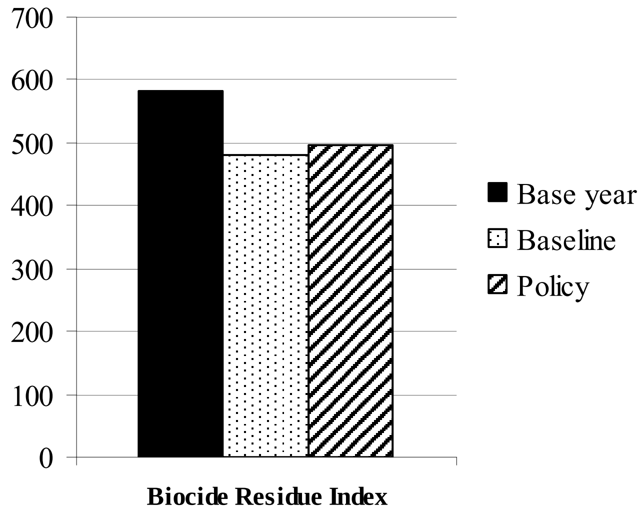

Figure 98. Bio residue index (-) for Changzhou farm type 1 in the base year, baseline and policy scenario

3.12 Model outcome of Zhenjiang Farm type 4

3.12.1 Stimulation of SSNM with training and education

In the base year the farm income without PMP term is 34786 Yuan (Figure 101). The off-farm income is 13065 Yuan, so the agriculture income is 73% of the total income. 73% of an availability of 625 Flabour days is 454 days. In case of running the model the PAD value is almost zero.

In the base year all land that is available for cultivation is used. In the baseline and policy scenario 2.24 ha is not used in the first period (Figure 99). In the base year 28% of the area is cultivated with SSNM and 72% with FF application, in the baseline and policy scenario the total area of crops is cultivated with FF application (Figure 100). There is no difference between the rotations chosen in the baseline and in the policy scenario (Figure 99). This leads to no difference in economic and environmental outputs for the baseline and the policy scenario (figure 101 until 107).

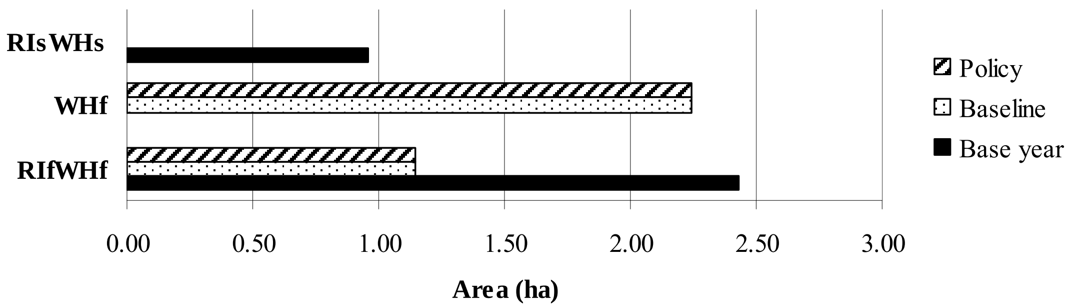

Figure 99. Rotations in the base year, baseline and policy scenario for Zhenjiang farm type 4

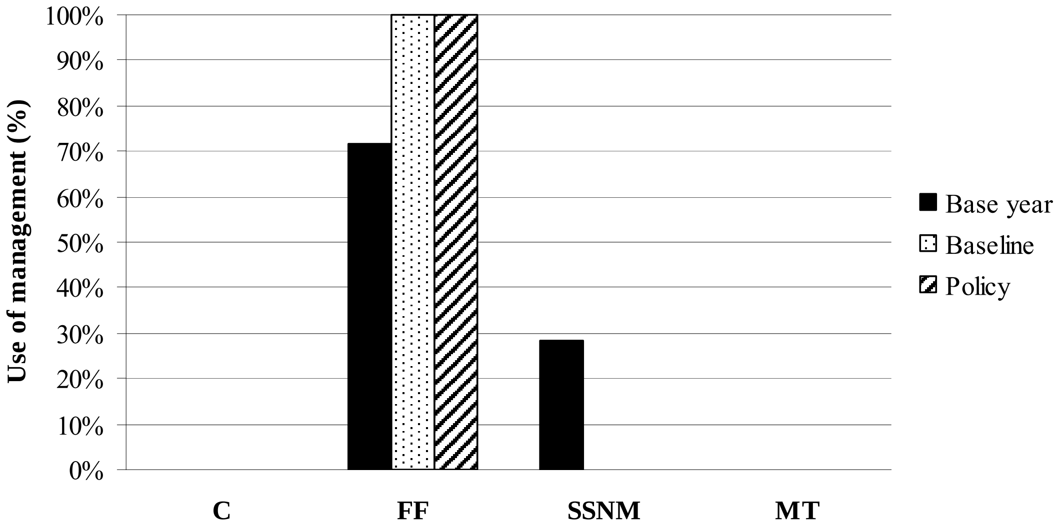

Figure 100. The use of different managements (%) in the base year, baseline and policy scenario for Zhenjiang farm type 4

The farm income decreases in 2015, because the gross production decreases more than the decrease of the total costs (Figure 101). In 2008 temporary labour is hired (209 days are hired), in case of subtracting the wage for the temporary labour from the farm income, then the farm income decreases even more from 2008 to 2015. If the costs of family and permanent labour are taken into account the farm income is still positive (Figure 101). This means that with working on-farm could be earned more than with working off-farm.

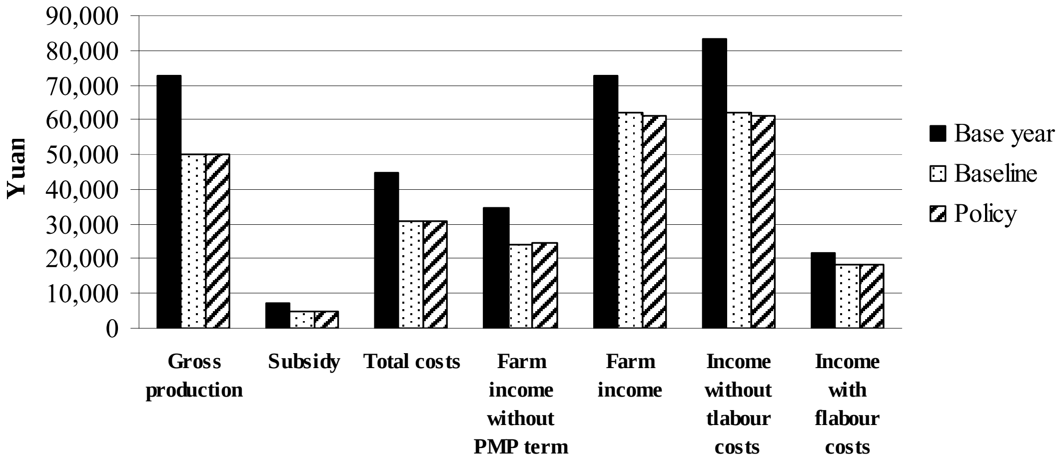

Figure 101. Economic results (Yuan) for Wuxi farm type 3 for the base year, the baseline and policy scenario. Farm income includes the PMP term and does therefore not directly reflect outputs-inputs. Farm income without PMP term does indicate what the farmers earn, i.e. gross production + subsidy – total costs. The income without the temporary labour costs, flabour is put on a lower value for the baseline and policy scenario so normally hiring labour is not needed. The income including family and permanent labour costs reflect the opportunity costs of agriculture; when negative labour costs are not covered and off-farm employment will be more attractive.

All environmental inputs and outputs are higher in 2008 compared to 2015 (Figure 102 until 107).

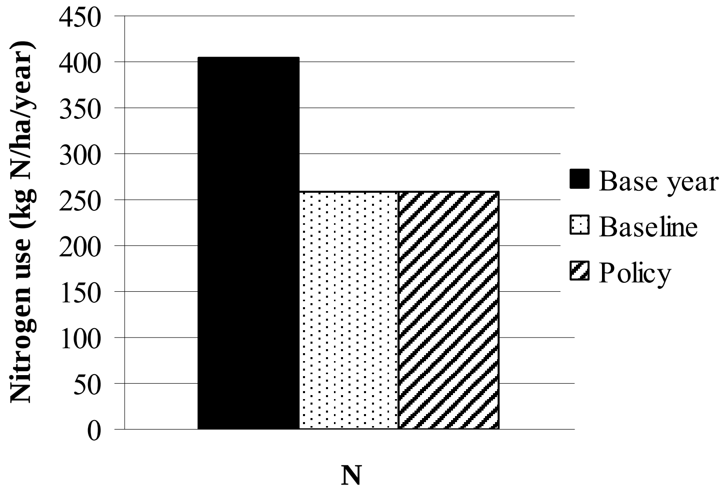

Figure 102. Nitrogen application (kg N/ha/year) in the base year, baseline and policy scenario for Zhenjiang farm type 4

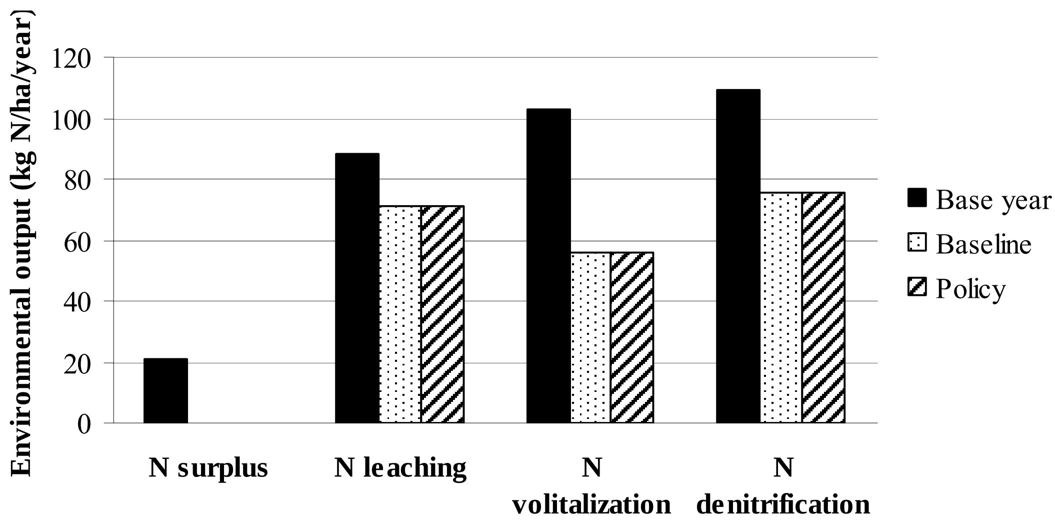

Figure 103. Environmental outputs of nitrogen (kg N/ha/year) for the base year, baseline and policy scenario for Zhenjiang farm type 4

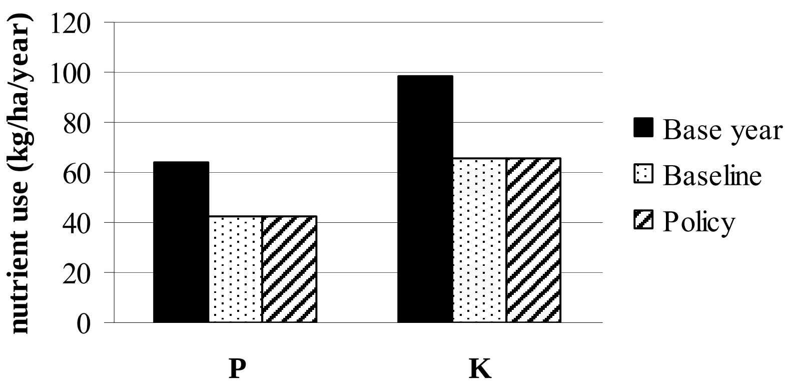

Figure 104. Phosphorus and potassium application (kg /ha/year) in the base year, baseline and policy scenario for Zhenjiang farm type 4

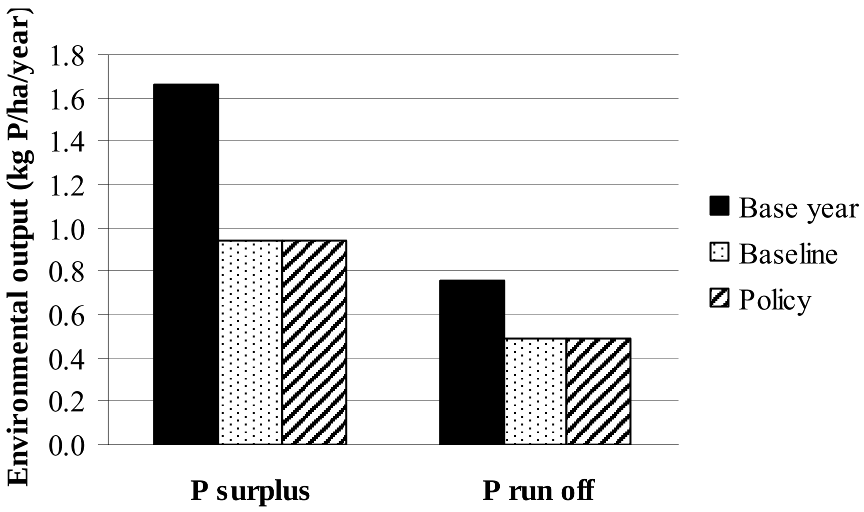

Figure 105. Environmental outputs of phosphorus (kg P/ha/year) for the base year, baseline and policy scenario for Zhenjiang farm type 4

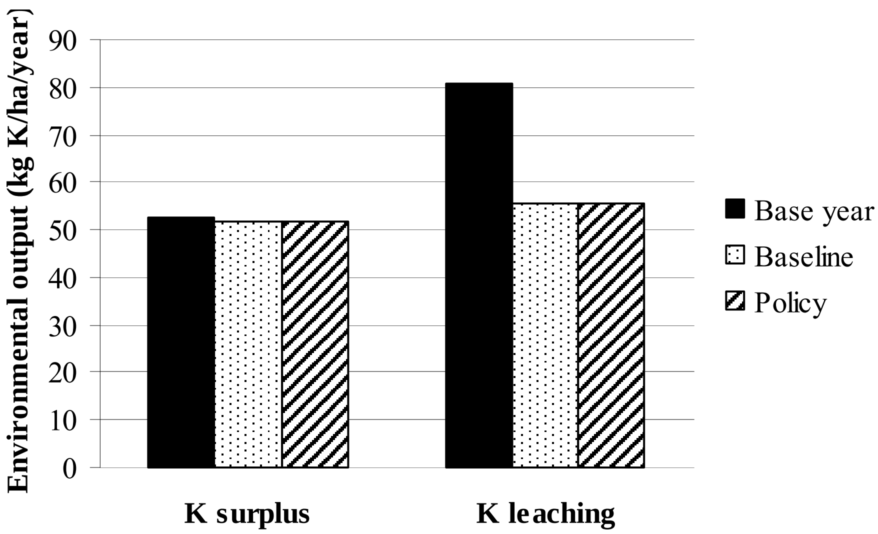

Figure 106. Environmental outputs of potassium (kg K/ha/year) for the base year, baseline and policy scenario for Zhenjiang farm type 4

Although the BRI is lower in 2015, the values are all still above the threshold value of 200 (Figure 107).

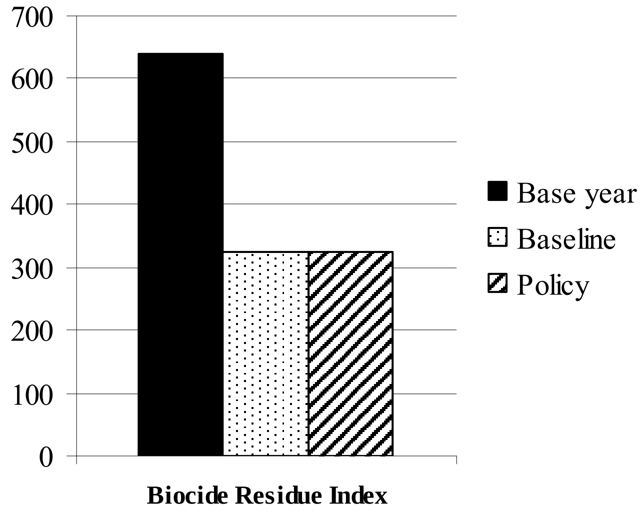

Figure 107. Bio residue index (-) for Zhenjiang farm type 4 in the base year, baseline and policy scenario

3.12.2 Stimulating the use of SSNM with training, education and with subsidy

Stimulating SSNM with not only training and education, but also with increasing the input subsidy for the use of SSNM leads to more use of SSNM in farm type 4, Zhenjiang (Figure 108). The environmental outputs are the lowest when the input subsidy is 1500 Yuan/ha for SSNM and for the other managements there is no input subsidy (Table 11).

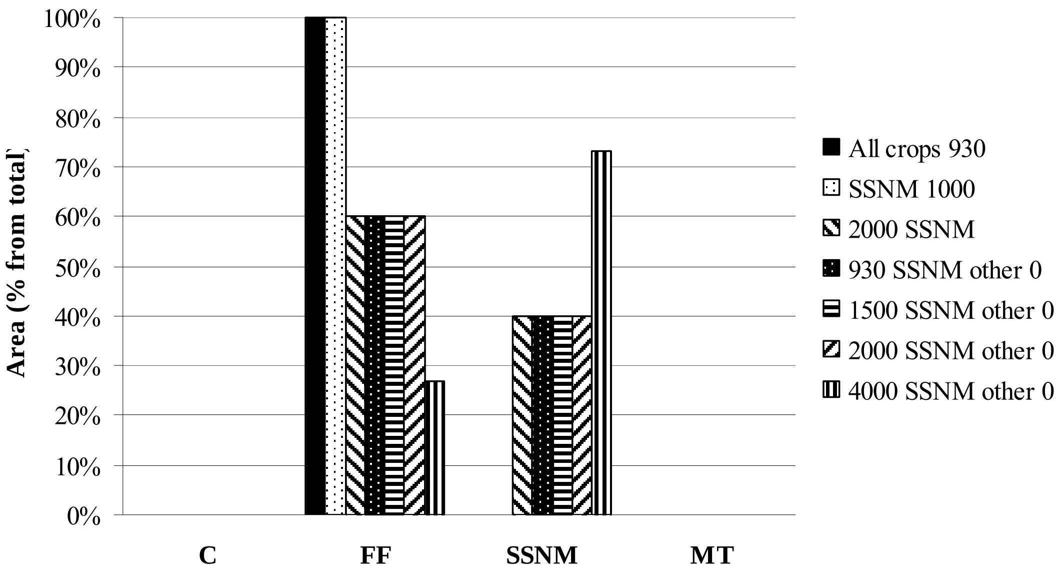

Figure 108. Percentage of use of different managements with different input subsidies with an elasticity of 1000 and a value of Flabour of 448. In the baseline an input subsidy of 930 Yuan/ha for all crops is assumed.

Table 11. Different environmental outputs and inputs for the policy scenario with different percentages of use of SSNM

Input subsidy for SSNM (Yuan/ha)	930	1500	4000	6000
Input subsidy for other crops (Yuan/ha)	930	0	0	0
Use of SSNM (%)	0	40	73	100

Environmental results				
Water use (mm)	1,233	2,103	3,582	4,059
N surplus (kg N/ha/year)	0.00	0.00	0.00	0.00
P surplus (kg P/ha/year)	0.94	0.00	0.00	0.00
K surplus (kg K/ha/year)	52	0.00	0.00	0.00
P Runoff (kg P/ha/year)	0.49	0.28	0.55	0.70
N leaching (kg N/ha/year)	71	28	43	46
K leaching (kg K/ha/year)	56	21	66	91
N volatilization (kg N/ha/year)	56	46	61	55
N denitrification (kg N/ha/year)	76	38	57	56
Biocide Residue Index (-)	326	336	578	641
Nitrogen application (kg N/ha/year)	260	158	286	345
Phosphorus application (kg P/ha/year)	42	27	54	74
Potassium application (kg K/ha/year)	66	51	84	112

3.12.3 Importance of wage

In the large farm type 4, labour is hired in the base year, and therefore the wages influence the decisions made. In 2015 the expected wage is 108 Yuan/day, decreasing the wage to 76 Yuan/day or lower will result in hiring labour (model elasticity is multiplied by 100 and the threshold value of family and permanent labour is 454) (Figure 109). In case temporary labour is for free, the use of it will be 412 days (Figure 109), so the maximum labour use will be 866 days in the baseline (compared to 834 days in the base year). With this value all land will be in use in every period for cropping (Figure 110).

If labour costs are low enough for hiring labour, the farmer will use less FF application and more SSNM (Figure 111). More rice is cultivated when the labour costs are low, the area of wheat stays the same (Figure 112).

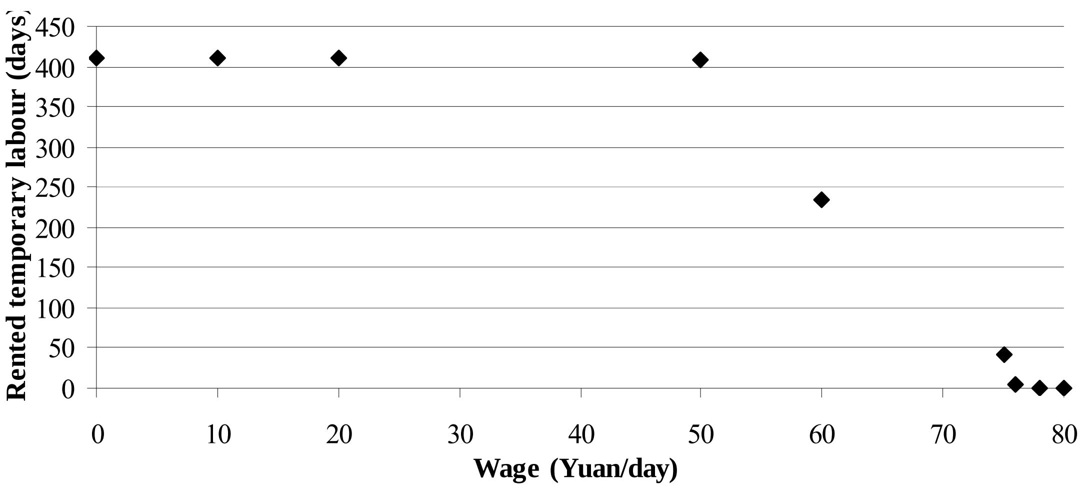

Figure 109. Rented temporary labour (days) for different wages for Zhenjiang farm type 4 in 2015. Expected wage in 2015 is 108 Yuan/day. (Elasticity of the crops is multiplied by 100 and the threshold value for family and permanent labour is 454 days)

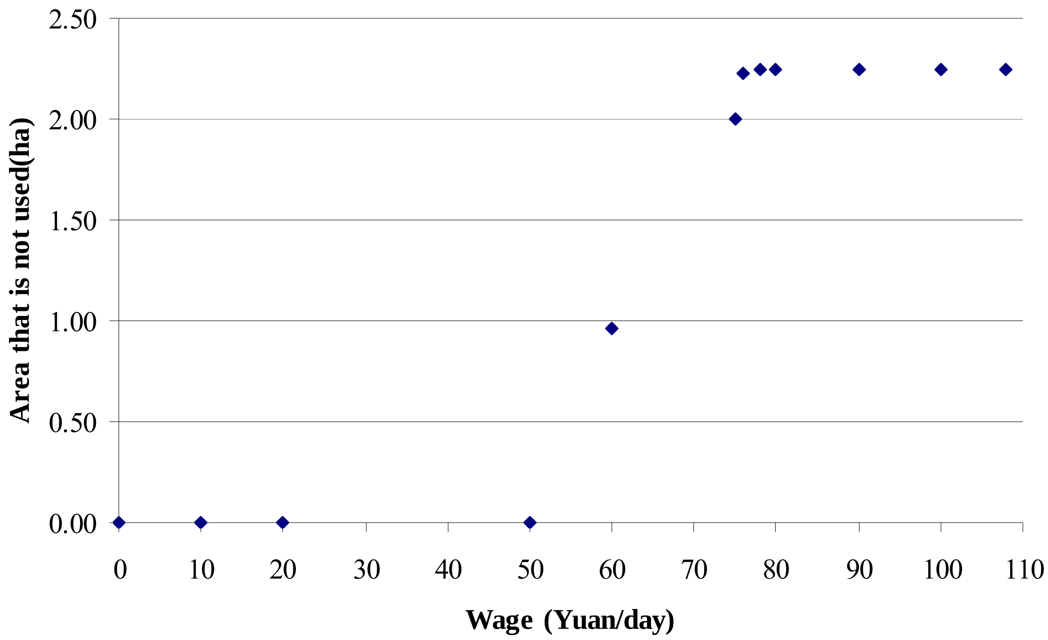

Figure 110. Not used area (ha) for different wages for Zhenjiang farm type 4 in 2015. Expected wage in 2015 is 108 Yuan/day. Not used area is the sum of the area that is not used in the first and in the second period. (Elasticity of the crops is multiplied by 100 and the threshold value for family and permanent labour is 454 days)

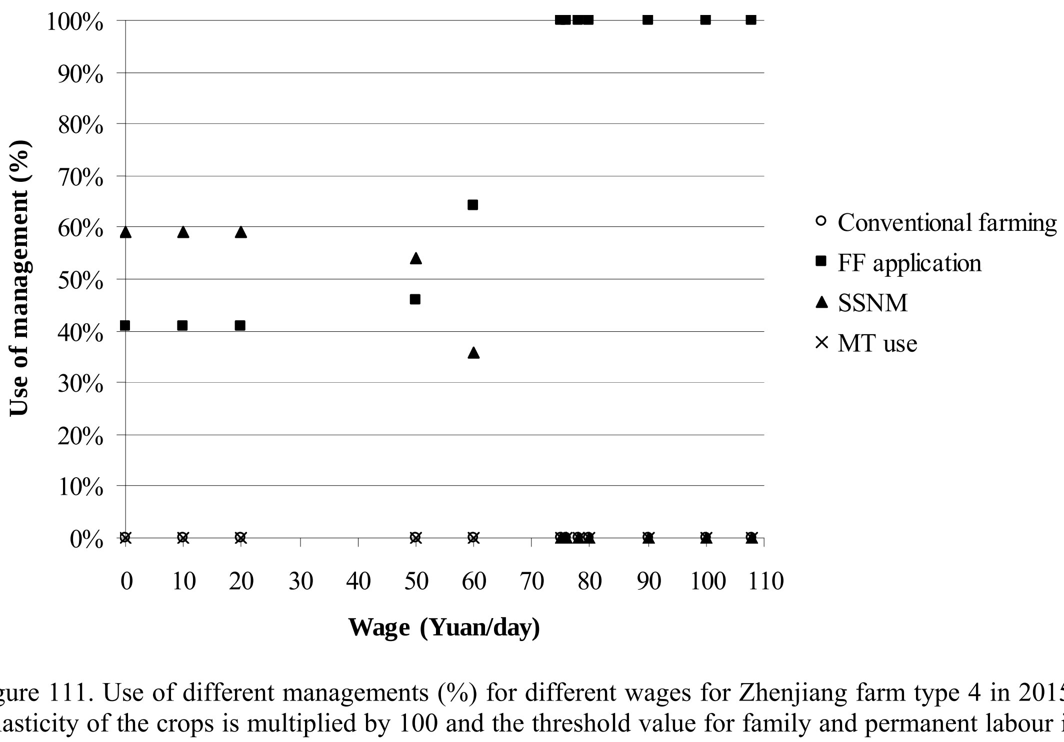

Figure 111. Use of different managements (%) for different wages for Zhenjiang farm type 4 in 2015. (Elasticity of the crops is multiplied by 100 and the threshold value for family and permanent labour is 454 days)

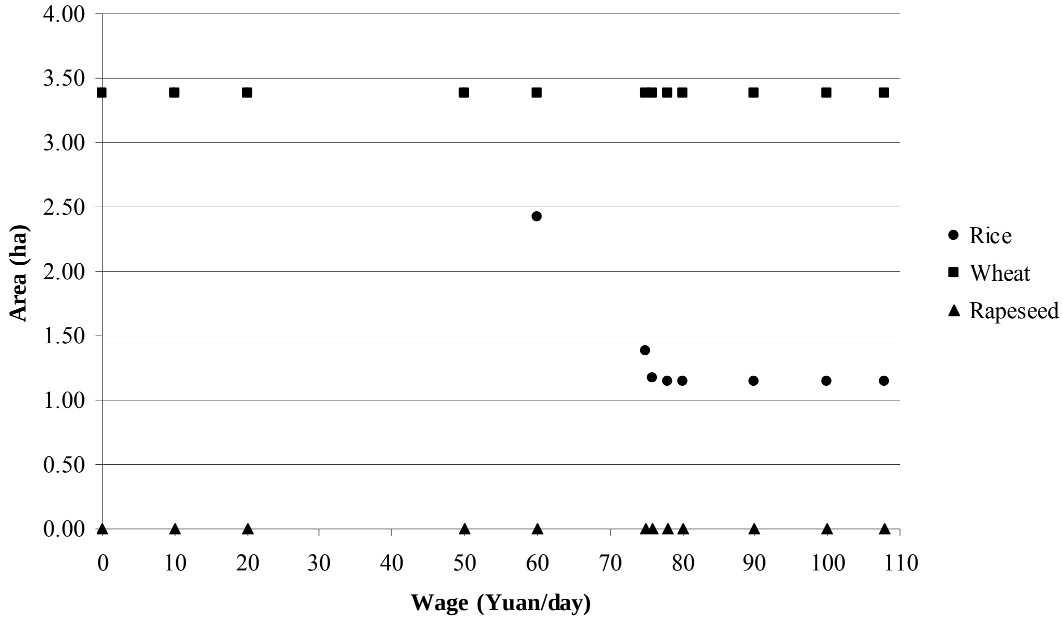

Figure 112. Area of different crops for different wages for Zhenjiang farm type 4 in 2015. (Elasticity of the crops is multiplied by 100 and the threshold value for family and permanent labour is 454 days)

3.12.4 Price change

As the influence of price changes may be different for a small farm type in Wuxi compared to a large farm type in Zhenjiang, also for this farm type a sensitivity analysis has been performed on price changes. The model is not so sensitive to price change of wheat, 20% reduction of expected the price of wheat (expected in 2015 is a price of wheat of 1.71 Yuan/ton) does not change the area of rice, wheat or rapeseed (Figure 113). 30% or more reduction of the price of wheat will change the area of rice and wheat. If the price of wheat is reduced to 10% of the expected price, then there will be no wheat cultivated anymore (Figure 113).

The model is also not sensitive to price change of rice. Until 30% increase of the expected price of rice (expected in 2015 is price of rice of 2.23 Yuan/ton) does not influence the area of rice, wheat and rapeseed much (Figure 114). Increasing the price of rice with 40% or more of the expected price of rice will lead to an area of rice of 1.39 ha and an area of wheat of 1.39 ha (Figure 114). With this price increase of rice of 40% the area of rice increases a bit while the area of wheat decreases sharply. Labour is the major limitation, rice needs more labour than wheat. Rice cultivation leads to a higher income per hectare due to the higher yields and a higher price. With a price which is 40% than the expected price of 2015 it is profitable enough to hire extra labour for the cultivation of rice. With a price which is 40% or higher there will be 246 days labour hired.

Rapeseed is not cultivated in the base year, therefore no rapeseed will be cultivated in the baseline due to the PMP procedure. So any change in the price of rapeseed will not influence the model results.

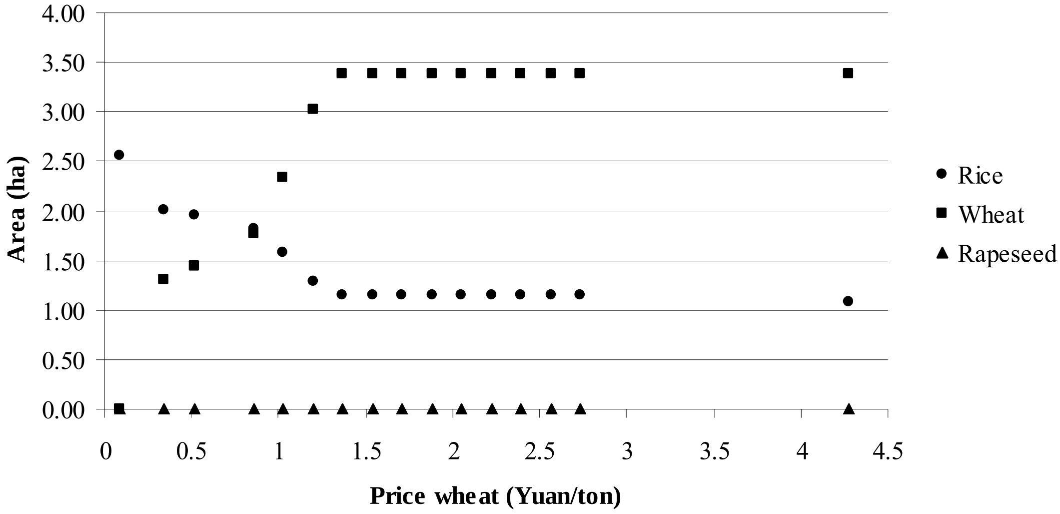

Figure 113. Influence on the area of rice, wheat and rapeseed when the price of wheat increases or decreases. The expected price of wheat in 2015 is 1.71 Yuan/ton.

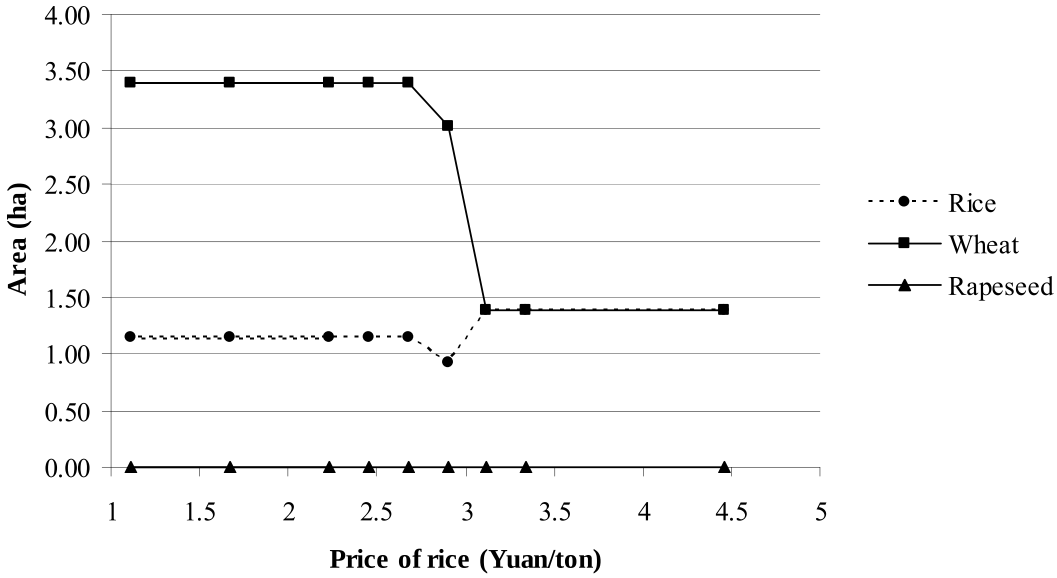

Figure 114. Influence on the area of rice, wheat and rapeseed when the price of rice increases or decreases. The expected price of rice in 2015 is 2.23 Yuan/ton.

3.13 Basic subsidy for buffer zone

Wuxi farm type 1 has 0.3% of the total area in the buffer zone, Wuxi farm type 2 has 1.8%, Wuxi farm type 3 11.6% and Wuxi farm type 4 has no area in the buffer zone. Changzhou farm type 1 5.7% of the total area in the buffer zone and Zhenjiang farm type 4 has no area in the buffer zone. So only a very small or no area of the total area is in the buffer zone, this means that the influence of the buffer zone on the farm income and on the environmental inputs and outputs at farm level is none or very low.

The basic subsidy for the buffer zone is in Wuxi 6750 Yuan/ha, in Changzhou 9000 Yuan/ha and in Zhenjiang it is 7500 Yuan/ha (Table 12). For Zhenjiang farm type 4 the compensation for the area in the buffer zone is quite low compared to what could be earned when none of the area is in the buffer zone (Table 12), the income what could be earned when all land is in the buffer zone is only 35% of the farm income in the base year. For Changzhou and Wuxi the compensation payment is also lower than what could be earned with cultivating crops, for Wuxi farm type 1 the compensation payment when all land is in the buffer zone is 78% of the farm income in the base year, for Wuxi farm type 2 the compensation payment is 74% of the farm income in the base year, for Wuxi farm type 3 it is 62% and for Wuxi farm type 4 it is 61% in the base year. For Changzhou farm type 1 the compensation payment is 76% of the farm income in the base year. In the baseline and policy scenario the compensation payment for the area in the buffer zone is only for the farm types were off-farm income is high (farm type 2 and 3), higher than what could be earned with cultivating crops. This is because those farm types do not work much on the farm and already do not use most of the land for cultivation of their crops. If not taken into account farm type 2 and 3, then the compensation payment for the buffer zone is too low if the same subsidy is given in 2015.

Table 12. Comparison of the farm income with the income when all land is in the buffer zone for all farm types that are modelled.

Municipality, farm type	Income when all land is in the buffer zone (Yuan/year)	Farm income base year from model outcome (Yuan/year)	Farm income baseline (Yuan/year)	Farm income policy scenario with SSNM stimulation (Yuan/year)
Wuxi, 1	2,153	2,761	2,679	2,962
Wuxi, 2	1,755	2,369	905	967
Wuxi, 3	1,688	2,725	903	890
Wuxi, 4	19,082	31,432	35,564	35,362
Changzhou, 1	2,718	3,569	3,487	3,581
Zhenjiang, 4	25,403	72,615	61,912	61,273

3.14 Sustainability indicators

Figure 115 and Figure 116 show the effect of three different policy measures on the sustainability indicators. The positive indicators are: crop production (tons/year), net farm income (PMP term included) (Yuan/year), input costs (Yuan/year), labour use efficiency (Yuan/day), rice production (tons/year), K:N ratio (-).

For positive indicators: $\frac{\text{value in policy scenario - value in the baseline}}{\text{value in the baseline}} \cdot 100\%$

The negative indicators are: Biocide Residue Index (-), N input (kg/ha/year), N leaching (kg/ha/year).

For negative indicators: $\frac{\text{value in policy scenario - value in the baseline}}{\text{value in the baseline}} \cdot -100\%$

So in the Figures 115 until 123 a positive area in the graph, means a positive change of the values of the policy scenario compared the baseline.

Stimulating the use of SSNM helps to reach the sustainable development targets (Figure 115). Only giving training and education already helps a lot to reach the targets, extra subsidy in combination with extra training and education is a bit better for sustainability than only giving training and education (Figure 115). It should be taken into account however, that although crop production increases compared to the baseline, the increasing labour costs have reduced crop areas compared to the base year. Less land is used mainly due to going from double to single cropping.

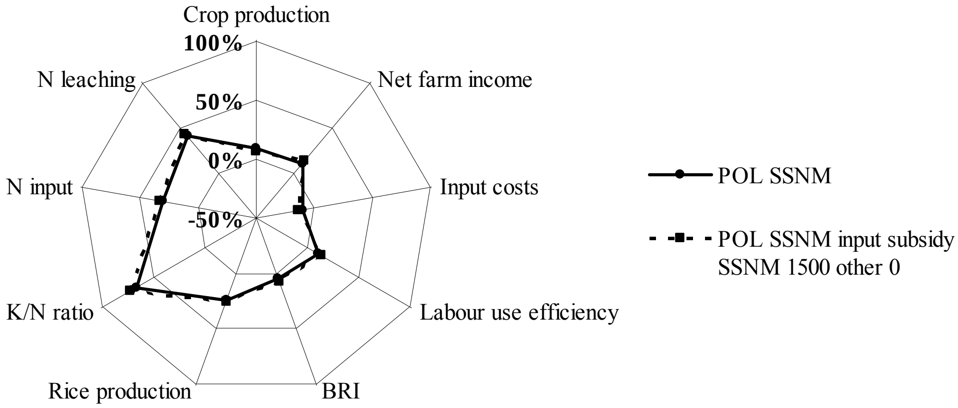

Figure 115. Wuxi farm type 1, policy scenarios with an elasticity multiplied by 1000 and Flabour availability is put on 40 days. Policy scenario of stimulating SSNM with only training and education and policy scenario with training and education and with input subsidy for using SSNM of 1500 Yuan/ha and no input subsidy for cultivation of other crops.

Although the stimulation of MT is a policy option, this does not help to reach the sustainable development targets (Figure 116). The stimulation of MT has a positive influence on all the economic indicators, on labour use efficiency of the social indicators, but a negative influence on the social indicators rice production and BRI and on all environmental indicators.

Scale enlargement has a positive influence on all indicators. The land area of the farm increases, only not all land will be used. The environmental outputs and inputs per hectare are therefore less.

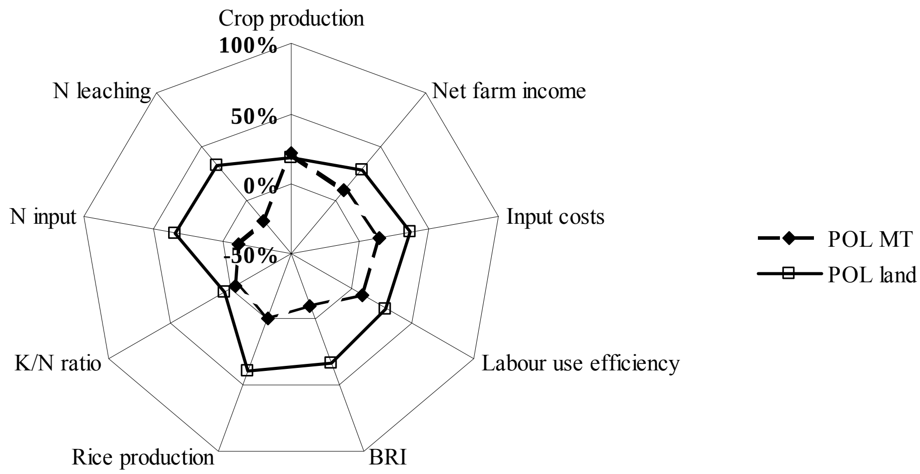

Figure 116. Wuxi farm type 1, policy scenarios with an elasticity multiplied by 1000 and Flabour availability is put on 40 days. For mechanical transplanting the rent is lowered until 1125 Yuan/ha. The scale enlargement policy scenario has enlarged the land two times and the input subsidy is increased by 500 Yuan/ha.

The stimulation of MT in combination with the stimulation of SSNM does not differ much from only stimulation of SSNM on sustainability indicators for Wuxi farm type 1. The crop production, rice production, labour use efficiency and the net farm income are a bit higher and the costs are a bit lower in the policy scenario with SSNM and MT stimulation compared to only SSNM stimulation. The BRI, N input and N leaching are a bit higher and the K:N ratio is a bit lower for the policy scenario with SSNM and MT stimulation compared to only SSNM stimulation (Figure 117).

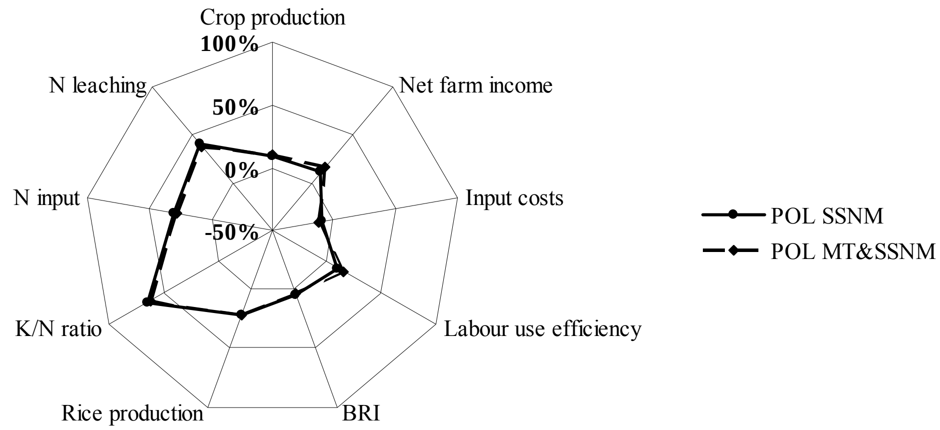

Figure 117. Wuxi farm type 1, policy scenarios with an elasticity multiplied by 1000 and Flabour availability is put on 40 days. Policy scenario of stimulating SSNM with training and education and policy scenario with stimulation of SSNM with training and education and the stimulation of MT by lowering the until 1125 Yuan/ha.

Stimulating the use of SSNM helps to reach the social and environmental sustainability indicators for Wuxi farm type 2 (Figure 118). For the economic sustainability indicators only the input costs have a negative influence (Figure 118). The input costs are defined as a positive indicator, so if the input costs increase this is positive for the sustainable development. It is a positive indicator, because the extra costs that a farmer makes stimulates the industry and services. In this case the input costs decrease in the policy scenario compared to the baseline, so this has a negative effect on the industry and services, but for the farmer it is positive.

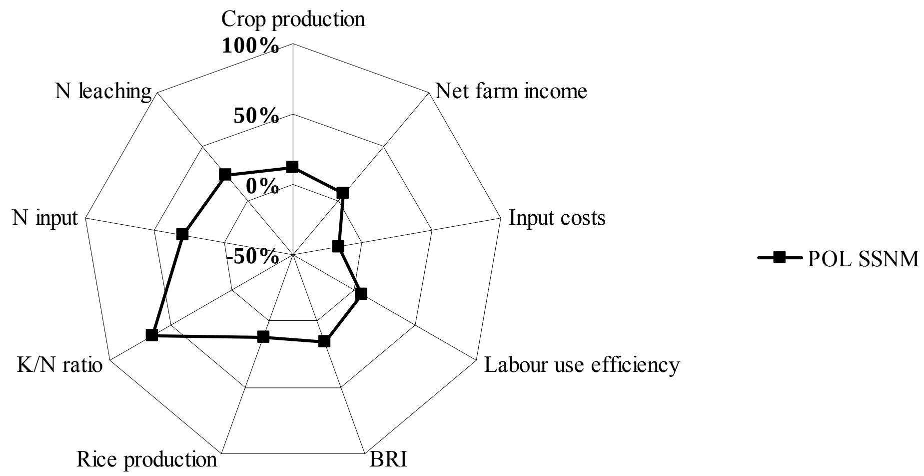

Figure 118. Wuxi farm type 2, policy scenarios with an elasticity multiplied by 1000 and Flabour availability is put on 10 days. Policy scenario of stimulating SSNM with training and education.

For Wuxi farm type 3 the stimulation of SSNM does not help to reach the sustainable indicators more than no stimulation of SSNM (Figure 119). For Wuxi farm type 3 the labour availability is lowered to a level of 5 days, SSNM costs more labour compared to other managements and is not implemented due to the low labour availability.

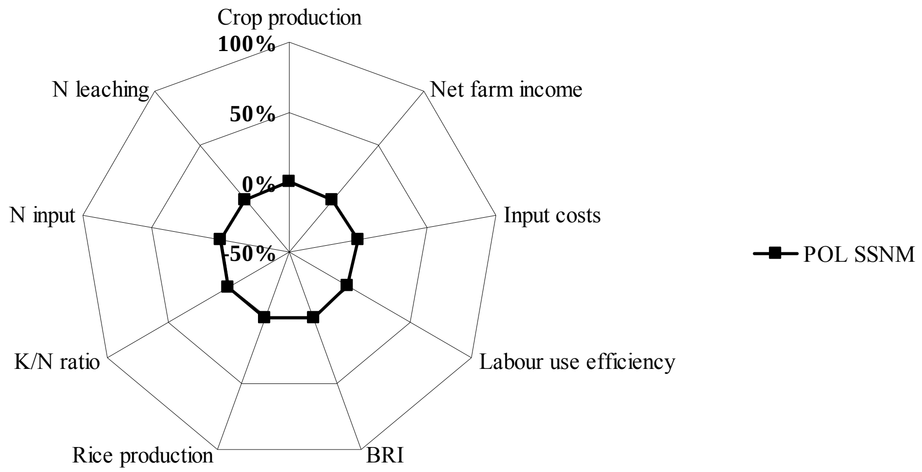

Figure 119. Wuxi farm type 3, policy scenarios with an elasticity multiplied by 1000 and Flabour availability is put on 5 days. Policy scenario of stimulating SSNM with training and education.

For Wuxi farm type 4 the stimulation of SSNM has a positive effect on the environmental indicators (Figure 120), not much effect on the economic indicators and has a negative effect on the BRI, but not much effect on the other social indicators.

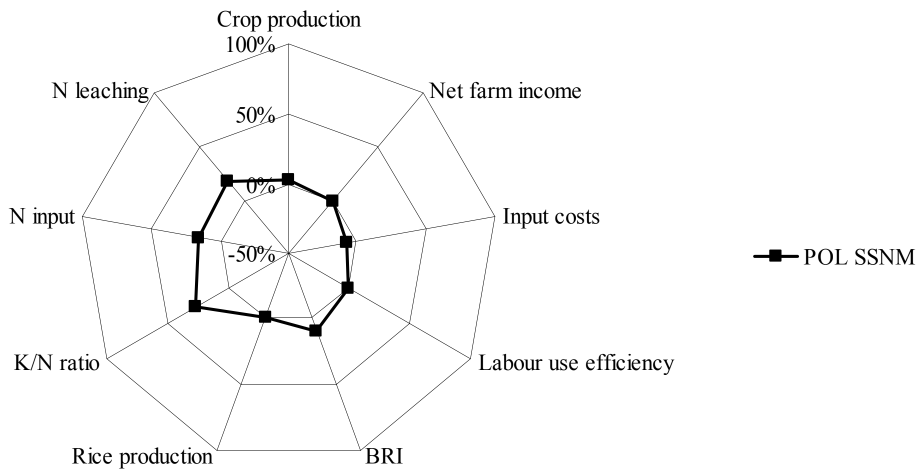

Figure 120. Wuxi farm type 4, policy scenarios with an elasticity multiplied by 1000 and Flabour availability is put on 310 days. Policy scenario of stimulating SSNM with training and education.

Assessing the sustainability at regional level for Wuxi, then can be concluded that stimulating SSNM by training and education helps to have all sustainable indicators positive (Figure 121). All environmental indicators are positive and the social indicators are almost all positive except rice production and labour use efficiency, they are slightly negative for some farm types. At the economic indicators the input costs are for all four farm types negative. This is negative for the industry and services, but this is positive for the farmers. For Wuxi farm type 3 and 4 the farm income in the policy scenario is slightly negative compared to the baseline, but for Wuxi farm type 1 and 2 the farm income is much higher in the policy scenario as in the baseline (Figure 121).

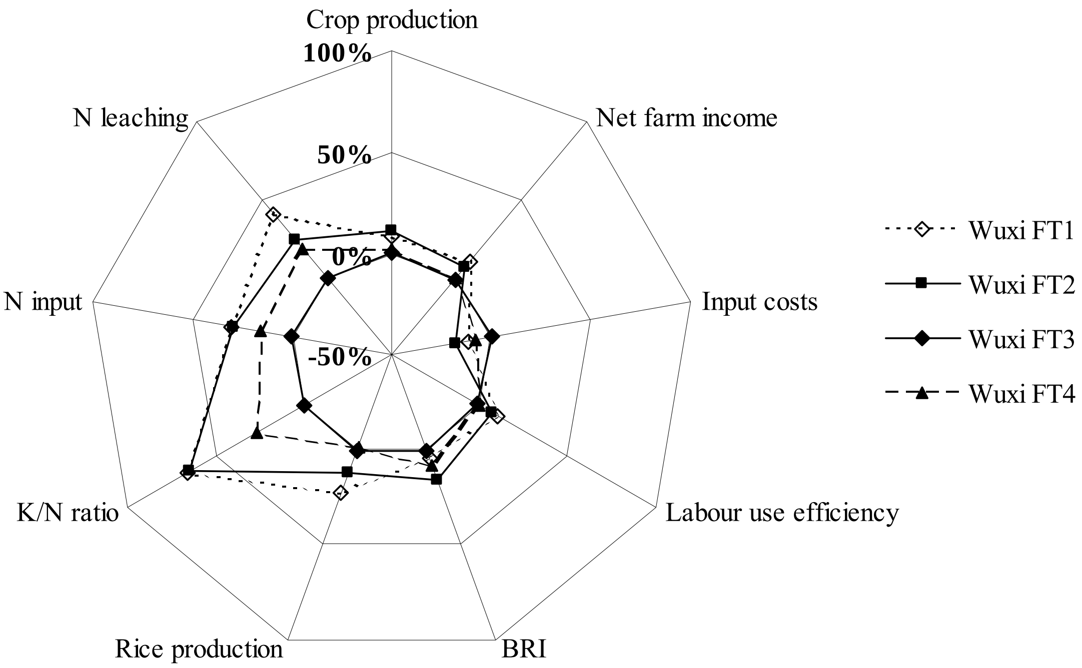

Figure 121 Policy scenario of SSNM stimulation by training and education for Wuxi farm type 1 until 4 (elasticity multiplied by 100; FLabour Wuxi farm type 1: 40, Wuxi farm type 2: 10, Wuxi farm type 3: 5, Wuxi farm type 4: 310)

For Changzhou farm type 1 the stimulation of SSNM by training and education has a positive effect on all environmental and economic sustainability indicators (Figure 122). From the social sustainability indicators is the BRI only not improved with the stimulation of SSNM (Figure 122). Changzhou farm type 1 with SSNM by training and education has a less positive effect on the sustainability indicators compared to Wuxi farm type 1 (Figure 122). Only the crop production indicator and the input cost indicator are higher compared to Wuxi farm type 1.

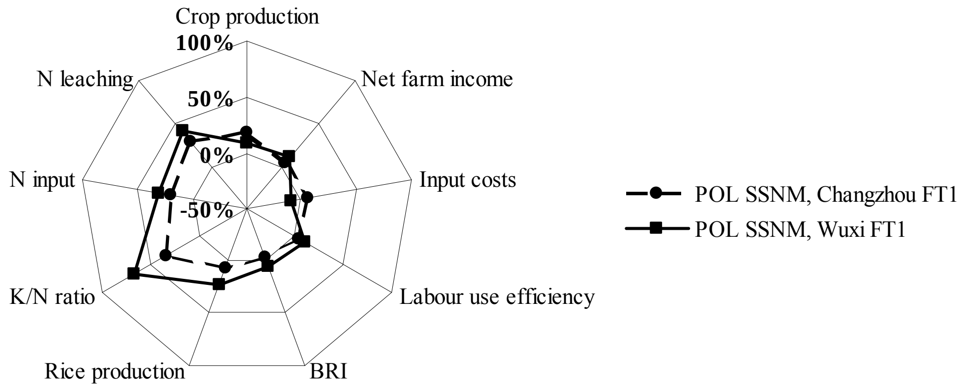

Figure 122. Changzhou farm type 1 compared with Wuxi farm type 1, policy scenarios with an elasticity multiplied by 1000 and Flabour availability is put on 49 days for Changzhou farm type 1 and on 40 days for Wuxi farm type 1. Policy scenario of stimulating SSNM with training and education.

For Zhenjiang farm type 4 the stimulation of SSNM by training and education has almost no effect on the sustainable development indicators (Figure 123). In case of giving an input subsidy of 1500 Yuan/ha for using SSNM and no subsidy for the other crops then there is a positive influence on the environmental indicators and a negative on the economic indicators. On the social indicators it has a positive effect on the rice production, a negative influence on the BRI and on the labour use efficiency (Figure 123). Wuxi farm type 4 with SSNM stimulation by training and education helps to reach more the sustainable indicators compared to Zhenjiang farm type 4 with only training and education (Figure 123).

In case of stimulating SSNM by training and education and by giving 1500 Yuan/ha input subsidy for SSNM and not for the other crops (for Zhenjiang farm type 4), the area of rice is in that case the doubled compared to the baseline and compared to only stimulating SSNM by training and education. The area of wheat is decreased to a very low level compared to the baseline and to the scenario of only stimulating SSNM by training and education. The total area of crops in case of stimulating SSNM by subsidy and training and education is almost half the level of stimulating SSNM with only training and education. These effects can be seen in Figure 123, the indicator rice production is 125% in case of giving subsidy and training and education and 0% in case of giving training and education. While the total level of crop production is -18% for stimulating SSNM with input subsidy and training and education it is 0% for only giving training and education.

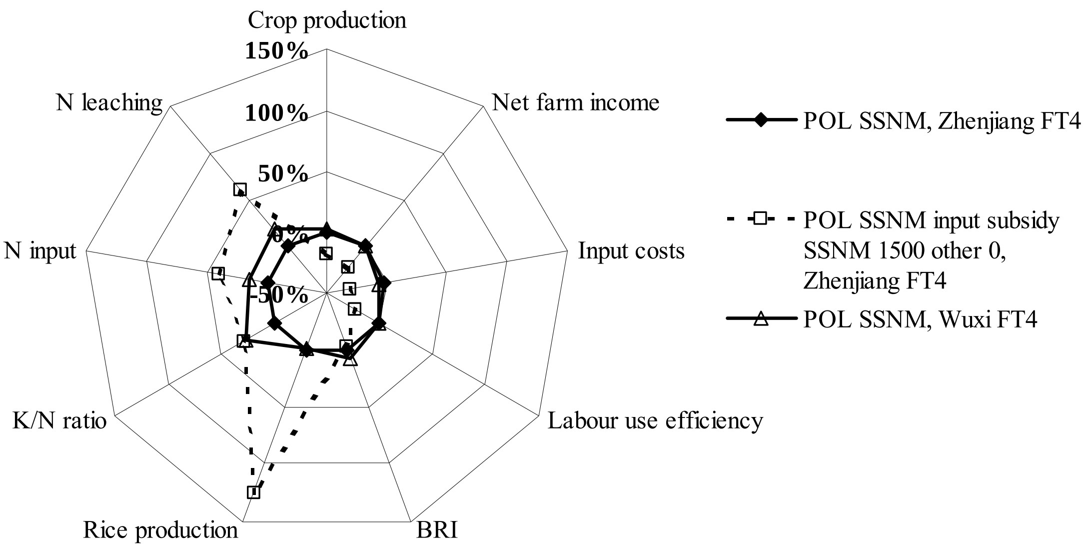

Figure 123. Zhenjiang farm type 4 and Wuxi farm type 4, policy scenarios with an elasticity multiplied by 1000 and Flabour availability is put on 454 days for Zhenjang farm type 4 and on 310 days for Wuxi farm type 4. Policy scenario of stimulating SSNM with only training and education and policy scenario with training and education and with input subsidy for using SSNM of 1500 Yuan/ha and no input subsidy for cultivation of other crops.

4. Discussion

4.1 Sensitivity of the model

The model is not very sensitive to changes in wage and prices of rice, wheat and rapeseed. For the small farm type tested, the wage should in 2015 be lowered to a level that is lower than the wage in 2008 before farmers will rent labour. For the large farm type tested the model was a bit more sensitive to changes in wage, the wage in 2015 should be lowered to 76 Yuan/day or less before the farmers will rent labour, while the expected wage in 2015 is 108 Yuan/day. So although in TechnoGIN wage and prices for 2015 were changed, this did not have much influence on the model outcome. The model is more sensitive to changes in alpha. Alpha is a vector that determines the weights of linear and non-linear costs of the activities in the objective function. The larger the value of alpha, the less sensitive the model is to price changes. In FSSIM-EU (Farm System SIMulator) alpha is not calculated by taking the revenues and the price elasticities of the crops like in FSSIM-China, alpha is in FSSIM-EU a fixed value. Alpha has a large influence on the cropping pattern. It seems to be better to calculate and simulate the needed value for alpha for the model instead of taking a fixed value, for getting reliable results of the model. In this thesis alpha is calculated based on the elasticity. To give a value for the elasticity, expectations of the model outcome have been set for the baseline situation (2015) and the elasticity is changed until the model outcome is closest to what is expected.

4.2 Stimulation SSNM

The stimulation of SSNM (Site Specific Nutrient Management) by training and education could help to improve the water quality of the Taihu Lake while still being social, economic and environmental sustainable. The stimulation of SSNM has a positive effect on most indicators for all farm types. Alhtough it should be taken into account that the results at farm level often seem more positive for the environment, as the model simulates changes from double to single cropping due to labour limitation. The SSNM concept has a promising agronomic and economic potential (Dobberman et al., 2002) and there is a potential for large scale dissemination (Hu et al., 2007). Whether SSNM will work, depends on the willingness of farmers to follow the planned scheme. According to other experiments that were done, not all farmers are prepared to follow the planned scheme of fertilizer management, this was due to conflicting working scheduels for off-farm jobs (Hu et al., 2007). Therefore the use of SSNM is in some cases a bit lower than was expected. Not only the willingness of farmers to follow the planned scheme will be necessary for implementation of SSNM, also the amount of training and education the farmers get is of importance. The amount of training and education is in this model represented as the change in price elasticity of the supply level of the activities. The price elasticity of rice, wheat and rapeseed is know, but the elasticity of crops in combination with management is unknown. For the baseline an elasticity is chosen which is 100 times more than the elasticity of rice, wheat and rapeseed. The elasticity of the crops in combination with management is much higher than the elasticity of the crops. Farmers change their cropping pattern almost never (interview farmers, May 2010), but change the management more often. For the policy scenario the elasticity of rice, wheat and rapeseed is multiplied by 1,000. In case of an elasticity which is multiplied by 100 in the policy scenario, then the use of SSNM is much lower compared to an elasticity which is multiplied by 1,000. So with the conventional elasticity SSNM is not much adopted. The high elasticity reflects that it is not easy to stimulate the use of SSNM.

In case of not stimulating SSNM by training and education, then most of the farmers will use FF (Formula Fertilizer) application or will still use the conventional fertilizer management.

Extra stimulation of SSNM by giving subsidies to the farmers for using SSNM helps to reach the sustainable indicator targets even more. Only subsidy does not help so much to stimulate the use of SSNM. So with more subsidy in combination with training and education the farmers are more prepared to use SSNM. The only pitfall of high subsidies is that farmers only use SSNM for the subsidy while not using SSNM correctly. An example of a failure of high subsidies in China is the stimulation of biogas digesters. In the 1970s a lot of farmers in China built a biogas digester, because of to the high subsidies. Only the utilization of the biogas digester was low (Foley, 1992).

A combination of SSNM stimulation by training and education and MT stimulation by giving subsidy to the farmers for renting the MT machine does not lead to more improvement of the sustainability indicators compared to only stimulating SSNM with training and education. The use of MT increases a bit, but the use of SSNM decreases a bit.

4.2.1 Biocide Residue Index

Although in all cases the BRI decreases in case of stimulating SSNM, the use of biocides is still too high. Almost all farm types still have a BRI that is above the threshold value of 200. This is due to that there is almost no difference between the managements in biocide use in the model. The use of mechanical transplanting machine has a very small reduction of the use of biocides. There is only a difference between the crops in biocide use, for rice the most biocides is used, then for wheat and for rapeseed the least biocides are used. The farm types that have a BRI below 200 do not cultivate crops on most of the area that they have.

So the use of biocides can only be reduced in the model by changing the cropping pattern or by cultivating fewer crops. To reduce the use of biocides there should also be another policy option that is there for the reduction of the use of biocides. A way to simulate this is to create a scenario in the technology sheet of TechnoGIN that stimulates the decrease of use of biocides. For example the policy levels G, H and I could be exactly the same as baseline levels D, E and F only then the biocide use could be in level I 0.9 times the use in the base year. In this example only level I has a reduction in use of biocides, because level I is with the crops with a SSNM, SSNM users have better insights in the use of biocides compared to other farmers. Further reductions should be possible, but data in literature should be collected to see what is feasible.

The use of biocides is so high in China, due to misperception and overestimations of damages to crops. Also farmers resort to use more biocides due to the high labour costs (Heong et al., 1995). For farmers who cultivate vegetables the use of alternatives of biocides is already stimulated in the Taihu lake basin. Nets and lights are being subsidized to get the farmers use less insecticide. Next to the subsidy stimulation of the lights and nets is also by letters with instructions about the use and benefits of the lights and nets (field survey, May 2010).

4.2.2 K:N ratio

The Chinese agriculture is now characterized by high levels of fertilizer use, but with highly unbalanced N:P:K ratio. The area of K-deficient soils is expanding more and more (Chao et al., 2006). When the supply of K is small in relation to P and N, the whole supply of K will be taken up by the crop. The supply of N is large compared to the other nutrients, crop growth will therefore be limited by the low availability of K and the crop cannot make use of the whole supply of N (Janssen et al., 1990).

The stimulation of SSNM has as effect that the K:N ratio increases. This means that there will be more input of fertilizer K compared to the input of N. So stimulating the use of SSNM leads to increased use of potassium fertilizer. China is very short in mineral potassium resources. The difference between potassium demand and its limited supply capacity (Chao et al., 2006) will therefore increase even more if SSNM is stimulated.

4.2.3 Nitrogen

There is a significant correlation between total nitrogen concentration and flow discharge load (Gao et al., 2004), so the reduction of nitrogen input helps to reduce the flow of nitrogen into the Taihu lake. Stimulating the use of SSNM helps to reduce the leaching of nitrogen.

According to Hu et al. (2007) the use of SSNM saves 30% of the fertilizer N use and a higher or comparable yield is obtained. SSNM is simulated in TechnoGIN as an activity which has always a higher yield and lower inputs compared to FF and conventional fertilizer management. QUEFTS calculates for SSNM the needed nutrient inputs for a specific target yield. This means that for the SSNM always the most optimal fertilizer application is used, while for FF and conventional fertilizer management this is not the case. The output from FSSIM when stimulating the use of SSNM leads to a reduced fertilizer N use within a range of 0% (Wuxi farm type 3 and Changzhou farm type 1) until 30% (Wuxi farm type 1 and 2) compared to no stimulation of SSNM, yield is also higher or comparable. When comparing the model results for the stimulation of SSNM with Hu et al. (2007), then can be concluded that in some cases stimulating SSNM helps to increase the use of SSNM while in other not.

4.2.4 Phosphorus run-off

Phosphorus is the limiting factor for eutrofication, because most algae can utilize atmospheric nitrogen (Cao et al., 2004). So controlling phosphorus helps to minimize eutrofication of the Taihu lake. The stimulation of SSNM helps to reduce the amount of phosphorus run-off events and could therefore help to minimize the eutrofication in the Taihu lake.

QUEFTS (Quantitative Evaluation of the Fertility of Tropical Soils) is used in TechnoGIN to calculate the fertilizer application for crops with SSNM. QUEFTS calculates the needed nutrient inputs for the target yield (Janssen et al., 1990). So when FSSIM selects crop with SSNM the nutrient input will always be optimal and therefore not lead to run-off.

4.3 Stimulation of mechanical transplanting of rice

The use of MT is stimulated by giving subsidy for renting the machine. In case of higher subsidy more farmers are prepared to use the MT machine. The environmental and social sustainability indicators are decreasing with more stimulation of MT and the economic indicators are increasing. Although stimulating the use of MT does not help to reach the sustainability indicators, it is still quite important for the farm households. In farm households most young male farmers are leaving the farm to work off-farm (Choa, 2006). This leads to labour shortage at peak periods like transplanting of rice (Zeigler et al., 1995).

4.4 Scale enlargement

More and more farmers are migrating to urban areas and they rent their land to those farmers who are staying behind (Van den Berg et al., 2007). So on the long term farms are getting larger. The policy scenario of scale enlargement for Wuxi farm type 1 has a positive influence on all sustainability indicators. While extra land is provided to the farmers, most of the extra land is not used, therefore the environmental sustainability indicators are positive. The extra land that is provided is not used due to the low family and permanent labour available on the farm. If labour is not limited for Wuxi farm type 4, then the environmental inputs and outputs are much higher per hectare compared to the baseline. With more labour available more double cropping is used instead of single cropping compared to when labour is limited. Wuxi farm type 4 could also be seen as scale enlargement of Wuxi farm type 1, only then with more labour available.

Wuxi farm type 4 has in the baseline higher environmental outputs and a higher income than Wuxi farm type 1 with scale enlargement and limited labour available. For both Wuxi farm type 1 with scale enlargement and for Wuxi farm type 4 the money earned by working on-farm is higher than for working off-farm.

According to Van den Berg et al. (2007) mechanisation is necessary to increase in farm size. This was also observed in this thesis, as farm type 4 in Wuxi uses 100% MT, and also scale enlargement for farm type 1 results in high MT use. Labour limitation maybe too high, but reflects the problem. A high use of MT machine is observed from FSSIM for Wuxi farm type 4 and for Wuxi farm type 1 with scale enlargement.

Although farmers are saying they want to save labour for working off-farm (interviews farmers May 2010) not in all cases the income what could be on average earned with working off-farm is higher than when working on-farm. For Wuxi farm type 4 and Zhenjiang farm type 4 the income with Flabour taken into account is positive. So for the larger farms, belonging to farm type 4, the income with working on-farm is higher than with working off-farm.

4.5 Subsidies

4.5.1 Input and basic subsidies

The current height of the input and basic subsidies look acceptable. The subsidy is in the base year on average 20% of the total farm income, in the baseline the subsidy share of income is on average 16%. The avarage availabe family and permanent labour days is 261, one person works 250 days a year. So the farm income for a household is based on the work for 1 person. According to Gale et al. (2005) the subsidy in China is on average 1-2% of the average farm household income per person. Due to difference in subsidies per municipality and per year, the average subsidy share of income could be higher for Wuxi, Changzhou and Zhenjiang compared to the country average.

Although the current height of the input and basic subsidies looks acceptable, it should be taken into account that in the future the wages for off-farm income are increasing and therefore cultivation of crops seems to be less attractive. Farmers are cultivating in 2008 mostly rotations while in 2015 only one crop is cultivated in one year. Meanwhile the food production should still be on a high level to meet the demand (Lin, 2006). Therefore it could be necessary to increase the subsidies for the cultivation of crop. The stimulation of SSNM seems to be quite difficult due to the high amount of training and education that is needed and the conflicting working scheduels for off-farm jobs. So for keeping up the high food demand and the cultivation of crops still being environmental friendly, the government should increase the subsidies for the use of SSNM.

4.5.2 Compensation payment for buffer zone

The compensation payment for the buffer zone is too low compared to what could be earned with cultivation of crops for all farm types tested. To get a better compensation for the area that cannot be used for cropping, the payment should be around 10,000 Yuan/ha in Wuxi instead of 6,750 Yuan/ha. For Changzhou the payment should be around 12,000 Yuan/ha instead of 9,000 Yuan/ha and for Zhenjiang the payment should be around 20,000 Yuan/ha instead of 7,500 Yuan/ha. Only the influence of the compensation payment is not large, because the area in the buffer zone is very small in all farm types. In the future the area in the buffer zone probably will increase from 200m until 1 km area of buffer zone from the river. Only most farms in the field survey are not near the river, so the increased buffer zone will not influence the area in the buffer zone much for the farm types that were selected.

On farm level the impact of the buffer zones is low, due to the very small areas per farm in the buffer zone. On regional level the impact of the buffer zone is larger. Buffer zones reduce the nutrient leaching to the surface water (Klok et al., 2002) and are therefore a good potential for a sustainable agriculture if payment to farmers would be increased.

4.6 Limitations and suggestions

4.6.1 Exact reproduction of the base year scenario

FSSIM is used to exactly reproduce the base year activity levels; there should not be a gap between the observed data and the simulated results. The PMP modeling procedure is there to reduce the gap between the observed data and the simulated results of the model (Kanellopoulos et al, 2010). In the results of FSSIM-China the model does not exactly reproduce the base year activities for all farm types in the municipality, because the PAD (Percentage Absolute Deviation) is not zero for all farm types that were tested. The PAD value the deviation between the simulated activity levels and the observed activity level per unit of actual activity level. For Wuxi farm type 1 there is a PAD value of 4.0%, for Wuxi farm type 2 the PAD value is 2.88%, for Wuxi farm type 3 it is 1.121%, for Wuxi farm type 4 it is 0.2%, for Changzhou farm type 1 it is 7.9% and for Zhenjiang farm type 4 the PAD value is almost zero.

Not all farm types have an upper calibration constraint which is binding. This is due to the total land constraint, more land is available for the base year than is used for the observed activity levels. So for some soil types not all land is needed to be used to get the observed activity levels and therefore the upper calibration constraint is not binding. In case of running the model the outcome will be, that more land will be used than observed, due to the non binding upper calibration constraint. In the observed situation not all land is used, due to inability of the use of some soils. The inability of growing rice on upland soils is already taken into account. So another factor then the inability of rice to grow on upland soil should play a role why not all land is used for farming which should be taken into account in the model. A factor which could be improved in the model to solve get the observed activity levels closer to the model outcome is to calibrate on basis of rotations instead of crops.

4.6.2 Comparison of the expected values with the model outcome

Expected use of FF, SSNM and MT is different from the model outcome. Expected was that for all municipalities the use of FF was around 71%, the use of SSNM 28% and conventional fertilizer application around 1%. For MT use was expected in Wuxi and Changzhou to be 100% and in Zhenjiang 60%, these expectations were based on logistic curves which were parameterized by the observed data from 2004 until 2008.

In the baseline, only in Wuxi farm type 2 and Changzhou farm type 1 the area of SSNM increases slightly, in all other farm types tested the area of SSNM decreases in the baseline compared to the base year. SSNM costs more labour and the gain of the extra yield is lower compared to the extra costs for labour that are needed. FF application decreases in Wuxi farm type 3 and 4, in all other scenarios the use of FF increases. Only the increase is not as high as expected. The elasticity and the labour availability are already changed to get closer to what is expected. The expectations are probably set to high, because the extra gain from SSNM and FF compared to conventional fertilizer management is lower than expected due to the high labour costs.

Wuxi farm type 3 and Zhenjiang farm type 4 did not use MT machine in 2008, therefore the model will not select rice with MT in 2015. Due to the PMP procedure the model will not select activities which are not present in the observed activity level. In the future it could be possible that the farmers use the MT machine, the village could buy the machine and the farmers could rent the machine then from the extension services. Farmers are very willing to use MT machine (interview farmers May 2010), because saving labour is very important for them.

Although expected was that the ratio of the area of rice, wheat and rapeseed will stay the same, the model outcome is different. In 2015 for all farm types modeled, there will be no rapeseed anymore. This is due to the high labour need and the lower returns. The area of wheat will decrease for Wuxi farm type 1 and 2 and for Changzhou farm type 1. In FSSIM the managements are coupled to the crops. The elasticity of the managements is higher than the elasticity of the crops. The elasticity of rice is 0.208, for wheat 0.167 and for rapeseed 0.326. While the elasticity of the crops in combination with their management is in the baseline 100 times more and in the policy scenario 1000 times more. In the model the elasticity is increased to get the expected model outcome for the changes in managements. So due to the increase in elasticity the cropping pattern will also change, while this is not expected.

Although it was not expected that the area of wheat and rapeseed will decrease, it seems very logical that it will happen. The income of farmers is already very low; the farm income should be in 2015 above the threshold value of 15,000 Yuan (Yu'an District Agricultural Extension Station, 2008). For most of the simulated farm types the farm income is not above that threshold value. Only for the large farm types (farm type 4) the farm income is above the threshold value. Therefore it is logically that farmers have to choose for the most profitable activities, otherwise they have to live below the poverty boundary.

In case of letting the model not changing the ratio of the area of rice, wheat and rapeseed much, this could be done by adding a constraint for a minimum area of rice, wheat and rapeseed. Another solution is to use an extended version of the PMP approach. The standard PMP approach which is used for FSSIM-China estimates the production function for each land use activity separately. The same crop grown under two technologies is therefore treated if it were two separate crops. In the extended version of PMP a crop with two different technologies is simulated by a total crop activity which is the sum of these variant activities. Substitution between rather similar crops is now better possible (Röhm and Dabbert, 2003). A final solution is to increase the subsidy for cultivation of wheat and rapeseed. The Chinese government wants self sufficiency in agriculture and long term food security. Therefore the Chinese government gives subsidies to stimulate food production (Lin, 2006).

4.6.3 The use of model chain TechnoGIN-FSSIM

TechnoGIN has been used to serve as a database file for the agricultural inputs and outputs for FSSIM. The use of TechnoGIN as a database file for FSSIM did work good. A couple of changes were needed to couple TechnoGIN to FSSIM. In TechnoGIN the several policy scenarios were simulated by changing values in the technology sheet. This was an easy way to simulate the scenarios. Overall the model chain TechnoGIN-FSSIM has proven to be a useful tool for ex-ante assess of agricultural policies at farm level in Taihu Basin. Constraints for the adaptation of technologies, and impacts on environmental, economic and social indicators are evaluated, allowing to better target policies.

5. Conclusion

This thesis analysed the impacts of different policy measures on agricultural sustainability in Taihu lake basin. For this analysis the bio-economic farm model FSSIM was used, in order to assess the impacts of the policies. As input database for FSSIM TechnoGIN was used, which quantifies the input-output relationships of different agricultural activities.

Four policy options were used to assess the effect on the sustainability. The stimulation of formula fertilizer (FF) is the first policy option and is already implemented in the base year (2008). The second policy option is the stimulation of SSNM (Site Specific Nutrient Management). SSNM has more potential to reduce the environmental pollution and therefore SSNM is extra stimulated in the policy scenario and FF not. The third policy option is the stimulation of the use of mechanical transplanting (MT) machine. The fourth policy option is the use of buffer zones. In the base year, baseline and policy scenario is the effect of the policy options analysed, while in the policy scenario also the influence of scale enlargement was analysed.

The first policy option is FF application. In most cases the percentage use of FF application will be higher in the baseline (2015) as in the base year (2008). In case of stimulating the use of SSNM by training and education in the policy scenario, then the use of FF application according will decrease and the use of SSNM will increase.

The stimulation of SSNM was the second policy measure. It was stimulated by training and education and it did help to reduce non-point source pollution from agriculture and therefore improves the water quality of the Taihu lake. With stimulation of SSNM, the leaching of N to the lake decreases and the run-off of P declined. The K:N ratio also improves when SSNM is stimulated, the input of N decreases and the input of K increases. The stimulation of SSNM is not only good for the environmental sustainability, but also for the social and economic sustainability. The yield increases and also the farm income. Only the BRI is in most cases still too high to be permissible. It is only difficult to stimulate the use of SSNM, due to the need for training and education of the farmers while labour is limited. To stimulate the use of SSNM more, extra subsidy has proven to be a good option by FSSIM, although extra subsidy does in practice not necessary have to lead to better management. So for the reduction of water pollution the stimulation of SSNM by training and education is a good option. For getting an even better water quality the government has to give more training and education to the farmers about reduction of biocide use. Due to no available data for SSNM, the fertilizer application of crops with SSNM was calculated in TechnoGIN with QUEFTS (Quantitative Evaluation of the Fertility of Tropical Soils). QUEFTS calculates the optimal nutrient input for crops with SSNM; therefore the environmental inputs and outputs are always at a minimum level for crops with SSNM.

The third policy option is the stimulation of MT by subsidy. This policy did not help to improve the quality of the water of the Taihu lake. Although the use of MT machine did not help to reduce the environmental outputs, it is still very important for farmers. Farmers on small farms earn more with working off-farm so saving labour is very important for them, therefore the use of MT machine is important for farmers. In case of stimulating SSNM there is a high use of MT and most sustainable indicators are positive.

The third policy option is the buffer zone. Buffer zones have on farm level little impact and compensation payments are nevertheless too low, but buffer zones are expected to have a large impact on the water quality.

Scale enlargement is the last policy measure; this measure did lead to more mechanisation on the farm if labour was limited. On larger farms it is more profitable to work on-farm then to work off-farm, while on small farms it is more profitable to work off-farm. The disadvantage of scale enlargement is that the environmental outputs per hectare increase compared to smaller farms if labour was not limited.

The model chain TechnoGIN-FSSIM has proven to be useful to ex-ante assess agricultural policies at farm level in Taihu Basin. Constraints for the adaptation of technologies, and impacts on environmental, economic and social indicators are evaluated, allowing to better target policies.

References

Asai, M. (2009). "Assessing the impacts of agricultural intensification on biodiversity in Taihu lake basin, China: multi scale and socio-ecological perspectives." MSc thesis. Wageningen University, Wageningen: 54.

Cao, Z.H. and. Zhang, H. C. (2004). "Phosphorus losses to water from lowland rice fields under rice-wheat double cropping system in the Tai Lake region." Environmental Geochemistry and Health **26**: 229-236.

Chao, G., Bo, S., Tao-Lin, Z. (2006). "Sustainable nutrient management in Chinese agriculture: challenges and perspective." Pedosphere **16**(2): 253-263.

Che, X. (2009). "Analysis of Influencing Factors on Farm Technology Behavior – Case of Taihu Lake. College of Land Management." MSc thesis. Nanjing, Nanjing Agricultural University..

Chen, Y., Qin, B., Teubner, K., Dokulil, M.T. (2003). "Long-term dynamics of phytoplankton assemblages: *Microcystis*-domination in Lake Taihu, a large shallow lake in China." Journal of plankton research **25**(1): 445-453.

Chern, W. S., Ishibashi, K., Taniguchi, K. and Tokoyama, Y. (2003). "Analysis of the food consumption of Japanese households. " Food and agriculture organisation of the United Nations, Rome: 1-72.

China FAOSTAT data 1990-2008. Assessed on March 2010.

Dobberman, A., Witt, C., Dawe, D. Abdulrachman, S., Gines, H.C., Nagerajan, R., Satawathananont, S., Son, T.T., Tan, P.S., Wang, G.H., Chien, N.V., Thoa, V.T.K., Phung, C.V., Staling, P., Muthukrishnan, P., Ravi, V., Babu, M., Chatuporn, S., Sookthongsa, J., Sun, Q., Fu, R., Simbahan, G.C., Adviento, M.A.A. (2002). "Site-specific nutrient management for intensive rice cropping systems in Asia. " Field Crop Research **74**: 37-66.

Ellis, E.C., Wang, S.M. (1997). "Sustainable Traditional Agriculture in the Taihu Lake Region of China. " Agriculture, Ecosystems & Environment **61**: 177-193.

Fan, M., Lu, S., Jiang, R., Liu, X., Zeng, X., Goulding, K.W.T., Zhang, F. (2007) "Nitrogen input, ^{15}N balance and mineral N dynamics in a rice-wheat rotation in southwest China." Nutrient Cycle Agroecosystem **79**: 255-265 .

Foley, F. (1992). "Renewable energy in third world development assistance: Learning from experience. " Energy policy: 355-364.

Gale, F., Lohmar, B., Tuan, F. (2005). "China's new farm subsidies. " Economic research service/USDA: 2-16.

Guo, H.Y., Zhu, J.G., Wang, X.R., Wu, Z.H., Zhang, Z. (2004). "Case study on nitrogen and phosphorus emission from paddy field in Taihu region." Environmental Geochemistry and Health **26**: 209-219.

Hazell P., Norton R. (1986). "Mathematical Programming for economic analysis in agriculture. " Macmillan Publishing Company, New York.

Heckelei, T. (2005). " Shadow price in PMP and consequences for calibration and estimation of programming models. " Paper prepared for presentation at the PMP, Extensions and alternative Methods Organised Session of the XIth EAAE Congress

Helming, H., Tscherning, K., Köning, B., Sieber, S., Wiggering, H., Kuhlman, T., Wascher, D., Perez-Soba, M., Smeets, P., Tabbush, P., Dilly, O., Hüttl, R., Bach, H. (2008). "Ex ante impact assessment of land use changes in European regions – the SENSOR approach. " Sustainability Impact Assessment of Land Use Changes, Springer: 77-105.

Hengsdijk, H., Guanghuo, W., Van den Berg, M.M., Jiangdi, W., Wolf, J., Changhe, L., Roetter, R.P., Van Keulen, H. (2007). "Poverty and biodiversity trade-offs in rural development: A case study for Pujiang county China." Agricultural Systems **94**: 851-861.

Heon, K.L., Teng, P.S., Moody, K. (1995). "Managing Rice Pests with Less Chemicals. " GeoJournal **35.3**: 337-349

Howitt, R.E. (1995). "Positive mathematical programming." American journal of agricultural economics **77**: 329-342.
Hu, R., Cao, J., Huang, J., Peng, S., Huang, J., Zhong, X., Zou, Y., Yang, J., Buresh, R.J. (2007). "Farmer participatory testing of standard and modified site-specific nitorgen management for irrigated rice in China. " Agricultural Systems **94**: 331-340
Huang, Y., Zhu, M. (1995). "The water quality of Lake Taihu and its protection." GeoJournal **40**(1-2): 39-44.
Janssen B.H., Guiking, F.C.T., Van der Eijk, D., Smaling, E.M.A., Wolf, J., Van Reuler, H. (1990). "A system for quantitative evaluation of the fertility of tropical soils (QUEFTS). " Geoderma **46**: 299-318.
Jiangsu Province Government (2004). " Ecological Province Construction Plan of Jiangsu Province. "
Jing Q. (2007). "Improving resource use efficiency in rice-based cropping systems: Experimentation and modeling. " PhD thesis, Wageningen University, Wageningen, The Netherlands.
Kanellopoulos, A., Berentsen, P., Heckelei, T., Van Ittersum, M., Oude Lansink, A. (2010). Assessing the forecasting performance of a generic bio-economic farm model calibrated with two different PMP variants. Journal of agricultural economics **61** (2): 274-294.
Kang, C. (2009). "Quantifying agro-ecological relationships to assess the impact of policies on agricultural sustainability in Taihu lake basin, China. " MSc thesis. Wageningen University, Wageningen**:** 51.
Klok, C., Römkens, P., Naeff, H., Arts, G., Runhaar, H., Van Diepen, K., Noij, G.J. (2002). "Gebiedsgerichte milieumaatregelen voor waterkwaliteit en natuur in Reconstructiegebieden van Noor-Brabant. " Alterra document project number 035-11585.
Liang, X.Q., Li, H., He, M.M., Cheng, G.M., Tian, G.M., Xu, S.Y. (2008). "The ecologically optimum application of nitrogen in wheat season of rice-wheat cropping system." Agronomy journal **100** (1): 67-72.
Lin, G. (2006). "Development and application of an economic model for agricultural policy simulation in China. " Farming and rural system economics **78**: 1-185
Louhichi, K., Flichman, G., Blanco, M. (2007). A generic template for FSSIM for all farming systems. SEAMLESS, EU 6th Farmework Program.
Marra, M., Pannell, D.J., Ghadim, A.A. (2003). "The economics of risk, uncertainty and learning in the adaptation of new agricultural technologies: where are we on the learning curve?" Agricultural Systems **75**: 215-234.
Nesheim, I., McNeill, D., Reidsma, P., Cornu, C., Imbernon, J., Kuiper, M., Bonin, M., Köning, H., Bezlepkina, I., Verburg, R., Gcahimbi, L., Wamuongo, J., Gicheru, P., Cissé, Y., Sghaier, M., Ounalli, N., Feng, S., Shi, X., Kashyap, S.N., Purushothaman, S., Widyatmanti, W., Sartohadi, J., Rodrigues, S. (2008). "D2.2 - Definition of components of the analytical framework that will be accomplished by the consortium. " LUPIS, EU 6th Framework Program.
Perez-Soba, M., Petit, S., Jones, L., Bertrand, N., Briquel, V., Omodei-Zorini, L., Contini, C., Helming, K., Farrington, J., Tinacci Mossello, M., Wascher, D., Kienast, F., De Groot, R. (2008). "Land use functions – a multifunctionality approach to assess the impacts of land use change on land use sustainability. " Sustainability Impact Assessment of Land Use Changes, Springer: 375-404
Ponsioen, T.C., Laborte, A.G., Rötter, R.P., Hengsdijk, H., Wolf, J. (2003). "TechnoGIN-3: a technical coefficient generator for cropping systems in East and Southeast Asia. " Quantitative Approaches to Systems Analysis **26**: Wageningen, The Netherlands.
Ponsioen, T. C., Hengsdijk, H., Wolf, J., Van Ittersum, M.K., Rotter, R.P., Son, T.T., Laborte, A.G. (2006). "TechnoGIN, a tool for exploring and evaluating resource use efficiency of cropping systems in East and Southeast Asia." Agricultural Systems **87**: 80-100.
Qin, B., Xu, P., Wu, Q., Luo, L., Y. Zhang (2007). "Environmental issues of Lake Taihu, China." Hydrobiologica **581**: 3-14.

Reidsma, P., Koning, H., Feng, S., Bezlepkina, I., Verburg, R., Van Ittersum, M., Van Keulen, H., Ewert, F., Nesheim, I., McNeill, D., Kuiper, M., Bonin, M., Sieber, S., Tscherning, K., Helming, K., Brouwer, F. (2008). "D4.1 - Methodological framework for the complementary use of mainly SENSOR and SEAMLESS approaches for sustainability impact assessment of land use policies in developing countries. " LUPIS, EU 6th Framework Program.

Reidsma, P., Feng, S., Van Keulen, H., Shi, X., Qu, F. (2009). "D10.1 - Description of the pre-modelling phase concluding with the procedure for integrated impact assessment in the case study of China. " LUPIS, EU 6th Framework Program.

Reidsma, P, König, H., Feng, S., Bezlepkina, I., Nesheim, I., Bonin, M., Sghaier, M., Purushothaman, S., Sieber, S., Van Ittersum, M.K., Brouwer, F. (2010). "Methods and tools for integrated assessment of land use policies on sustainable development in developing countries. " Under review.

Roelcke, M., Han, Y., Cai, Z., Richter, J. (2002). "Nitrogen mineralization in paddy soils of the Chinese Taihu Region under aerobic conditions. " Nutrient Cycling in Agroecosystems **63**: 255-266.

Shoa, W. (2009). "Effectiveness of water protection policy in China: A case study of Jiaxing." Science of the Total Environment **408**: 690-710.

Shi X., Zhang C., Feng S., Qu F. (2008) "D3.1 - Non-point Agricultural Source Pollution in Taihu Lake, P.R. China. " LUPIS, EU 6th Framework Program.

Van den Berg M.M., Hengsdijk H., Wolf J., Van Ittersum M.K., Guanghuo W., Roetter R.P. (2007). "The impact of increasing farm size and mechanization on rural income and rice production in Zhejiang province, China. " Agricultural Systems **94**:841-850.

Van Ittersum, M. K., Rabbinge, R. (1997). "Concepts in production ecology for analysis and quantification of agricultural input-output combinations." Field crops Research **52**: 197-208.

Van Ittersum, M. K., Ewert, F., Heckelei, T., Wery, J., Olsson, J.A., Andersen, E., Bezlepkina I., Brouwer, F., DOnatelli, M., Flichman, G., Olsson,L., Rizzoli, A.E., Van der Wal, T., Wien, J.E., Wolf, J. (2008). "Integrated assessment of agricultural systems - A component based framework for the European Union (SEAMLESS)." Agricultural Systems **96**: 150-165.

Vasisht A.K., Sujith Kumar S., Aggarwal P.K., Kalra N., Pathak H., Joshi H.C., Choudhary R.C. (2007). "An Integrated Evaluation of Trade-Offs between Environmental Risk Factors and Food Production Using Interactive Multiple Goal Linear Programming - A Case Study of Haryana"

Verburg, R., Bezlepkina, I., McNeill, D., Bonin, M., Sieber, S., Reidsma, P., Gcahimbi, L., Gicheru, P., Sghaier, M., Feng, S., Purushothaman, S., Widyatmanti, W., Sartohadi, J., Rodrigues, S. (2008). "D2.3 - Land use policies and sustainable development in developing countries. Defining sustainable development in the context of LUPIS. " LUPIS, EU 6th Framework Program

Wang, D.J., Liu, Q., Lin, J.H., Sun, R.J. (2004). "Optimum nitrogen use and reduced nitrogen loss for production of rice and wheat in the Yangtse Delta region." Environmental geochemistry and health **26**: 221-227.

Yu'an District Agricultural Extension Station (2008). "Mechanization of rice transplanting Yu'an district education demonstrative economic analysis techniques. " Anhui Agricultural Mechanization web portal

Zeigler, R.S., Puckridge, D.W., International Rice Research Institute (1995). " Improving Sustainable Productivity in Rice-based Rainfed Lowland Systems of South and Southeast Asia. " GeoJournal **35**.3: 307-324.

Zhang, H., Cao, Z., Wang, G., Zhang, H., Wong, M.H. (2003). "Winter runoff losses of phosphorus from paddy soils in the Taihu Lake Region of South China. " Chemosphere **52**: 1461-1466.

Zhang, Z., Zhang, J.Y., He, R. Wang, Z.D., Zhu, Y.M. (2007). "Phosphorus interception in floodwater of paddy field during the rice-growing season in TaiHu Lake Basin. " Environmental Pollution **145**: 425-433.

Appendix I Changes made in TechnoGIN

Input and outputs of agricultural activities are assessed by TechnoGIN. TechnoGIN includes several data sheets: technology, crop, land use type (LUT), land management unit (LMU), nutrient, biocide, efficiency, fertilizer and currencies. The inputs and outputs of agricultural activities assessed by TechnoGIN are the database for FSSIM (Farm System SIMulator). For linking TechnoGIN to FSSIM the model was extended such that it forms a complete database for inputs for FSSIM.

Several changes are made in TechnoGIN (Technical coefficient Generator for Ilocos Norte Province). The changes can be subdivided in two groups:
1) Model adaptations
2) Input parameter adoptations

1.1 Model adaptations

Addition of FSSIM input files

The original TechnoGIN model has two files (Kang, 2009): one data file with the inputs, and one model file including the outputs. The code was adapted such that the model file creates all input files (.inc) needed for FSSIM and that it defines the constraints for each farm type. The input files are (indicated in grey in TechnoGIN):

- Price.inc, prices for the products of the crops in the base year.
- Price_change.inc, prices for the products of the crops in the base year, baseline and policy scenario.
- Vari_price.inc, standard deviation of the price of the products of the crops.
- CAPRI-prices.inc, prices of the products of the crops in the base year.
- NR.inc, number of year within each crop rotation. In FSSIM-EU a rotation was over several year; in FSSIM-China the values in this sheet are all 1, because the rotation is in 1 year.
- P.inc, the periods (3 for FSSIM-China).
- RC.inc, combination of rotation, crop and period.
- Rotations.inc, all rotations.
- S.inc, all soil types.
- SYS.inc, the systems (base year, baseline and policy).
- T.inc, the techniques.
- Subset_T_SYST.inc, coupling techniques to systems. Inserted in TechnoGIN, but not used for FSSIM.
- Crops.inc, all crops.
- ACRO_crops.inc, all crops.
- GRSS_crops, empty file. This file is for grassland, but this is not used for FSSIM-China (it was used in FSSIM-EU).
- CP.inc, coupling crops to products.
- Products_Link.inc, was used in FSSIM-EU for matching CAPRI and FSSIM products, here it also couples crops to products.
- Families.inc, all families of the crops.
- FC.inc, combination of family and crop.
- Pact.inc, all crops.
- Observed_act_level.inc, the observed activity level in 2008 for a specific farm type in a specific municipality.
- FADN_activity.inc, all crops.
- CAPRI-activity.inc, all crops.
- CAPRI-prod.inc, all crops.

- Activity_link.inc, in FSSIM-EU it is for mapping between FADN and FSSIM crop list. In FSSIM-China it is all crops and after the crop is a dot and then the same crop is mentioned.
- CAPACT-link.inc, in FSSIM-EU it is for matching CAPRI and FSSIM activities. In FSSIM-China it is all crops and after the crop is a dot and then the same crop is mentioned.
- Products.inc, all products of the crops.
- RY.inc, reference year; in this case it is 2008.
- PSDPAY_T.inc, direct payments defined for all crops.
- Costs.inc, costs per rotation, soil type, technique, period and scenario.
- Input.inc, inputs of water, N, P and K per rotation, soil type, technique, period and scenario.
- Input_dekad.inc, inputs of water per rotation, soil type, technique, dekad and scenario.
- LabReq.inc, labour requirement per rotation, soil type, technique, period and scenario.
- Yield.inc, yield per rotation, crop, product, soil type, technique, period and scenario.
- Vari_yield.inc, standard deviation of crop yield.
- Trend_CEILFAC.inc, cut factor when payments exceed budget level for base year and baseline. This factor is not used for FSSIM-China.
- Trend_price.inc, the price for 2015 is already calculated in the file Price_change.inc so this file is not needed for FSSIM-China.
- Prem_A.inc, direct payments defined for all crops.
- Basic_prem.inc, the amount of subsidy defined for all crops in a scenario.
- Enviro.inc, the amount of N denitrification, N volatalization, N, P, K surplus, N, P, K run-off and BRI for all rotations per soil type, technique and scenario.

The constraint files are (indicated in blue in TechnoGIN):

- Risk_AC_level.inc, risk aversion coefficient and risk costs.
- Environ_policy.inc, file can be used for penalties for farmers on environmental outputs. This file is not used for FSSIM-China.
- DPSETA.inc, direct payment to obligatory set aside. This file is not used in FSSIM-China.
- SETASIDE.inc, percentage of total land that should be at minimum and at maximum in the buffer zone for the base year, baseline and policy scenario.
- Miscdat.inc, the wage, total land per soil type and total available water for the base year.
- Miscdat_Change.inc, the wage, total family and permanent labour available, total land per soil type and total available water for the base year, baseline and policy scenario.
- Miscdat_dekad.inc, the water and family and permanent labour available per dekad in the base year.
- Miscdat_Change_dekad.inc, the water and family and permanent labour available per dekad in the base year, baseline and policy scenario.
- Outputs.inc, all environmental outputs.
- LT_Credit.inc, long term interest rate, maximal share of long terme credit in investment, maximal share of annuity in expected income, investment cost of new building. This is not used in FSSIM-China.

Additions in the database

In the LUT sheet there is a high and a low target yield. The policy target yield is added. In the policy scenario will be investigated what the effect is of stimulating the use of SSNM. Assumed is that the farmers will gain a higher yield than in the baseline scenario. This is due to more education and training and therefore they will have a better management. This will mean that in the policy scenario the model runs with the policy target yield (Table 2, 3 and 4). In the base year the target yield is the low target yield. In 2015 the target yield will be higher than in 2008, because assumed is that the farmers will improve their management skills (Table 2, 3 and 4). In the baseline the target yield will be the high yield.

Low target yields are calculated by the averages of survey data. In Kang (2009), the averages for the region are given, in this study average yields are calculated per municipality. For SSNM in the base year is assumed that a higher yield can be obtained than the average of FF, because farmers that use SSNM have a better management. This higher yield is calculated as the average of the FF yield that is observed and the highest yield that can be obtained. The highest yield that can be obtained is based on what can be obtained according to experiments and crop modeling (Jing, 2007), and the highest yields that were observed in the farm survey (Kang 2009). The high target yields which are used in the baseline scenario are based on the trend of the yield for rice, wheat and rapeseed from 1990 until 2008 in China (Figure 1). As yield increases have slowed down since the 90's, 1990 is taken as the starting year to calculate trends. Based on linear regression, the slope is calculated and extrapolated towards 2015. The yields for 2015 are expected to be 4.2% higher for rice compared to 2008. The expected increase from 2008 until 2015 for wheat is 12.3% and for rapeseed it is 14.5% (Table 1). As data is not available on yield increases per technology or soil type, the same relative increase is assumed for each technology and soil type. For SSNM the yield in the baseline scenario is calculated as the average of the FF yield in the baseline and the highest obtainable yield.

For the policy target yields for cultivating crops with SSNM are the highest obtainable yields. The yields for conventional cropping and for FF application are the same as in the baseline scenario.

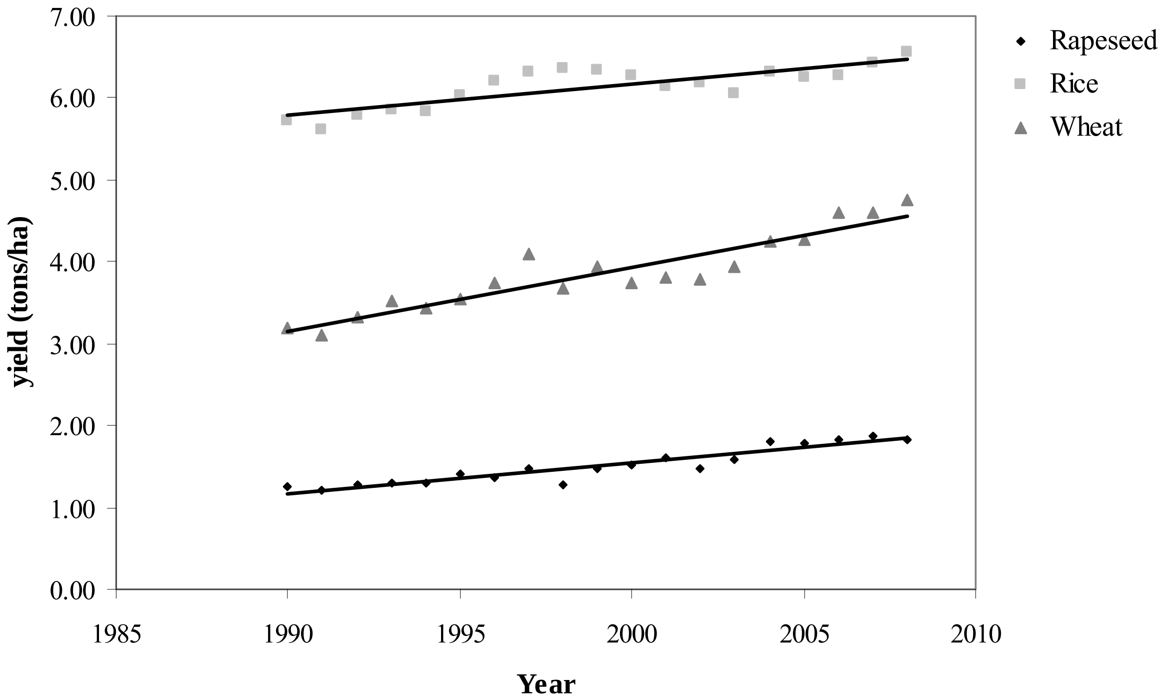

Figure 1. Yield trend in China from 1990 until 2008 for rice, wheat and rapeseed (China FAOSTAT data 1990-2008). Trend line rice: R^2=0.6894; Y=0.0383X-70.446. Trend line wheat: R^2=0.8629; Y=0.0786X-153.34. Trend line rapeseed: R^2=0.8772; Y=0.0373X+73.096.

Table 1. Expected yield (tons/ha) increase from 2008 until 2015

	Yield 2008	Yield 2015	Increase (%)
Crop			
Rice	6.46	6.73	4.2
Wheat	4.49	5.04	12.3

Rapeseed	1.80	2.06	14.5

Due to large differences in obtained yield per municipality, the data for yield is split up per municipality (Table 6, 7 and 8).

From the observed levels of crops the area of rice is in most of the cases not exactly the same as the area of wheat or rapeseed. This means that not all land is used for rotations of two crop in a year and besides single rice, also single whea or rapeseed occurs. This is, because wheat and rapeseed are able to grow on paddy or dry land and rice can only grow on paddy land (personal communication Shuyi Feng). To reproduce this in the model lowland and upland soils are added in TechnoGIN. When cultivating a crop this can now be done on clay, loam or sand on either upland or lowland. On lowland soils (paddy soils) the yield will be as normal (Table 6, 7 and 8). On uplands (the dry lands) the yield of rice will be zero, to reproduce the inability of rice to grow on dry lands. The yield for wheat and rapeseed will be the same as on upland, because wheat and rapeseed are able to grow on uplands. FSSIM will not choice to grow rice on upland soil types, because it is not profitable.

Table 2. Low, high and policy target yields (tons/ha) for municipality Wuxi for different crops and different soil types on low land

Target yield (tons/ha)		Low			High			Policy		
	Low land soil types	Clay	Loam	Sand	Clay	Loam	Sand	Clay	Loam	Sand
Abbreviation	Crop									
RIc	Rice	7.3	7.8	7.2	7.6	8.1	7.5	7.6	8.1	7.5
RImc	Rice with mechanical transplanting	7.3	8.1	7.5	7.6	8.4	7.8	7.6	8.4	7.8
WHc	Wheat	5.4	5.6	6.3	6.1	6.3	7.1	6.1	6.3	7.1
RAc	Rapeseed	2.6	2.1	2.5	2.9	2.4	2.8	2.9	2.4	2.8
RIfc	Rice with FF application	7.0	8.5	5.9	7.3	8.9	6.2	7.3	8.9	6.2
RIfmc	Rice with FF application and mechanical transplanting	7.1	7.1[I]	7.1[I]	7.3	7.3	7.3	7.3	7.3	7.3
RIssc	Rice with SSNM	8.5	9.3	8.0	8.7	9.4	8.1	10.0	10.0	10.0
RIssmc	Rice with SSNM and mechanical transplanting	9.0	9.01[I]	9.0[I]	9.2	9.2	9.2	11.0	11.0	11.0
WHfc	Wheat with FF application	5.3	5.4	5.3	5.9	6.0	5.9	5.9	6.0	5.9
WHssc	Wheat with SSNM	6.4	6.4	6.4	6.7	6.8	6.7	7.5	7.5	7.5
RAfc	Rapeseed with FF application	2.5	3.0	2.7	2.8	3.5	3.2	2.8	3.5	3.2
RAssc	Rapeseed with SSNM	3.5	3.8	3.6	3.6	3.9	3.8	4.5	4.5	4.5

[I] No data available, therefore the value is the same as the yield for clay

Table 3. Low, high and policy target yields (tons/ha) for municipality Changzhou for different

crops and different soil types

Target yield (tons/ha)		Low			High			Policy		
	Low land soil types	Clay	Loam	Sand	Clay	Loam	Sand	Clay	Loam	Sand
Abbreviation	Crop									
RIc	Rice	7.6	6.6	6.9	7.9	6.8	7.2	7.9	6.8	7.2
RImc	Rice with mechanical transplanting	7.3	7.0	7.7	7.6	7.3	8.0	7.6	7.3	8.0
WHc	Wheat	5.2	4.8	4.9	5.8	5.4	5.6	5.8	5.4	5.6
RAc	Rapeseed	2.3	2.6	2.6	2.6	2.9	3.0	2.6	2.9	3.0
RIfc	Rice with FF application	9.1	6.8	6.8	9.5	7.0	7.0	9.5	7.0	7.0
RIfmc	Rice with FF application and mechanical transplanting	6.8	8.1	7.4[I]	7.1	8.4	7.7	7.1	8.4	7.7
RIssc	Rice with SSNM	9.5	8.4	8.4	9.7	8.5	8.5	10.0	10.0	10.0
RIssmc	Rice with SSNM and mechanical transplanting	8.9	9.5	9.2	9.0	9.7	9.4	11.0	11.0	11.0
WHfc	Wheat with FF application	4.1	5.9	5.3	4.6	6.6	5.9	4.6	6.6	5.9
WHssc	Wheat with SSNM	5.8	6.7	6.4	6.0	7.1	6.7	7.5	7.5	7.5
RAfc	Rapeseed with FF application	1.9	1.5	2.3	2.1	1.7	2.5	2.1	1.7	2.5
RAssc	Rapeseed with SSNM	3.2	3.0	3.4	3.3	3.1	3.5	4.5	4.5	4.5

[I] No data available, value is based on the average values for clay and loam

Table 4. Low, high and policy target yields (tons/ha) for municipality Zhenjiang for different crops and different soil types

Target yield (tons/ha)		Low			High			Policy		
	Low land soil types	Clay	Loam	Sand	Clay	Loam	Sand	Clay	Loam	Sand
Abbreviation	Crop									
RIc	Rice	3.6	7.0	8.5	3.8	7.3	8.8	3.8	7.3	8.8
RImc	Rice with mechanical transplanting	8.3	8.3[I]	8.3[I]	8.6	8.6	8.6	8.6	8.6	8.6
WHc	Wheat	4.3	4.5	2.0	4.8	5.1	5.2	4.8	5.1	5.2
RAc	Rapeseed	2.4	2.3	2.0	2.6	2.6	2.2	2.6	2.6	2.2
RIfc	Rice with FF application	6.8	6.7	7.9	7.1	7.0	8.2	7.1	7.0	8.2
RIfmc	Rice with FF application and mechanical	7.9[II]	7.9[II]	7.9[II]	8.2	8.2	8.2	8.2	8.2	8.2

	transplanting									
RIssc	Rice with SSNM	8.4	8.3	8.9	8.6	8.5	9.1	10.0	10.0	10.0
RIssmc	Rice with SSNM and mechanical transplanting	9.5	9.5	9.5	9.6	9.6	9.6	11.0	11.0	11.0
WHfc	Wheat with FF application	4.3	4.8	4.7	4.9	5.4	5.3	4.9	5.4	5.3
WHssc	Wheat with SSNM	5.9	6.2	6.1	6.2	6.5	6.4	7.5	7.5	7.5
RAfc	Rapeseed with FF application	3.0	2.3	1.5	3.4	2.5	1.7	3.4	2.5	1.7
RAssc	Rapeseed with SSNM	3.8	3.4	3.0	3.9	3.5	3.1	4.5	4.5	4.5

[I] No data available, value based on the value for clay
[II] No data available, value based on average of the municipalities

Changes in the code
When cultivating single crops, TechnoGIN considered N, P, K soil supply based on the whole year, leading to high nutrient leaching and recommendations of zero N, P, K supply for SSNM management. The code of TechnoGIN was adopted, such that for single crops only the cultivated period is considered for calculations.

Old situation in TechnoGIN:
If N_fert(crp) > 0 Then N_duration = N_duration + dekads_season(crp)
If P_fert(crp) > 0 Then P_duration = P_duration + dekads_season(crp)
If K_fert(crp) > 0 Then K_duration = K_duration + dekads_season(crp)

New situation in TechnoGIN:
N_duration = N_duration + dekads_season(crp)
P_duration = P_duration + dekads_season(crp)
K_duration = K_duration + dekads_season(crp)

Next to change in code for cultivating single crops also the the code for P-run off is changed. P-run off is an important indicator for impact assessment on water quality in Taihu Basin. In TechnoGIN, the P-run off was not dependend on P-application, only on the slope, while the slope in Taihu is close to zero. Due to high P-applications, P has accumulated in the soil and P-run off takes places. Therefore the formula for P run-off is changed, now the P run-off is calculated with the formula for P recovery (equation 1).

P recovery = 1 - P fixation – P run off (equ. 1)

The P fixing fraction is estimated as 0.7.
The P run-off fraction is calculated with equation 2.

P run-off fraction = a*clay% + b*precipitation + c*slope + d (equ. 2)

1.2 Input parameter adaptation

Fertilizer use per municipality
In Kang (2009) there was one TechnoGIN file for the three municipalities. Due to large differences per municipality in fertilizer gifts, yields, subsidies per crop, price of MT (mechanical transplanting) machine rent. Therefore the data for fertilizer gift is split up per

municipality (Table 5, 6 and 7). For crops with SSNM the fertilizer gift is calculated by TechnoGIN.

Table 5. Current fertilizer gift (kg/ha/year) per crop for municipality Wuxi for different soil types and different nutrients

	Soil type								
	Clay			Loam			Sand		
Fertilizer input	N	P	K	N	P	K	N	P	K
Crop									
RIc	415	71	72	266	44	44	424	183	99
WHc	235	62	61	250	40	40	119	36	36
RAc	193	56	58	178	71	71	172	53	53
RIfc	350	39	70	367	41	76	443	41	82
WHfc	236	45	78	221	35	66	465	60	120
RAfc	195	29	44	233	30	60	298[I]	73[I]	108[I]
RImc	461	86	94	360	43	40	288	48	48
RIfmc	252	41	79	258[I]	43[I]	85[I]	330[I]	45[I]	78[I]

[I] No data available, therefore the value is based on the average of the municipalities

Table 6. Current fertilizer gift (kg/ha/year) per crop for municipality Changzhou for different soil types and different nutrients

	Soil type								
	Clay			Loam			Sand		
Fertilizer input	N	P	K	N	P	K	N	P	K
Crop									
RIc	379	62	57	370	78	83	301	53	53
WHc	232	50	50	190	42	42	226	48	48
RAc	170	41	41	203	52	52	175	59	59
RIfc	420	49	93	533	60	38	289	79	116
WHfc	290	58	100	129	27	47	289	79	116
RAfc	372	48	96	336	60	38	404	110	163
RImc	297	53	53	392	65	65	486	69	69
RIfmc	375	42	84	258	43	85	330[I]	45[I]	78[I]

[I] No data available, therefore the value is based on the average of the municipalities

Table 7. Current fertilizer gift (kg/ha/year) per crop for municipality Zhenjiang for different soil types and different nutrients

	Soil type								
	Clay			Loam			Sand		
Fertilizer input	N	P	K	N	P	K	N	P	K
Crop									
RIc	390	72	72	372	61	77	494	81	81
WHc	232	51	51	156	58	58	242	58	62
RAc	195	47	47	73	26	26	279	67	82
RIfc	406	48	78	524	99	140	242	35	56
WHfc	207	31	51	426	98	99	136	28	41
RAfc	233	23	68	126	14	20	140	18	25
RImc	473	0	0	371[I]	51[I]	49[I]	457[I]	65[I]	65[I]
RIfmc	270[I]	41[I]	80[I]	258[I]	43[I]	85[I]	330[I]	45[I]	78[I]

[I] No data available, therefore the value is based on the average of the municipalities

Mechanical transplanting rent

The mechanical transplanting rent differs per municipality. Therefore different input files per municipality are made. For Wuxi the rent is 70-80 Yuan/mu, for Changzhou it is 120-130 Yuan/mu and for Zhenjiang it is 100 Yuan/mu (personal communication Shuyi Feng).

Input and basic premium
The input and basic premiums differ per municipality (Table 8) (personal communication Shuyi Feng).

Table 8. Premiums for different crops per municipality

		Municipality		
		Wuxi	Chanzhou	Zhenjiang
Premium (Yuan/ha)	Crop			
Basic premium	Rice	300	300	150
	Wheat	150	0	150
	Rapeseed	150	0	0
	Bufferzone	6750	9000	7500
Input premium	Rice	930	930	930
	Wheat	930	930	930
	Rapeseed	930	930	930

Farm gate price
The prediction for the farm gate prices for 2015 for rice, wheat and rapeseed made by Kang (2009) for TechnoGIN were based on the annual average increasing rate calculated from 1987-2007 (Figure 2), resulting in very high values.

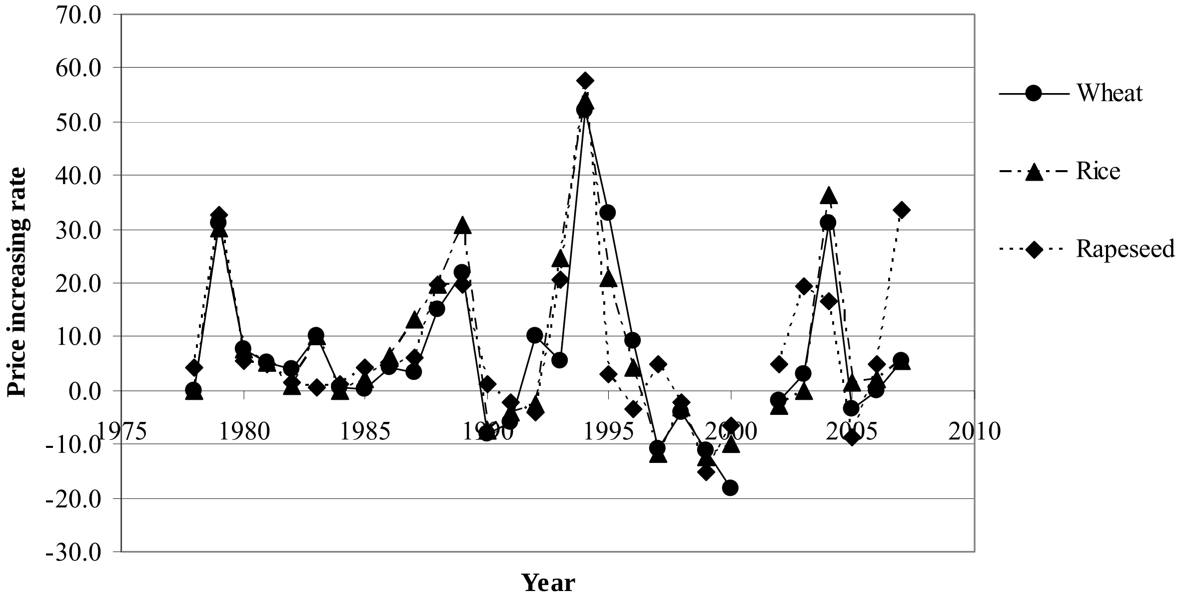

Figure 2. Increase of the price of wheat, rice and rapeseed from 1987 until 2007 (Kang, 2009)

Another way of looking at the price change is looking at the price index of rapeseed, wheat and rice (Figure 3, 4 and 5).

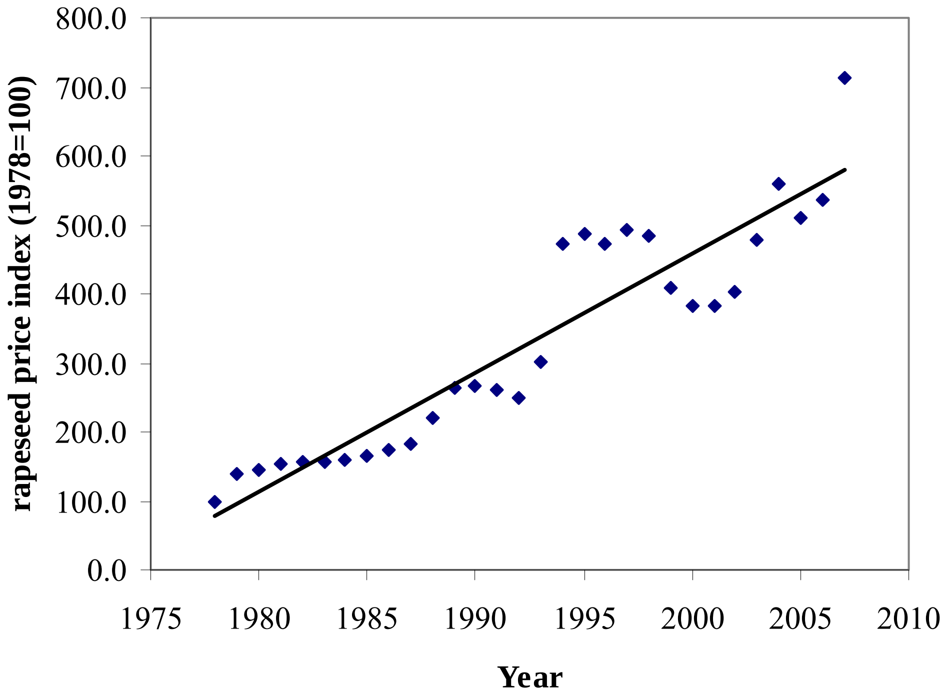

Figure 3. Rapeseed price index (1987=100). Trend line: R^2=0.8579; Y=17.279X-34099

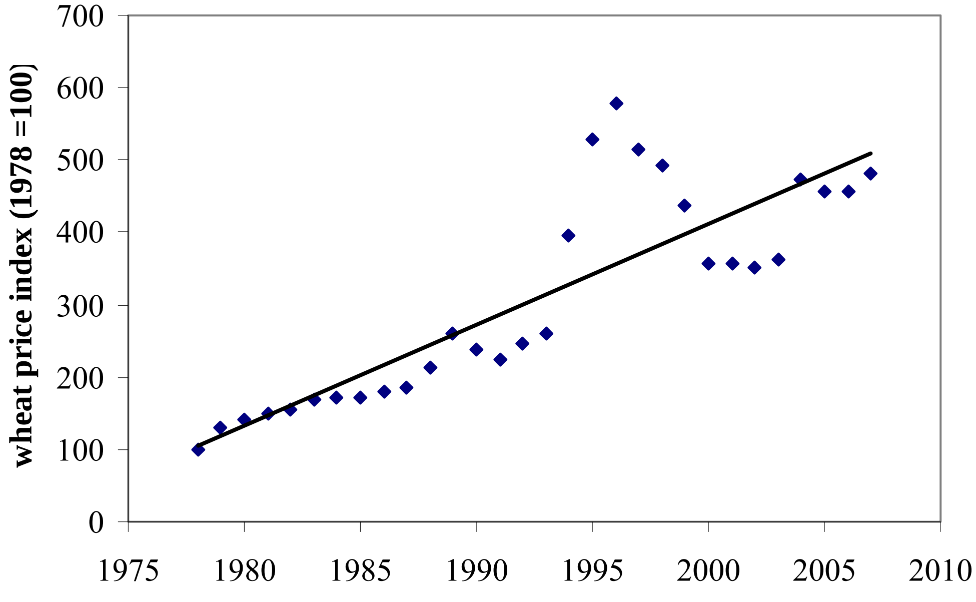

Figure 4. Wheat price index (1987=100). Trend line: R^2=0.7256; Y=13.953X-27493

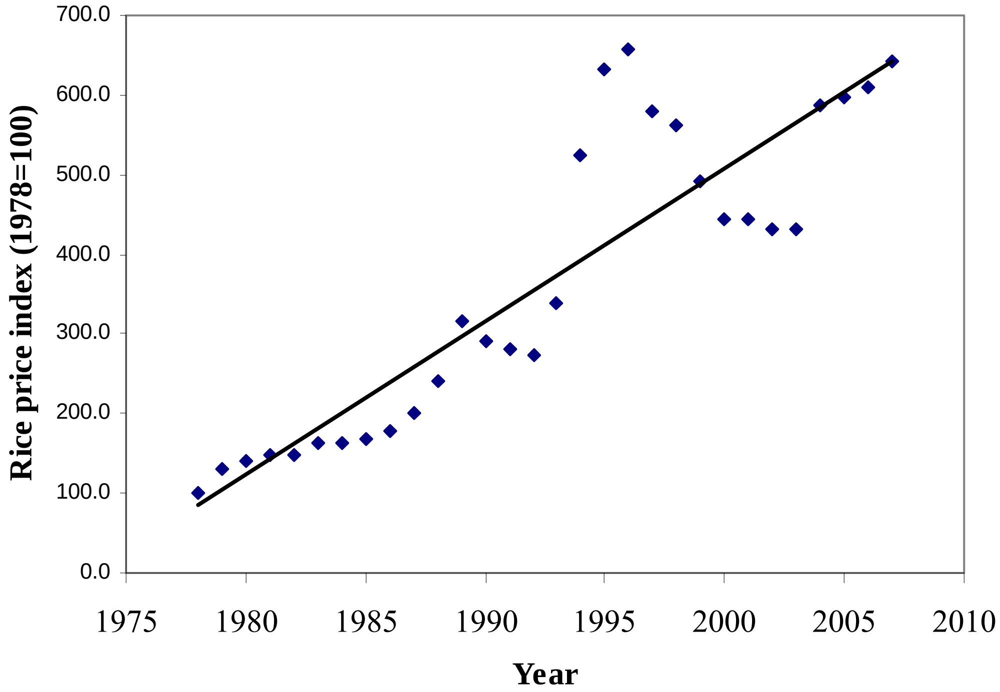

Figure 5. Rice price index (1987=100). Trend line: R^2=0.7965; Y=19.162X-0.7965

The data on the prices is from 1978 until 2007, so the price for 2008 is unknown. To calculate the price for 2008 and for 2015 the estimated trend from 1987 until 2007 will be extrapolated for 2008 and 2015. With the formula for the trend of the price index of rapeseed (Figure 3), the price in 2008 will be 3.09 Yuan/ton and the price in 2015 will be 3.72 Yuan/ton. For wheat also the price index trend is used (Figure 4), the price in 2008 will then be 1.44 Yuan/ton and in 2015 it will be 1.71 Yuan/ton. For rice also the trend of the price index is used (Figure 5) the price in 2008 will then be 1.85 Yuan/ton and in 2015 the price will be 2.23 Yuan/ton (Table 9).

Table 9. Farm gate prices for different crops and different time scale

Crop	Year	Price index (1978=100)	Price (Yuan/ton)
Rapeseed	2007	579.953	3.00
	2008	597.232	3.09
	2015	718.185	3.72
Wheat	2007	510.671	1.40
	2008	524.624	1.44
	2015	622.295	1.71
Rice	2007	641.134	1.80
	2008	660.296	1.85
	2015	794.43	2.23

Wage

The prediction for the agricultural wages for 2015 made by Kang (2009) for TechnoGIN were based on the annual average increasing rate calculated from 1987-2007, and were relatively low. Kang (2009) expected that the wage increased linear, but the trend from 1978 until 2007 is that the wage increases exponential (Figure 6).

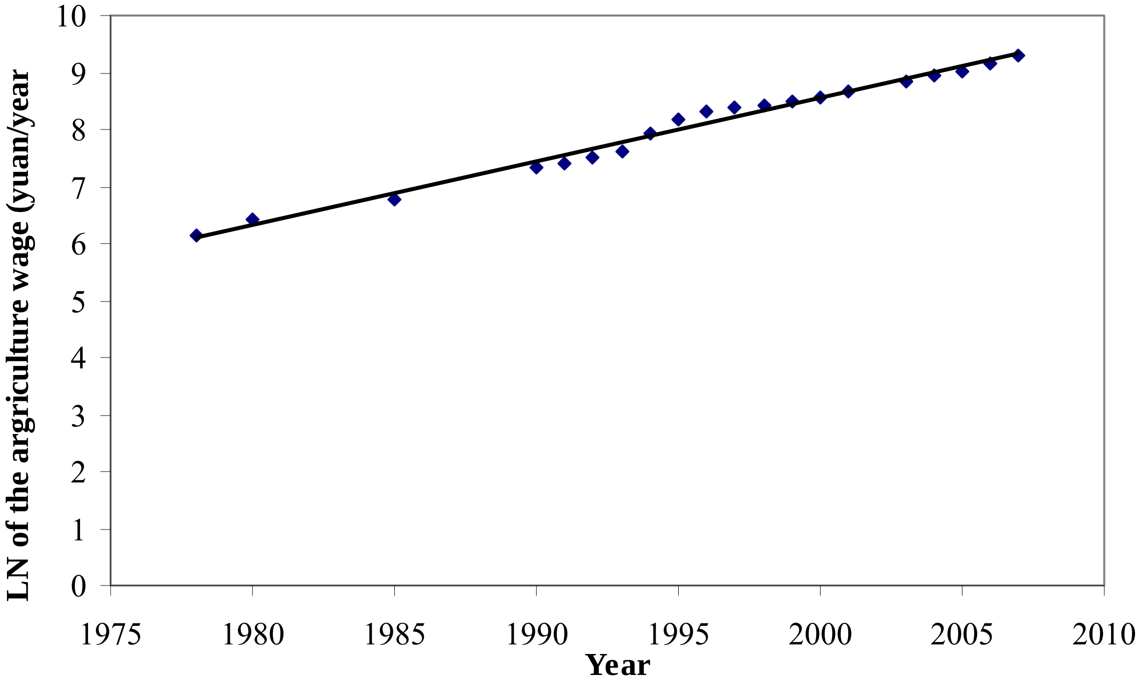

Figure 6. Agriculture wage from 1978 until 2007. Trend line: R^2=0.9859; Y=0.1104X-212.17

Therefore, the wage for 2015 has been projected based on a exponential trend line. The wage in 2008 is 50.00 Yuan/day, the expected wage in 2015 with an exponential increase is 108.29 Yuan/day.

Biocide use for mechanical transplanting of rice

According to expert, for 66,667 ha of rice 26,000 kg of biocides is needed if it is hand transplanted (Shuyi Feng, personal communication) For mechanical transplanting only 13,000 kg of biocides is needed. The reduction will then be 0.389 kg/ha. On a total of 76 kg or liter/ha of biocides that is used for rice (Kang, 2009) this will mean a reduction of 0.5% in biocide use when using mechanical transplanting instead of hand transplanting. In Kang (2009), biocide use was reduced with 10% for rice transplantede mechanically. This factor has now been changed to 0.5%.

Formula for P run-off

As mentioned before, the code for P-run off is changed (equation 1) and therefore constants should be chosen to get a correct outcome (equation 2).

P recovery = 1 - P fixation – P run off (equ. 1)

The P fixing fraction is 0.7 in TechnoGIN.
The P run-off fraction is calculated with equation 2.

P run-off fraction = a*clay% + b*precipitation + c*slope + d (equ. 2)

The constants a until d are estimated on the basis of the outcome of Cao and Zhang (2004). Cao and Zhang (2004) compared the P fertilization rate for rice and wheat with the P run-off. Analysis was done in Wuxi (loamy clay, permeable) and Changsu (silt loam, waterlogged) in 2000 (dry year) and 2001 (wet year).

The outcome of the P run-off of Cao and Zhang (2004) is plotted against P application (Figure 7 and 8) and the linear relationship between the points is calculated (Table 10 and 11).

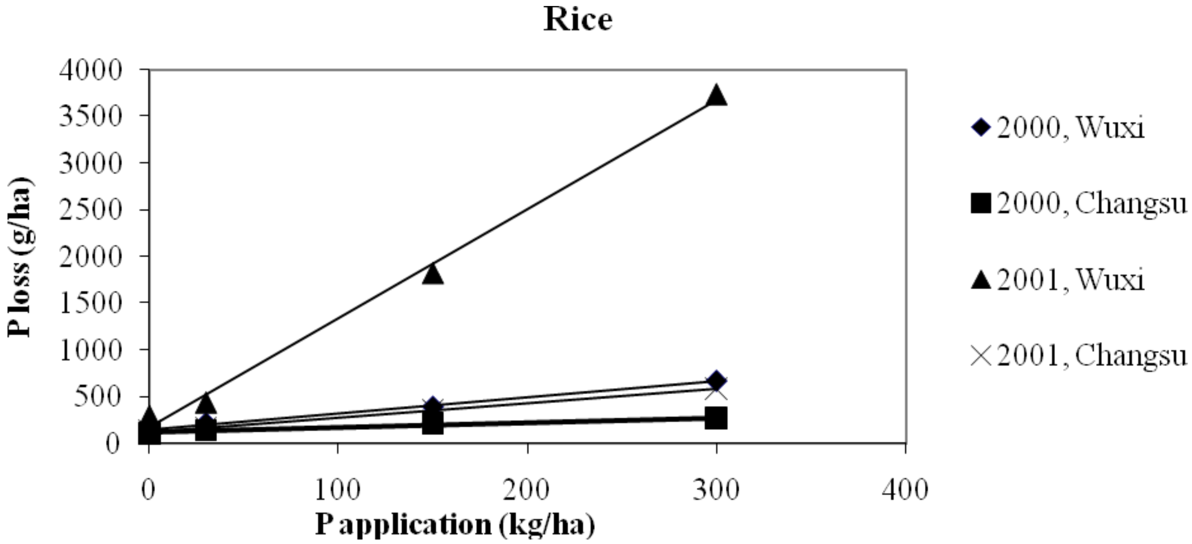

Figure 7. P application of rice against P loss for different years and different stations

Table 10. Equation for P loss (g/ha) with different P applications (kg/ha) for rice

Station	Year	Equation
Wuxi	2000	Y = 1.6962X+155.2
Changsu	2000	Y = 0.5387X+115.85
Wuxi	2001	Y = 11.71X+172.34
Changsu	2001	Y = 1.55X+124.5

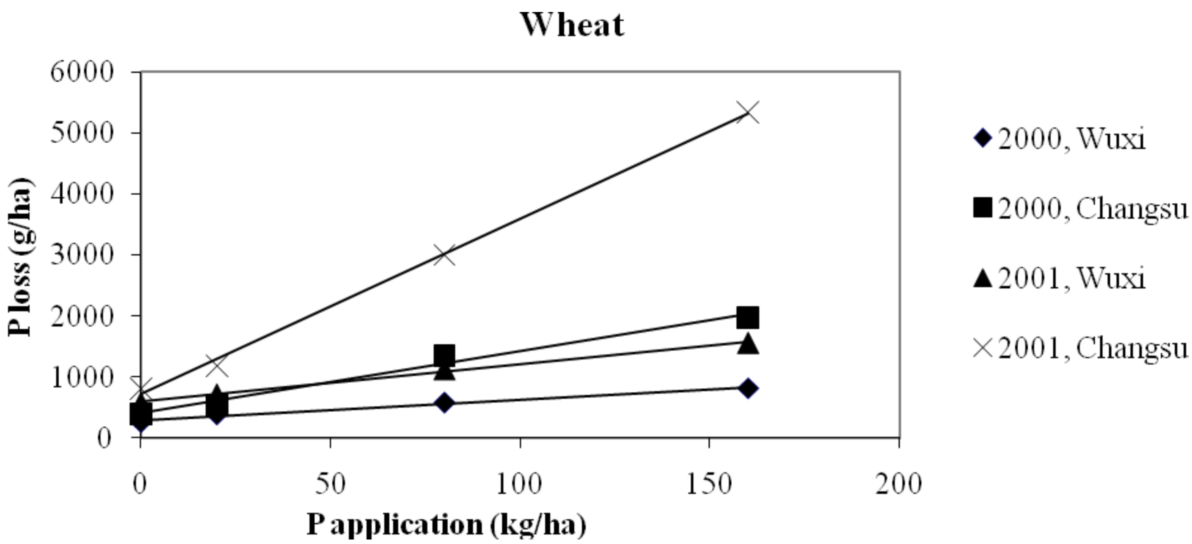

Figure 8. P application of wheat against P loss for different years and different stations

Table 11. Equation for P loss (g/ha) with different P applications (kg/ha) for wheat

Station	Year	Equation
Wuxi	2000	Y = 3.4048X+286.94

Changsu	2000	Y = 6.1377X+590.3
Wuxi	2001	Y = 10.174X+404.68
Changsu	2001	Y = 28.745X+714.34

The P run-off fraction is calibrated on the rotation rice-wheat.
Equation 2:
Constant a = 0.000167
Constant b = 0.000012
Constant c = 0
Constant d = 0

The outcome of TechnoGIN for P-run off when running with the constants a until d can be found in table 12.

Table 12. P run-off (kg/ha) per period calculated by TechnoGIN for the rotation rice-wheat in the current situation for different technologies, soil types and fertilization rate (kg/ha) per period

No	Technology	Soil	Fertilization 1	Fertilization 2	Fertilization 3	P run-off 1	P run-off 2	P run-off 3	Total P run-off
1	A	Clay	69	56	0	0.97	0.71	0.03	1.71
2	D	Clay	69	56	0	0.91	0.66	0.05	1.62
3	A	Loam	72	43	0	0.95	0.51	0.02	1.47
4	D	Loam	72	43	0	0.88	0.37	0.04	1.29
5	A	Sand	75	50	0	0.93	0.54	0.02	1.49
6	D	Sand	75	50	0	0.82	0.37	0.03	1.25

Table 13. P run-off (kg/ha), outcome is the average for the linear equations by Cao et al. (2004) for the different fertilization rates mentioned in table 3

No	Wheat	Rice	Sum	Difference with TechnoGIN outcome
1	0.390	1.179	1.570	0.14
2	0.390	1.179	1.570	0.05
3	0.402	1.019	1.421	0.05
4	0.402	1.019	1.421	-0.13
5	0.411	1.101	1.512	-0.02
6	0.411	1.101	1.512	-0.26

Long term soil supply of nitrogen
Calculations of the long term soil supply of nitrogen were based on soil with a clay content of 35 and 51% and the soil was called a loam soil (Kang 2009 and Liang et al, 2008). For soils included in TechnoGIN for Taihu Basin a soil with a clay content of 35% is a clay soil and a soil with a clay content of 30% is a loam soil. This will mean that a soil with a clay content between 35% and 51% is a clay soil and not a loam soil, according to TechnoGIN. Therefore the long term soil supply of clay will be 70 kg N/ha as estimated for loam, instead of 95 kg N/ha. Loam will be 60 kg N/ha and sand will be 50 kg N/ha. The low and high yields without N, P and K fertilizer application are 3500 and 6000 kg/ha for rice and 1100 and 4000 kg/ha for wheat as calculated by TechnoGIN, this is also according to several studies (Jing et al, 2007 and Liang et al 2008).

Anaerobic volatilization fraction

The anaerobic recovery fraction for nitrogen, as estimated by Kang (2009), seems to be high, compared to what is expected (Wang, 2004). The recovery fraction for nitrogen is calculated by one minus the total loss fraction. The total loss fraction of nitrogen is the sum of N leaching, denitrification and ammonia volatilization (Kang, 2009). The anaerobic volatilization fraction is calculated by a parameter times 100 minus the clay content. So with a higher clay content the volatilization fraction will be lower. For requiring a recovery fraction that is lower the volatilization fraction parameter should be changed. The volatilization fraction for rice should be between 0.24 and 0.32 (Wang et al., 2007) and generally 1/3 is assumed. With 0.004 as parameter instead of 0.0035, the volatilization fraction will be between 0.26 and 0.30. The recovery fraction under anaerobic conditions will with these volatilization fractions be between 0.33 and 0.35.

Potassium leaching

The recovery fraction of potassium, as estimated by Knag (2009), seems to be high under anaerobic conditions, compared to what is expected. These fractions were based on earlier studies in Puiang (Van der Berg et al., 2007), but are reconsidered. The recovery fraction is calculated by one minus the total loss fraction. The total K loss fraction is the loss by leaching plus the loss by fixation (Kang, 2009). Expected is that the leaching for K is higher in rice than in wheat and rapeseed, because paddy soils have a smaller soil layer.

In TechnoGIN the K leaching fraction was put on zero (Kang, 2009), but for getting the recovery fraction of potassium under anaerobic conditions on a value of around 0.5 the value for K leaching fraction should be changed, because the fixation is the same for anaerobic conditions and aerobic conditions. The fixation fraction under aerobic and anaerobic conditions is 0.15 so for getting a recovery fraction of 0.5 the leaching fraction should be put on 0.35 under anaerobic conditions. The K leaching fraction under aerobic conditions stays the same. This means that under or aerobic conditions with a clay content less than 35% with no precipitation 0.25 and with 2500 mm of precipitation the fraction of leaching is 0.4. When the clay content is between 35 and 55% the leaching fraction will be 0.25 for no precipitation and 0.2 for 2500 mm of precipitation.

Appendix II Changes made in FSSIM

2.1 Coupling FSSIM to TechnoGIN

Environmental inputs and outputs

In TechnoGIN the environmental inputs and outputs are calculated per activity. The environmental inputs and outputs per activity from TechnoGIN are inputs for FSSIM for the calculation of the environmental inputs and outputs for those activities which are chosen in the scenarios.

To couple the environmental inputs and outputs from TechnoGIN to FSSIM, the same names as displayed in TechnoGIN should be defined in FSSIM. In the file ENVIRO.inc are the environmental outputs per activity which are transferred from TechnoGIN. In the file INPUT.inc are the environmental inputs per activity which are transferred from TechnoGIN. In the file FSSIM_model.gms are the names of the parameters declared which are in the INPUT.inc file and in ENVIRO.inc file.

The added parameters in FSSM_Model.gms are:

```
SURPLUS_N(rotations,S,T,SYST)    "Surplus of N per agricultural activity (kg/ha/year)"
SURPLUS_P(rotations,S,T,SYST)    "Surplus of P per agricultural activity (kg/ha/year)"
SURPLUS_K(rotations,S,T,SYST)    "Surplus of K per agricultural activity (kg/ha/year)"
ROFF_N(rotations,S,T,SYST)       "Run-off of N per agricultural activity (kg/ha/year)"
ROFF_P(rotations,S,T,SYST)       "Run-off of P per agricultural activity (kg/ha/year)"
ROFF_K(rotations,S,T,SYST)       "Run-off of K per agricultural activity (kg/ha/year)"
LEACH_N(rotations,S,T,SYST)      "Leaching of N per agricultural activity (kg/ha/year)"
LEACH_K(rotations,S,T,SYST)      "Leaching of K per agricultural activity (kg/ha/year)"
BRI(rotations,S,T,SYST)          "Biocide Residue Index per agricultural activity (-)"
N(rotations,S,T,P,SYST)          "N use (kg/ha/year)"
Po(rotations,S,T,P,SYST)         "P use (kg/ha/year)"
Ka(rotations,S,T,P,SYST)         "K use (kg/ha/year)"
```

The ENVIRO parameter is changed and therefore new variables should be made in and declared (in FSSIM_model.gms):

```
NSURPLUS     "Surplus of N at farm level (kg/ha/year)"
PSURPLUS     "Surplus of P at farm level (kg/ha/year)"
KSURPLUS     "Surplus of K at farm level(kg/ha/year)"
NROFF        "Run-off of N at farm level(kg/ha/year)"
PROFF        "Run-off of P at farm level(kg/ha/year)"
KROFF        "Run-off of K at farm level(kg/ha/year)"
NLEACH       "Leaching of N at farm level(kg/ha/year)"
KLEACH       "Leaching of K at farm level(kg/ha/year)"
BioRI        "Biocide Residue Index at farm level(-)"
Nin          "use of N at farm level(kg/ha/year)"
Kin          "use of K at farm level(kg/ha/year)"
Pin          "use of P at farm level(kg/ha/year)"
```

Because of the new variables also new equations should be declared and they are added in FSSIM_model.gms:

```
E_NSURPLUS      "Surplus of N at farm level"
E_PSURPLUS      "Surplus of P at farm level"
E_KSURPLUS      "Surplus of K at farm level"
E_NROFF         "Run-off of N at farm level"
E_PROFF         "Run-off of P at farm level"
E_KROFF         "Run-off of K at farm level"
E_NLEACH        "Leaching of N at farm level"
E_KLEACH        "Leaching of K at farm level"
E_BioRI         "Biocide Residue Index at farm level"
E_Nin           "Use of N at farm level"
E_Pin           "Use of P at farm level"
E_Kin           "Use of K at farm level"
```

The new equations are now declared, but they also need to be calculated. So I added in FSSIM_Model.gms calculations of environmental outputs:

```
*  Average Nitrogen surplus at farm level
E_NSURPLUS.. sum((r,s,t,sys)$(rst(r,s,t,sys)),X(R,S,T,SYS)* SURPLUS_N(r,s,t,sys))/
(sum((s), toland(s))*(1-(sum(fgr,LEVLo(fgr))/TOTLAND))=E= NSURPLUS;

*  Average Phosphorus surplus at farm level
E_PSURPLUS..sum((r,s,t,sys)$(rst(r,s,t,sys)),X(R,S,T,SYS)* SURPLUS_P(r,s,t,sys))/
(sum((s), toland(s))*(1-(sum(fgr,LEVLo(fgr))/TOTLAND))=E= PSURPLUS;

*  Average Potassium surplus at farm level
E_KSURPLUS.. sum((r,s,t,sys)$(rst(r,s,t,sys)),X(R,S,T,SYS)* SURPLUS_K(r,s,t,sys))/
(sum((s), toland(s))*(1-(sum(fgr,LEVLo(fgr))/TOTLAND)))=E= KSURPLUS;

*  Average Nitrogen run-off at farm level
E_NROFF.. sum((r,s,t,sys)$(rst(r,s,t,sys)),X(R,S,T,SYS)*ROFF_N(r,s,t,sys))/ (sum((s),
toland(s))*(1-(sum(fgr,LEVLo(fgr))/TOTLAND)))=E=NROFF;

*  Average Phosphorus run-off at farm level
E_PROFF.. sum((r,s,t,sys)$(rst(r,s,t,sys)),X(R,S,T,SYS)*ROFF_P(r,s,t,sys))/ (sum((s),
toland(s))*(1-(sum(fgr,LEVLo(fgr))/TOTLAND)))=E=PROFF;

*  Average Potassium run-off at farm level
E_KROFF.. sum((r,s,t,sys)$(rst(r,s,t,sys)),X(R,S,T,SYS)*ROFF_K(r,s,t,sys))/ (sum((s),
toland(s))*(1-(sum(fgr,LEVLo(fgr))/TOTLAND)))=E=KROFF;

*  Average Nitrogen leaching at farm level
E_NLEACH.. sum((r,s,t,sys)$(rst(r,s,t,sys)),X(R,S,T,SYS)*LEACH_N(r,s,t,sys))/
(sum((s), toland(s))*(1-(sum(fgr,LEVLo(fgr))/TOTLAND)))=E=NLEACH;

*  Average Potassium leaching at farm level
E_KLEACH.. sum((r,s,t,sys)$(rst(r,s,t,sys)),X(R,S,T,SYS)*LEACH_K(r,s,t,sys))/
(sum((s), toland(s))*(1-(sum(fgr,LEVLo(fgr))/TOTLAND)))=E=KLEACH;

*  Average Bio Residue Index at farm level
E_BioRI.. sum((r,s,t,sys)$(rst(r,s,t,sys)),X(R,S,T,SYS)*BRI(r,s,t,sys))/ (sum((s),
toland(s))*(1-(sum(fgr,LEVLo(fgr))/TOTLAND)))=E=BioRI;

*  Average water use at farm level
E_WATUSE ..    sum((r,s,t,p,sys)$(rst(r,s,t,sys)),X(R,S,T,SYS)*W(r,s,t,p,sys)) =E=
WATER;
```

```
* Average N input at farm level
E_Nin.. sum((r,s,t,p,sys)$(rst(r,s,t,sys)),X(R,S,T,SYS)*N(r,s,t,p,sys))/ (sum((s),
toland(s))*(1-(sum(fgr,LEVLo(fgr))/TOTLAND)))=E=Nin;

* Average P input at farm level
E_Pin.. sum((r,s,t,p,sys)$(rst(r,s,t,sys)),X(R,S,T,SYS)*Po(r,s,t,p,sys))/ (sum((s),
toland(s))*(1-(sum(fgr,LEVLo(fgr))/TOTLAND)))=E=Pin;

* Average K input at farm level
E_Kin.. sum((r,s,t,p,sys)$(rst(r,s,t,sys)),X(R,S,T,SYS)*Ka(r,s,t,p,sys))/ (sum((s),
toland(s))*(1-(sum(fgr,LEVLo(fgr))/TOTLAND)))=E=Kin;
```

Added in Farm_data.gms at section data definition:

```
SURPLUS_N(R,S,T,syst)     =ENVIRO(R,S,T,syst,'SURPLUS_N');
SURPLUS_P(R,S,T,syst)     =ENVIRO(R,S,T,syst,'SURPLUS_P');
SURPLUS_K(R,S,T,syst)     =ENVIRO(R,S,T,syst,'SURPLUS_K');
ROFF_N(R,S,T,syst)        =ENVIRO(R,S,T,syst,'ROFF_N');
ROFF_P(R,S,T,syst)        =ENVIRO(R,S,T,syst,'ROFF_P');
ROFF_K(R,S,T,syst)        =ENVIRO(R,S,T,syst,'ROFF_K');
LEACH_N(R,S,T,syst)       =ENVIRO(R,S,T,syst,'LEACH_N');
LEACH_K(R,S,T,syst)       =ENVIRO(R,S,T,syst,'LEACH_K');
BRI(R,S,T,syst)           =ENVIRO(R,S,T,syst,'BRI');
N(R,S,T,P,syst)           =INPUT(R,S,T,P,SYST,'N');
Po(R,S,T,P,syst)          =INPUT(R,S,T,P,SYST,'P');
Ka(R,S,T,P,syst)          =INPUT(R,S,T,P,SYST,'K');
```

For showing the environmental outputs in the results I added in FSSIM_results.gms the following:

```
ENVIRONMENTAL_RESULT('N surplus (kg N/ha/year)',SENAR) = NSURPLUS.L;
ENVIRONMENTAL_RESULT('P surplus (kg P/ha/year)',SENAR) = PSURPLUS.L;
ENVIRONMENTAL_RESULT('K surplus (kg K/ha/year)',SENAR) = KSURPLUS.L;

ENVIRONMENTAL_RESULT('N Runoff (kg N/ha/year)',SENAR)= NROFF.L;
ENVIRONMENTAL_RESULT('P Runoff (kg P/ha/year)',SENAR)= PROFF.L;
ENVIRONMENTAL_RESULT('K Runoff (kg K/ha/year)',SENAR)= KROFF.L;

ENVIRONMENTAL_RESULT('N leaching (kg N/ha/year)',SENAR) = NLEACH.L;
ENVIRONMENTAL_RESULT('K leaching (kg K/ha/year)',SENAR) = KLEACH.L;

ENVIRONMENTAL_RESULT('Biocide Residue Index (-)',SENAR) = BioRI.L;

ENVIRONMENTAL_RESULT('N use (kg N/ha/year)',SENAR) = Nin.L;
ENVIRONMENTAL_RESULT('P use(kg P/ha/year)',SENAR) = Pin.L;
ENVIRONMENTAL_RESULT('K use(kg K/ha/year)',SENAR) = Kin.L;

USED_DATA(R,P,C,"Average",S,T,SYS,' Surplus of N (Kg
N/ha/y)',SENAR)$(X.L(R,S,T,SYS) and comb(r,c,s,t,p,sys))          =
SURPLUS_N(r,s,t,sys);
USED_DATA(R,P,C,"Average",S,T,SYS,' Surplus of P (Kg
P/ha/y)',SENAR)$(X.L(R,S,T,SYS) and comb(r,c,s,t,p,sys))          =
SURPLUS_P(r,s,t,sys);
```

```
USED_DATA(R,P,C,"Average",S,T,SYS,' Surplus of K (Kg
K/ha/y)',SENAR)$(X.L(R,S,T,SYS) and comb(r,c,s,t,p,sys))          =
SURPLUS_K(r,s,t,sys);
USED_DATA(R,P,C,"Average",S,T,SYS,' field run off of N (Kg
N/ha/y)',SENAR)$(X.L(R,S,T,SYS) and comb(r,c,s,t,p,sys))          =
ROFF_N(r,s,t,sys);
USED_DATA(R,P,C,"Average",S,T,SYS,' field run off of P (Kg
P/ha/y)',SENAR)$(X.L(R,S,T,SYS) and comb(r,c,s,t,p,sys))          =
ROFF_P(r,s,t,sys);
USED_DATA(R,P,C,"Average",S,T,SYS,' field run off of K (Kg
K/ha/y)',SENAR)$(X.L(R,S,T,SYS) and comb(r,c,s,t,p,sys))          =
ROFF_K(r,s,t,sys);
USED_DATA(R,P,C,"Average",S,T,SYS,' Leaching of N (Kg
N/ha/y)',SENAR)$(X.L(R,S,T,SYS) and comb(r,c,s,t,p,sys))          =
LEACH_N(r,s,t,sys);
USED_DATA(R,P,C,"Average",S,T,SYS,' Leaching of K(Kg
K/ha/y)',SENAR)$(X.L(R,S,T,SYS) and comb(r,c,s,t,p,sys))          =
LEACH_K(r,s,t,sys);
USED_DATA(R,P,C,"Average",S,T,SYS,' Bio Residue Index (-)',SENAR)
$(X.L(R,S,T,SYS) and comb(r,c,s,t,p,sys)) = BRI(r,s,t,sys);
```

Water requirement
At the file parameter input.inc (this file contains data from TechnoGIN and is transferred to FSSIM) we have called irrigation water requirement per crop within each activity as w instead of watc (it was called watc in FSSIM-EU). Therefore I changed on all places watc to w.

```
W(rotations,S,T,P,SYST)    "irrigation water requirement per crop within each activity
(mm)"
W(R,S,T,P,syst)          =INPUT(R,S,T,P,syst,'W');
```

2.2 Policy changes

Land rent
Put landrent to zero at Farm_data.gms at section data definition, because FSSIM-EU used landrent and in FSSIM-China it is not used.

Sugar reform
In FSSIM_Policy.gms switched off the following:

```
*$include fssim-mp\policy\sugar-reform.gms
```

Sugar reform is not needed for the Chinese case study. No sugar beets in the Chinese case study.

System
The set syst includes now BAY, BLY, POL instead off current and future.

```
SET SYST "" /
BAY
BLY
POL
/;
```

Scenarios
Changed the scenarios at Farm_data.gms. The scenarios were BAY, BAL13 and BAL20. It is changed to: BAY, BLY and POL

On other places were BAL13 and BAL20 were mentioned, I also changed the names of the scenarios. Another change that I made is that the data 2003 changed into 2008, were it was needed.
The scenarios are changed, because the baseyear is in the Chinese case study is 2008 and not 2003. The baseline scenario is 2015 and not 2013 or 2020, further we also have a policy scenario.

SENAR gave errors and I changed it by out commenting the statements behind BAY, BLY and POL. And also added SENAR(SIM)=yes and DISPLAY senar.

Farm_data.gms

```
SIM             "Scenarios"
/
BAY
*Baseyear
BLY
*Baseline(2015)
POL
*Policy scenario
/

SENAR(SIM) ""

;
SENAR(SIM)  =yes;

DISPLAY senar;
```

Subsidy
Added at the set PSDPAY_T and PSDPAY(PSDPAY_T) in Policy_sets.gms at the section SET declarations the following:

```
Subs_Crop    "Subsidy defined to crop "
Subs_Fert    "Subsidy defined to fertilizer"
```

This is added, because the names in the set PSG_to_A (Prem_A.inc) and the names in the parameter Basic_prem (Basic_Prem.inc) are changed and therefore they should be declared at policy_sets.gms. The names are changed, because in FSSIM-China there is another subsidy model than in FSSIM-EU.

The calculation of the subsidy in the Chinese case study is different with the European calculation. In the Chinese case study a lot of things are not used that are used in the European version of FSSIM. Therefore a complete new premium_model.gms is made and it is called subsidy_model.gms.

The parameter basic_prem is also changed now it is BASIC_PREM(PSDPAY_T, Crops, SIM) and it was BASIC_PREM(PSDPAY_T,SIM). I also made a parameter BASIC_SUBS.

```
* Subsidy_model.gms
*
=================================================================
=
*-----*-----*-----*-----*-----*-----*-----*-----*-----*-----*-----*-----*-----*-----*-----*---*
```

```
PARAMETER
BASIC_PREM(PSDPAY_T,crops,*)          "Subsidy per crop (Yuan/ha) for baseyear,
baseline and policy"
SUBS                "Subsidy defined for crop or fertilization of a crop (Yuan/ha)"
BASIC_SUBS(PSDPAY_T,crops)          ""
  ;

  POSITIVE VARIABLES
  SUBSIDY       "received subsidy(Yuan)"
 ;

EQUATIONS
*
* --- Defined subsidy
E_SUBS   "received subsidy (Yuan)"
;

*   ---- Calculation of  received subsidy
E_SUBS..     sum((C,S,T,SYS,PSDPAY_T)$(BASIC_SUBS(PSDPAY_T,crops) gt
0),X(C,S,T,SYS)*BASIC_SUBS(PSDPAY_T,crops)) =E= SUBSIDY;
```

Instead of premium_data.gms there is now subsidy_data.gms.
The file subsidy_data is as follows:

```
* Subsidy_data.gms; 1 March 2010
*
=================================================================
===============

*   This file will be introduced when running basyear, baseline and policy scenarios    *
*-----*-----*-----*-----*-----*-----*-----*-----*-----*-----*-----*-----*-----*-----*---*

*   ---- include subsidy files

$include FSSIM-DM\INPUTDATA\PREMIUM_DATA\BASIC_PREM.INC
;

BASIC_SUBS(PSDPAY_T,crops) =    BASIC_PREM(PSDPAY_T,crops,'BAY')   ;
```

The last line in subsidy_data.gms is also in Baseline2013_data.gms:

```
BASIC_SUBS(PSDPAY_T,crops) =    BASIC_PREM(PSDPAY_T,crops,'BLY')   ;
```

And in PolicyEXP_data.gms:

```
BASIC_SUBS(PSDPAY_T,crops) =    BASIC_PREM(PSDPAY_T,crops,'POL')   ;
```

On all places were PRME and PREM is it should be changed.
The FSSIM_model.gms is changed to consider the new subsidy files. At FSSIM_model.gms is changed:

```
POSITIVE VARIABLES
SUBSIDY         "received subsidy (Yuan)"

E_INCOME ..    Zc
          + Za
          + SUBSIDY
```

```
        =e= Z;

E_INCDEV(K)..
           Zcn(k)
         + Zan(k)
         + SUBSIDY
         - Z
         =E= DEV(K);

E_INCOME_S ..  Zc
         + Za
         + SUBSIDY
          -AGM*sum(s,RLand(s))
         =e= Z;

E_INCDEV_s(K).. Zcn(k)
         + Zan(k)
         + SUBSIDY
          -AGM*sum(s,RLand(s))
         - Z
         =E= DEV(K);

E_INCOMEQ ..   Zc
          + Za
          + SUBSIDY
*           - ANNUIT
*   ---- PMP terms
         + PMPterm
        =E= Z;

E_INCDEVQ(K)..  Zcn(k)
          + Zan(k)
          + SUBSIDY
*           - ANNUIT
*   ---- PMP terms
         + PMPterm
         - Z
         =E= DEV(K);

E_INCOMEQ_BL ..  Zc
         + Za
         + SUBSIDY*(1-(Prem_Mod/100)*BV_modula)*(1-
(sum(outputs$(Environ_policy(outputs,"penalty") gt
eps),Environ_policy(outputs,"penalty")/100*Bv_cross(outputs))))
         + PMPterm
       =E= Z;

E_INCDEVQ_BL(K).. Zcn(k)
         + Zan(k)
         + SUBSIDY*(1-(Prem_Mod/100)*BV_modula)*(1-
(sum(outputs$(Environ_policy(outputs,"penalty") gt
eps),Environ_policy(outputs,"penalty")/100*Bv_cross(outputs))))
         - Z
         =E= DEV(K);
```

No premium anymore, so I switched off the line for premium and added a new one for subsidy.

In PMP-SF_Solve.gms:

- subsidycrop(C)$(croparea(C)gt 0)=sum((r,s,t,p,sys)$(comb(r,c,s,t,p,sys)),basic_subs('subs_crop',c)*X.l(r,s,t,sys))/croparea(c);
- subsidyfert(C)$(croparea(C)gt 0)=sum((r,s,t,p,sys)$(comb(r,c,s,t,p,sys)),basic_subs('subs_fert',c)*X.l(r,s,t,sys))/croparea(c);
- Grossmargincrop(C)= sum(PRD,PRICE(C,PRD)*yieldcrop(C,PRD))+subsidycrop(C)+subsidyfert(C)-costpercrop(C);
- Parm

  /
  ……
  SUBSIDC
  SUBSIDF
  ….
  /
- APOTELESMA('SUBSIDC',C,PRD,'2008')$cp(c,prd) = subsidycrop(C);
- APOTELESMA('SUBSIDF',C,PRD,'2008')$cp(c,prd) = subsidyfert(C);

In FSSIM_Baseline.gms:

- subsidycrop(C)$(croparea(C)gt 0)=sum((r,s,t,p,sys)$(comb(r,c,s,t,p,sys)),basic_subs('subs_crop',c)*X.l(r,s,t,sys))/croparea(c);
- subsidyfert(C)$(croparea(C)gt 0)=sum((r,s,t,p,sys)$(comb(r,c,s,t,p,sys)),basic_subs('subs_fert',c)*X.l(r,s,t,sys))/croparea(c);
- APOTELESMA('SUBSIDC',C,PRD,'2015B')$cp(c,prd) = subsidycrop(C);
- APOTELESMA('SUBSIDF',C,PRD,'2015B')$cp(c,prd) = subsidyfert(C);

In FSSIM_Policy.gms:

- subsidycrop(C)$(croparea(C)gt 0)=sum((r,s,t,p,sys)$(comb(r,c,s,t,p,sys)),basic_subs('subs_crop',c)*X.l(r,s,t,sys))/croparea(c);
- subsidyfert(C)$(croparea(C)gt 0)=sum((r,s,t,p,sys)$(comb(r,c,s,t,p,sys)),basic_subs('subs_fert',c)*X.l(r,s,t,sys))/croparea(c);
- APOTELESMA('SUBSIDC',C,PRD,'2015P')$cp(c,prd) = subsidycrop(C);
- APOTELESMA('SUBSIDF',C,PRD,'2015P')$cp(c,prd) = subsidyfert(C);

Switched off decoupled in FSSIM_policy.gms, because it is not needed in our model (it is for calculation of premiums).

```
*$include fssim-mp\policy\decoupled.gms
```

Switched off subsidy_cal.gms in subsidy_data.gms, because it is not needed in our model (it is for calculation of premiums).

```
*$include FSSIM-MP\Premium\Subsidy_cal.gms
```

Switched off ceil_fact.inc in subsidy_data.gms, because it is not needed in our model (it is for calculation of premiums).

*$include FSSIM-DM\INPUTDATA\TREND_DATA\TREND_CEILFAC.INC

2.3 Error solving

Milk and meat

I got errors, because the model did not recognize 'milk' and 'meat' and on a lot of places it was referred to. Therefore I have to add products MILK and MEAT to the products that were defined in FSSIM. Now the sheet products in TechnoGIN contains also milk and meat, this sheet is transferred to FSSIM.

```
SET PRODUCTS "" /
GRAI
SEED
LEAF
FRUI
FALL
MEAT
MILK
/;
```

Not used data files

Some sets are not used in the Chinese case study model and therefore no files are generated for these sets by TechnoGIN. The sets are declared, because otherwise FSSIM does not recognize the sets when they are mentioned in an equation. In the equation they should not be taken into account, but should only be recognized, therefore there is no data in the inc files. For example for the following set and parameters, there is no data in it, but the set is declared.

In farm_data.gms:

```
$include FSSIM-DM\INPUTDATA\ECONOMIC_DATA\ADD_QPRICE.INC

$onempty
PARAMETER Addprice_D(pact,products,l,SIM) "" /
/;
$offempty
```

In farm_data.gms:

```
$include FSSIM-DM\INPUTDATA\POLICY_DATA\QUOTAS.INC

$onempty
PARAMETER QUOTA_D(pact,products,L,SIM)  "" /
/;
$offempty
```

In the FSSIM model for the European case study the sets GGRS and ACRO are in one file. In FSSIM for the Chinse case study the two sets are put in different files.

```
$include FSSIM-DM\INPUTDATA\GLOBAL_SET\ACRO_crops.INC
$onempty
$include FSSIM-DM\INPUTDATA\GLOBAL_SET\GRSS_crops.INC
$offempty
```

At GGRS_crops.inc we do not use grass, therefore the set is empty.

```
SET GGRS (crops) /
*grassland group (permanent + temporary grassland)
/;
```

At the set ACRO_crops.inc are all crops except grass.

```
SET ACRO(crops)/
* All arable crops except grass
RIc
WHc
RAc
RIfc
WHfc
RAfc
RImc
RIfmc
RIssc
WHssc
RAssc
RIssmc
FALL
/;
```

Marketable products
I switched off the marketable products, because it was only needed for calculation of the European premium. It is better to switch it off, because otherwise it should be changed when exporting the sheets of TechnoGIN to FSSIM when other crops are used.
Farm_data.gms:

```
*MPROD(products)     "marketable products"          /GRAI,SEED,LEAF,FRUI/
```

In the file MISCDAT there is no data about IRLAND, PERGRLAND, TEMGRLAND and LANDRENT, therefore these lines are switched off in farm_data.gms.

```
*   ---- Miscelaneous data: resources availability +other information
TOWATER      = MISCDAT('WATER','TOTAL');
TOLAND(S)    = MISCDAT('TOLAND',S);
*IRLAND      = MISCDAT('IRLAND','TOTAL');
FLABOUR      = MISCDAT('FLABOUR','TOTAL');
*PERGRLAND(S) = MISCDAT('PERGRLAND',S);
*TEMGRLAND(S) = MISCDAT('TEMGRLAND',S);
*LANDRENT     = MISCDAT('LANDRENT','TOTAL');
```

Techniques coupled to systems
The model did not recognize that technique TAC, TBC and TCF belong to system BAY (baseyear), that technique TDC, TEC and TFF belong to system BLY (baseline), and that TGC, THF, and TIF belong to POL (policy). To solve this some equations are changed.
At Crops_model.gms is the equation for total land changed, because it was not used in the correct way.
The new equation is as follows:

```
E_TOLAND(s) ..  sum((r,t,sys),X(R,S,T,SYS)) =l= toland(s)*(1-(sum(fgr,LEVLo(fgr))
/TOTLAND));
```

The old equation:

```
E_TOLAND(s) ..  sum((r,t,sys)$rst(r,s,t,sys),X(R,S,T,SYS)) =l= toland(s)*(1-
(sum(fgr,LEVLo(fgr))/TOTLAND))
```

The restriction for coupling every rotation to all soil types, techniques and all systems is deleted in the new equation. When this is deleted, the model does not choose wrong combinations of the technologies and systems anymore. First it was forced to choose for all combinations of techniques and systems, but when leaving out that restriction than the model does not select the wrong combinations of technologies and systems.

The same change is made for the constraint TOCLAND, new equation:

```
E_TOCLAND .. sum((s,r,t,sys),X(R,S,T,SYS)) =l= sum(s,toland(s))-
sum(fgr,LEVLo(fgr));
```

Old equation:

```
E_TOCLAND .. sum((s,r,t,sys)$rst(r,s,t,sys),X(R,S,T,SYS)) =l= sum(s,toland(s))-
sum(fgr,LEVLo(fgr));
```

The equation for allocation of land in one year was also not correct, more land was selected for cropping than the total land. Therefore I made a new equation for the allocation of land in one year.

```
 E_CROPPING(c,s,t,sys).. X(C,S,T,SYS) =E= sum((r,p) $(comb(r,c,s,t,p,sys)),
X(R,S,T,SYS) /nr(r));
```

The old equation was:

```
*E_CROPPING(c,s,t,sys) $sum((r,p)$(comb(r,c,s,t,p,sys)),1).. X(C,S,T,SYS)=E=
sum((r,p) $(comb(r,c,s,t,p,sys)), X(R,S,T,SYS) /nr(r));
```

I also added a new equation for the restriction of showing crops with zero cropping activity:

```
E_CROPPINGRES(R,S,T,SYS)$(NOT RST(R,S,T,sys)).. X(R,S,T,SYS)  =E=0;
```

Buffer zone

The observed activity level for the buffer zone is for some farm types zero. In the file PMP_data.gms is an equation for calibration of the area for the buffer zone. I switched off this line, because this will cause a negative value for the area of buffer zone.

At PMP_data.gms:

```
*SETASIDE      = (Levlo("FALL")-0.001)/sum(s,toland(s));
```

In the old model of FSSIM PR is used for the price of fallow land. In our model it is called FALL. Therefore I changed PR into FALL.

At Farm_data.gms:

```
*   link between crop and product exist if yield data exist
cp(c,prd)= yes$(sum((r,s,t,p,syst),yield(r,c,prd,s,t,p,syst)));
cp("Fall","FALL")=yes;
```

On farm used products

The model gave values for on farm used products, but everything should be sold and nothing should be kept on farm. To solve this I changed the following at Crops_model.gms:

```
E_USED_D(r,c,prd,s,t,p,sys)$(comb(r,c,s,t,p,sys)and
cp(c,prd))..USE_D(r,c,prd,s,t,p,sys)=E=0;
```

Yield for different states of nature and market

Yieldn is not changing for different states of nature and it should be. Therefore I changed the following to fix it:

Vari_yield

Vari_yield consists of GR (FAND activity/crops) and TIR (irrigation versus rainfed techniques), but TIR is for irrigation and it is not needed for the yield. Therefore I deleted TIR (TIR consists out of irri, rain and total) from the parameter vari_yield.

```
VARI_YIELD.inc
PARAMETER VARI_YLD "" /
RIc      1.6
WHc      1
RAc      0.7
RIfc     1.6
WHfc     1
RAfc     0.7
RImc     1.6
RIfmc    1.6
FALL     0
/;
```

When deleting TIR from the parameter vari_yield it should also be deleted when referring to the parameter.

Change at Crops_model.gsm:

```
vari_yld(gr)      "standrad devitation of irrigated and not irrigated crop yields (T/ha)"
```

When deleting TIR from the parameter vari_yield it should also be changed in the equation for yieldn.

At Farm_Data.gms:

```
yieldn(r,c,prd,s,t,p,syst,k)$(comb(r,c,s,t,p,syst)and
RPP(r,c,prd,p))=normal(yield(r,c,prd,s,t,p,syst),sum((gr)$(FFC(gr,c)),vari_yld(gr)*yield(r
,c,prd,s,t,p,syst)/100));
```

It should also be changed at Trend_2013.gms:

```
yieldn(r,c,prd,s,t,p,syst,k)$(comb(r,c,s,t,p,syst)and
RPP(r,c,prd,p))=normal(yield(r,c,prd,s,t,p,syst),sum((gr)$(FFC(gr,c)),vari_yld(gr)*yield(r
,c,prd,s,t,p,syst)/100));
```

The last change for vari_yld is made in FSSIM_results.gms:

```
* Marloes, changed vari_yield. In the parameter vari_yield is TIR not included anymore.
USED_DATA(R,P,C,"Average",S,T,SYS,'yield_var (%)',SENAR)$(X.L(R,S,T,SYS) and
comb(r,c,s,t,p,sys))              = sum((gr)$(FFC(gr,c)),vari_yld(gr));
```

2.4 Projection of trends

Trend_yield.inc and Trend_price.inc are not needed. Trend price, is already in the file price_change.inc. Trend price and trend yield are not like in FSSIM-EU calculated with an inflation rate, but calculations are based on historical time series. TechnoGIN is programmed such that rpices can be included per year, so in the linkage TechnoGIN-FSSIM it is more logical to use these vcalues instead of using a common inflation rate.d As only certain technologies can be selected per scenario, and the year for prices is linked ot the technologies, unput-output relationships already include the projected prices for 2015.

```
$onempty
PARAMETER TREND_Yield(CACT,*) "" /
/;
$offempty
```

Deleted in Trend_price.inc the data in it, because it is not needed.

```
$onempty
PARAMETER TREND_PRICE(CPRD,*) "" /
/;
$offempty
```

Trend_2013.gms

```
Costs(r,s,t,p,syst)=costs(r,s,t,p,syst)*INFLATE("BLY") ;
```

We do not make use of the inflation rate, but in the cost.inc file are the scenarios included.

```
Costs(r,s,t,p,syst)=costs(r,s,t,p,'BLY');
```

2.5 Improve forecasting capacity

FSSIM uses a PMP approach (Positive Mathematical Programming). In FSSIM-EU, the parameter alpha which is used for the PMP approach is defined as 1. In FSSIM-China alpha is coded as a parameter and is related to crops; the parameter that is developed is called alpha_c(gr).

The larger the value of alpha, the less sensitive the model is to price changes. The supply elasticity of the activity level is related to alpha (Kanellopoulos et al., 2010) according to:

$$\eta = \frac{p}{\alpha \cdot |\lambda|}$$

η = price elasticity of the supply level of an activity

λ = shadow price related to the calibration constraint per crop

p = revenues

Not only alpha_c(gr) is added, but also the formula for calculating alpha. The shadow price is already calculated by FSSIM. In case of running for a certain municipality, the correct revenues should be switch on. The revenues are put in a new file, reven.inc. The revenues per municipality are calculated by multiplying the yield with the price and adding the input and the basic subsidy. The price elasticity is put in a new file, eta.inc. The values for price elasticity for all crops are based on values of whole China (Lin, 2006). For rice the price elasticity is based on the average of early, middle and late rice (Lin, 2006) and is 0.208. The price elasticity for wheat is 0.167 and the price elasticity for rapeseed is 0.326 (Lin, 2006).

PMP-SF_solve.gms:

```
PARAMETER
ALPHA_C(GR)    " Vector that determines the weights of linear and non-linear costs of
the activities in the objective function "
eta(GR)        "Price elasticity, per crop"
reven(GR)      "Revenues per crop"
;
```

In PMP-SF_solve.gms the elasticity of rice, wheat and rapeseed is multiplied by 100 for the baseline and in case of running for the policy scenario it is multiplied by 1000.
PMP-SF_solve.gms:

```
$include FSSIM-MP\PMP\eta.inc

parameter eta    "" /
RIc    20.8
WHc    16.7
RAc    32.6
RIfc   20.8
WHfc   16.7
```

```
RAfc   32.6
RImc   20.8
RIfmc  20.8
RIssc  20.8
WHssc  16.7
RAssc  32.6
RIssmc 20.8
FALL   0.2
/;

$include FSSIM-MP\PMP\reven.inc

***Revenues to be used for Wuxi****
*$ontext
RIc       14994
WHc        9405
RAc       8507
RIfc      14448
WHfc       8716
RAfc      9504
RImc      15361
RIfmc      14283
RIssc      17932
WHssc       10298
RAssc      12245
RIssmc      17932
FALL      6750

*$offtext

***Revenues to be used for Changzhou****
$ontext
RIc       14204
WHc        8126
RAc       8678
RIfc      15165
WHfc       8220
RAfc      6723
RImc      14792
RIfmc      14978
RIssc      18279
RIssmc      18279
WHssc       9975
RAssc      1077
FALL      9000
$offtext

****Revenues to be used for Zhenjiang****
$ontext
RIc       12879
WHc        7543
RAc       7770
RIfc      14295
WHfc       7747
RAfc      7883
```

```
RImc       16343
RIfmc       15695
RIssc      18563
RIssmc       18563
WHssc       9814
RAssc       11359
FALL       7500
$offtext
/;

LAMDA(gr)$LEVLo(GR)  = E_CALIB_grL.M(GR)+E_CALIB_grU.M(GR);

alpha_c(GR)$(LAMDA(GR)ne 0)= reven(GR)/(eta(GR)*abs(LAMDA(GR)));

Q_SF(gr)$LEVLo(gr)   = abs(ALPHA_C(GR)*LAMDA(gr))/Levlo(gr) ;

D_SF(gr)$LEVLo(gr)   = LAMDA(gr)-abs(ALPHA_C(GR)*LAMDA(gr)) ;
```

2.6 Results per dekad

TechnoGIN is programmed such that several calculations are done per dekad. In this thesis this has not been used, but preparations are made in the model linkage. When running the model not for period, but per dekad, some files should be included.
Therefore I added a new set: DEKAD.

At Farm_sets.gms:

```
DEKAD         "Period of 10 days"

$include FSSIM-DM\INPUTDATA\FARM_SET\DEKAD.INC
SET DEKAD "" /
D1
D2
D3
…
D34
D35
D36
/;
```

Dekad is being used in the file MISCDAT_DEKAD.inc, MISCDAT_change_dekad.inc and in input_dekad.inc. Therefore I included these files.

At Farm_data.gms:

```
$include FSSIM-DM\INPUTDATA\FARM_DATA\MISCDAT_DEKAD.INC
$include FSSIM-DM\INPUTDATA\IO_DATA\INPUT_DEKAD.INC
```

At CommonPolicy_data.gms:

```
$include FSSIM-DM\INPUTDATA\FARM_DATA\Miscdat_change_dekad.INC
```

At Farm_data.gms I added the new parameter miscdat_dekad:

```
PARAMETER
    MISCDAT_DEKAD(*,DEKAD)            "Miscelaneous data: resources availability +
    dekad+ other information"
```

At Farm_data.gms I added the following:

D(DEKAD) = yes;

At Crops_model.gms I also added the following:

D(DEKAD) "Dekad"

When running with dekads instead of with periods lines should be added for FLabour per dekad and towater per dekad.

At Crops_model.gms I added the water constraint per dekad.

E_DEKADWATER "water constraint per dekad"
E_DEKADWATER(DEKAD) .. sum((r,s,t,sys) $rst(r,s,t,sys), X(R,S,T,SYS)* WATC(r,s,t,dekad,sys) / nr(r)) =l= DEKADWATER(DEKAD);

I added the following line at Farm_data.gms:

DEKADWATER(DEKAD) = MISCDAT_DEKAD('WATER',DEKAD);

When going to the baseline scenario the data for water per dekad change, therefore I added in the file Baseline2013_Data.gms the following:

DEKADWATER(DEKAD) = DEKADWATER(DEKAD) + (MISCDAT_Change_DEKAD("WATER",DEKAD,"BLY"));

In the policy file I also added a line for water per dekad.
Policy_EXP_Data.gms

DEKADWATER(DEKAD) = DEKADWATER(DEKAD) + (MISCDAT_Change_DEKAD("WATER",DEKAD,"POL"));

The equations are in the model, but they are not ask for when solving. So the equations are in the model, but are not being displayed in the model outcome.

2.7 Other changes

Displaying more economic results

At FSSIM_results.gms are several lines added for displaying more economic results. Two lines are added for displaying the farm income without hiring temporary labour. Also two lines are added for displaying the farm income without the PMP term. Two lines are added for displaying the farm income with the costs for permanent and family labour and one line for displaying the total costs with the inclusion of the costs for permanent and family labour.

ECONOMIC_RESULT('Farm income without PMP term',SENAR)=Z.l-PMPterm.l;
ECONOMIC_RESULT('Income without tlabour costs',SENAR)=Z.l+(TLABOUR.l*twage);
ECONOMIC_RESULT('Income with flabour costs',SENAR)=Z.l-(LUSE.L*(sum(s,toland(s))-sum(fgr,LEVLo(fgr)))*twage)+(TLABOUR.l*twage);
ECONOMIC_RESULT('Income per ha without PMP term',SENAR)=(Z.l-PMPterm.l)/(sum(s,toland(s))-sum(fgr,LEVLo(fgr)));
ECONOMIC_RESULT('Income/ha without tlabour costs',SENAR)=(Z.l+(TLABOUR.l*twage))/(sum(s,toland(s))-sum(fgr,LEVLo(fgr)));
ECONOMIC_RESULT('Income/ha with flabour costs',SENAR)=(Z.l-(LUSE.L*(sum(s,toland(s))-sum(fgr,LEVLo(fgr)))*twage)+(TLABOUR.l*twage))/(sum(s,toland(s))-sum(fgr,LEVLo(fgr)));
ECONOMIC_RESULT('Total costs with flabour(Yuan)',SENAR)=TCOST.l+(LUSE.L*(sum(s,toland(s))-sum(fgr,LEVLo(fgr)))*twage)+(TLABOUR.l*twage);

Gross production

For gross production only sales and price are needed for the calculation, therefore I will leave out the rest, as indicated by the stars.
At FSSIM_Model.gms:

```
E_GPRODT..   sum(cp(c,prd),SALES(c,prd)*price(c,prd))
*          + sum((c,prd,l)$(cp(c,prd) and cl(prd,l)),QSALES(c,prd,l)*Addprice(c,prd,l))
*          + sum(AP(An,prd),SALES(An,prd)*price(An,prd))
*          + sum((An,prd,l)$(ap(An,prd) and
cl(prd,l)),QSALES(An,prd,l)*Addprice(An,prd,l))
*          + sum((DA,An,Int,sys)$(DAN(DA,An) and DAT(DA,INT,sys) and
NAD(An)),DASELL(da,int,sys)*SHARE(DA,INT,An,sys)*price(An,"meat")*WEIGHT(
DA,INT,An,sys)/1000/NAD(An))
*          + NMAN_export*pmanure
*          + sum((r,s,t,p,sys)$(rst(r,s,t,sys)and
n(r,s,t,p,sys)),X(R,S,T,SYS)*n(r,s,t,p,sys)*pfertiliser/nr(r))
           =E= GPRODT ;
```

Modelstate folder
The MODELSTATE folder is now in FSSIM-MP instead of FSSIM-DM, all references are changed. This is changed, because in the folder FSSIM-DM are all input files and in the folder MODELSTATE are no input files. This facilitates the linkage with TechnoGIN. When running TechnoGIN, it creates a new FSSIM-DM folder with all files required.

Currency
The labour costs (TWAGE) are in Yuan/day instead of Euro/hour.
Available temporary labour (TLabour) and available family and permanent labour (FLabour) is in days instead of hours.
On other places in the text, I have made replacements of Euros to Yuan.
Basic premium (Basic_Prem) is in Yuan/ha.

Appendix III Input-output tables

TechnoGIN gives inputs for FSSIM. TechnoGIN quantifies the inputs and outputs for cropping systems at field level. So the complete database for inputs for FSSIM comes from TechnoGIN.

1.1 Input table

Table 1 gives several inputs for different kind of rotations, techniques and soil types:

1) Rotation
2) Technique
3) Soil type

For the following inputs:

4) Labour requirement (days)
5) N fertilization (kg N/ha/year)
6) P fertilization (kg P/ha/year)
7) K fertilization (kg K/ha/year)
8) Water requirement (mm)
9) Fertilizer costs (Yuan/ha/year)
10) Seed costs (Yuan/ha/year)
11) Insecticide costs (Yuan/ha/year)
12) Fungicide costs (Yuan/ha/year)
13) Herbicide costs (Yuan/ha/year)
14) Machinery rent costs (Yuan/ha/year)
15) MT rent costs (Yuan/ha/year)
16) Other costs (Yuan/ha/year)

Table 1. Inputs for different rotations coupled different techniques and different soil types for Wuxi

1 R	2 T	3 S	4 Lab req	5 N fert	6 P fert	7 K fert	8 Water req	9 Fert costs	10 Seed costs	11 Insect costs	12 Fungi costs	13 Herb costs	14 Mach rent	15 MT rent	16 Other costs
RIWH	A	CLAY	261	649	71	132	316	4,168	1,414	834	754	954	3,525	0	24,718
RIWH	D	CLAY	267	649	71	132	334	6,049	2,099	938	847	1,073	6,063	0	45,993

RIWH	G	CLAY	267	649	71	132	334	6,049	2,099	938	847	1,073	6,063	0	45,993
RIWH	A	LOAM	265	515	44	84	329	3,088	1,414	834	754	954	3,525	0	23,827
RIWH	D	LOAM	271	515	44	84	348	4,481	2,099	938	847	1,073	6,063	0	44,843
RIWH	G	LOAM	271	515	44	84	348	4,481	2,099	938	847	1,073	6,063	0	44,843
RIWH	A	SAND	267	543	183	135	331	4,374	1,414	834	754	954	3,525	0	25,184
RIWH	D	SAND	273	543	183	135	351	6,349	2,099	938	847	1,073	6,063	0	46,905
RIWH	G	SAND	273	543	183	135	351	6,349	2,099	938	847	1,073	6,063	0	46,905
RIRA	A	CLAY	385	607	71	129	302	3,910	5,089	774	583	1,134	3,600	0	34,321
RIRA	D	CLAY	399	607	71	129	307	5,675	7,558	871	656	1,274	6,192	0	65,403
RIRA	G	CLAY	399	607	71	129	307	5,675	7,558	871	656	1,274	6,192	0	65,403
RIRA	A	LOAM	371	444	44	114	311	3,092	5,089	774	583	1,134	3,600	0	32,815
RIRA	D	LOAM	383	444	44	114	317	4,487	7,558	871	656	1,274	6,192	0	62,521
RIRA	G	LOAM	383	444	44	114	317	4,487	7,558	871	656	1,274	6,192	0	62,521
RIRA	A	SAND	383	596	183	152	301	4,758	5,089	774	583	1,134	3,600	0	35,065
RIRA	D	SAND	396	596	183	152	306	6,906	7,558	871	656	1,274	6,192	0	66,383
RIRA	G	SAND	396	596	183	152	306	6,906	7,558	871	656	1,274	6,192	0	66,383
RI	A	CLAY	179	415	71	72	269	2,497	565	774	526	699	2,100	0	16,134
RI	D	CLAY	181	415	71	72	275	3,624	840	871	591	786	3,612	0	29,917
RI	G	CLAY	181	415	71	72	275	3,624	840	871	591	786	3,612	0	29,917
RI	A	LOAM	182	266	44	44	278	1,582	565	774	526	699	2,100	0	15,341
RI	D	LOAM	183	266	44	44	284	2,296	840	871	591	786	3,612	0	28,864
RI	G	LOAM	183	266	44	44	284	2,296	840	871	591	786	3,612	0	28,864
RI	A	SAND	179	424	183	99	269	3,476	565	774	526	699	2,100	0	17,101
RI	D	SAND	181	424	183	99	274	5,045	840	871	591	786	3,612	0	31,311
RI	G	SAND	181	424	183	99	274	5,045	840	871	591	786	3,612	0	31,311
WH	A	CLAY	82	235	62	61	17	1,670	848	60	228	255	1,425	0	8,578
WH	D	CLAY	86	235	62	61	21	2,424	1,260	67	257	287	2,451	0	16,039
WH	G	CLAY	86	235	62	61	21	2,424	1,260	67	257	287	2,451	0	16,039
WH	A	LOAM	83	250	40	40	18	1,506	848	60	228	255	1,425	0	8,487
WH	D	LOAM	87	250	40	40	22	2,186	1,260	67	257	287	2,451	0	15,978
WH	G	LOAM	87	250	40	40	22	2,186	1,260	67	257	287	2,451	0	15,978
WH	A	SAND	87	119	36	36	22	899	848	60	228	255	1,425	0	8,083
WH	D	SAND	92	119	36	36	27	1,304	1,260	67	257	287	2,451	0	15,594
WH	G	SAND	92	119	36	36	27	1,304	1,260	67	257	287	2,451	0	15,594
WH	A	UCLAY	82	0	0	0	17	0	848	60	228	255	1,425	0	6,907
WH	D	UCLAY	86	0	0	0	21	0	1,260	67	257	287	2,451	0	13,615

WH	G	UCLAY	86	0	0	0	21	0	1,260	67	257	287	2,451	0	13,615
WH	A	ULOAM	83	0	0	0	18	0	848	60	228	255	1,425	0	6,981
WH	D	ULOAM	87	0	0	0	22	0	1,260	67	257	287	2,451	0	13,793
WH	G	ULOAM	87	0	0	0	22	0	1,260	67	257	287	2,451	0	13,793
WH	A	USAND	87	0	0	0	22	0	848	60	228	255	1,425	0	7,185
WH	D	USAND	92	0	0	0	27	0	1,260	67	257	287	2,451	0	14,290
WH	G	USAND	92	0	0	0	27	0	1,260	67	257	287	2,451	0	14,290
RA	A	CLAY	205	193	56	58	48	1,413	4,524	0	58	435	1,500	0	18,187
RA	D	CLAY	221	193	56	58	49	2,051	6,718	0	65	489	2,580	0	35,841
RA	G	CLAY	221	193	56	58	49	2,051	6,718	0	65	489	2,580	0	35,841
RA	A	LOAM	189	178	71	71	48	1,510	4,524	0	58	435	1,500	0	17,474
RA	D	LOAM	202	178	71	71	48	2,192	6,718	0	65	489	2,580	0	33,955
RA	G	LOAM	202	178	71	71	48	2,192	6,718	0	65	489	2,580	0	33,955
RA	A	SAND	203	172	53	53	48	1,282	4,524	0	58	435	1,500	0	17,964
RA	D	SAND	219	172	53	53	48	1,861	6,718	0	65	489	2,580	0	35,421
RA	G	SAND	219	172	53	53	48	1,861	6,718	0	65	489	2,580	0	35,421
RA	A	UCLAY	205	0	0	0	48	0	4,524	0	58	435	1,500	0	16,774
RA	D	UCLAY	221	0	0	0	49	0	6,718	0	65	489	2,580	0	33,790
RA	G	UCLAY	221	0	0	0	49	0	6,718	0	65	489	2,580	0	33,790
RA	A	ULOAM	189	0	0	0	48	0	4,524	0	58	435	1,500	0	15,964
RA	D	ULOAM	202	0	0	0	48	0	6,718	0	65	489	2,580	0	31,764
RA	G	ULOAM	202	0	0	0	48	0	6,718	0	65	489	2,580	0	31,764
RA	A	USAND	203	0	0	0	48	0	4,524	0	58	435	1,500	0	16,682
RA	D	USAND	219	0	0	0	48	0	6,718	0	65	489	2,580	0	33,560
RA	G	USAND	219	0	0	0	48	0	6,718	0	65	489	2,580	0	33,560
RIfWHf	B	CLAY	245	586	39	147	312	3,869	1,414	834	754	954	3,525	0	23,590
RIfWHf	E	CLAY	250	586	39	147	326	5,615	2,099	938	847	1,073	6,063	0	43,726
RIfWHf	H	CLAY	250	586	39	147	326	5,345	2,099	938	847	1,073	6,063	0	43,455
RIfWHf	B	LOAM	253	588	41	143	339	3,748	1,414	834	754	954	3,525	0	23,865
RIfWHf	E	LOAM	258	588	41	143	357	5,439	2,099	938	847	1,073	6,063	0	44,448
RIfWHf	H	LOAM	258	588	41	143	357	5,314	2,099	938	847	1,073	6,063	0	44,323
RIfWHf	B	SAND	239	908	41	202	312	5,606	1,414	834	754	954	3,525	0	25,042
RIfWHf	E	SAND	244	908	41	202	322	8,136	2,099	938	847	1,073	6,063	0	45,601
RIfWHf	H	SAND	244	908	41	202	322	7,818	2,099	938	847	1,073	6,063	0	45,283
RIfRAf	B	CLAY	362	545	39	113	299	3,414	5,089	774	583	1,134	3,600	0	32,678
RIfRAf	E	CLAY	375	545	39	113	302	4,954	7,558	871	656	1,274	6,192	0	62,139

RIfRAf	H	CLAY	375	545	39	113	302	4,754	7,558	871	656	1,274	6,192	0	61,939
RIfRAf	B	LOAM	391	600	41	136	334	3,719	5,089	774	583	1,134	3,600	0	34,450
RIfRAf	E	LOAM	408	600	41	136	353	5,397	7,558	871	656	1,274	6,192	0	66,085
RIfRAf	H	LOAM	408	600	41	136	353	5,320	7,558	871	656	1,274	6,192	0	66,009
RIfRAf	B	SAND	367	742	41	190	299	4,942	5,089	774	583	1,134	3,600	0	34,480
RIfRAf	E	SAND	382	742	41	190	310	7,172	7,558	871	656	1,274	6,192	0	65,072
RIfRAf	H	SAND	382	742	41	190	310	6,811	7,558	871	656	1,274	6,192	0	64,711
RIf	B	CLAY	168	350	39	70	267	2,136	565	774	526	699	2,100	0	15,178
RIf	E	CLAY	169	350	39	70	270	3,099	840	871	591	786	3,612	0	28,099
RIf	H	CLAY	169	350	39	70	270	2,960	840	871	591	786	3,612	0	27,960
RIf	B	LOAM	175	367	41	76	291	2,221	565	774	526	699	2,100	0	15,636
RIf	E	LOAM	177	367	41	76	298	3,223	840	871	591	786	3,612	0	29,064
RIf	H	LOAM	177	367	41	76	298	3,174	840	871	591	786	3,612	0	29,015
RIf	B	SAND	162	443	41	82	267	2,611	565	774	526	699	2,100	0	15,380
RIf	E	SAND	163	443	41	82	267	3,790	840	871	591	786	3,612	0	28,173
RIf	H	SAND	163	443	41	82	267	3,636	840	871	591	786	3,612	0	28,020
WHf	B	CLAY	77	236	45	78	16	1,734	848	60	228	255	1,425	0	8,412
WHf	E	CLAY	81	236	45	78	20	2,516	1,260	67	257	287	2,451	0	15,626
WHf	H	CLAY	81	236	45	78	20	2,385	1,260	67	257	287	2,451	0	15,495
WHf	B	LOAM	78	221	35	66	17	1,527	848	60	228	255	1,425	0	8,229
WHf	E	LOAM	82	221	35	66	20	2,216	1,260	67	257	287	2,451	0	15,384
WHf	H	LOAM	82	221	35	66	20	2,140	1,260	67	257	287	2,451	0	15,308
WHf	B	SAND	77	465	60	120	16	2,995	848	60	228	255	1,425	0	9,661
WHf	E	SAND	81	465	60	120	20	4,347	1,260	67	257	287	2,451	0	17,428
WHf	H	SAND	81	465	60	120	20	4,181	1,260	67	257	287	2,451	0	17,263
WHf	B	UCLAY	77	0	0	0	16	0	848	60	228	255	1,425	0	6,678
WHf	E	UCLAY	81	0	0	0	20	0	1,260	67	257	287	2,451	0	13,110
WHf	H	UCLAY	81	0	0	0	20	0	1,260	67	257	287	2,451	0	13,110
WHf	B	ULOAM	78	0	0	0	17	0	848	60	228	255	1,425	0	6,702
WHf	E	ULOAM	82	0	0	0	20	0	1,260	67	257	287	2,451	0	13,168
WHf	H	ULOAM	82	0	0	0	20	0	1,260	67	257	287	2,451	0	13,168
WHf	B	USAND	77	0	0	0	16	0	848	60	228	255	1,425	0	6,666
WHf	E	USAND	81	0	0	0	20	0	1,260	67	257	287	2,451	0	13,081
WHf	H	USAND	81	0	0	0	20	0	1,260	67	257	287	2,451	0	13,081
RAf	B	CLAY	194	195	29	44	48	1,278	4,524	0	58	435	1,500	0	17,500
RAf	E	CLAY	209	195	29	44	49	1,855	6,718	0	65	489	2,580	0	34,381

RAf	H	CLAY	209	195	29	44	49	1,794	6,718	0	65	489	2,580	0	34,320
RAf	B	LOAM	216	233	30	60	52	1,498	4,524	0	58	435	1,500	0	18,814
RAf	E	LOAM	235	233	30	60	60	2,173	6,718	0	65	489	2,580	0	37,439
RAf	H	LOAM	235	233	30	60	60	2,146	6,718	0	65	489	2,580	0	37,411
RAf	B	SAND	205	298	73	108	48	2,331	4,524	0	58	435	1,500	0	19,100
RAf	E	SAND	222	298	73	108	54	3,382	6,718	0	65	489	2,580	0	37,278
RAf	H	SAND	222	298	73	108	54	3,174	6,718	0	65	489	2,580	0	37,070
RAf	B	UCLAY	194	0	0	0	48	0	4,524	0	58	435	1,500	0	16,222
RAf	E	UCLAY	209	0	0	0	49	0	6,718	0	65	489	2,580	0	32,526
RAf	H	UCLAY	209	0	0	0	49	0	6,718	0	65	489	2,580	0	32,526
RAf	B	ULOAM	216	0	0	0	52	0	4,524	0	58	435	1,500	0	17,316
RAf	E	ULOAM	235	0	0	0	60	0	6,718	0	65	489	2,580	0	35,266
RAf	H	ULOAM	235	0	0	0	60	0	6,718	0	65	489	2,580	0	35,266
RAf	B	USAND	205	0	0	0	48	0	4,524	0	58	435	1,500	0	16,769
RAf	E	USAND	222	0	0	0	54	0	6,718	0	65	489	2,580	0	33,896
RAf	H	USAND	222	0	0	0	54	0	6,718	0	65	489	2,580	0	33,896
RImWH	A	CLAY	197	695	86	155	292	4,564	848	830	751	951	3,675	1,125	22,573
RImWH	D	CLAY	202	695	86	155	310	6,624	1,260	934	844	1,069	6,321	1,935	40,869
RImWH	G	CLAY	202	695	86	155	310	6,624	1,260	934	844	1,069	6,321	1,935	40,869
RImWH	A	LOAM	202	610	43	80	310	3,468	848	830	751	951	3,675	1,125	21,729
RImWH	D	LOAM	207	610	43	80	328	5,032	1,260	934	844	1,069	6,321	1,935	39,860
RImWH	G	LOAM	207	610	43	80	328	5,032	1,260	934	844	1,069	6,321	1,935	39,860
RImWH	A	SAND	203	407	48	84	311	2,662	848	830	751	951	3,675	1,125	20,986
RImWH	D	SAND	209	407	48	84	331	3,863	1,260	934	844	1,069	6,321	1,935	38,868
RImWH	G	SAND	209	407	48	84	331	3,863	1,260	934	844	1,069	6,321	1,935	38,868
RImRA	A	CLAY	320	653	86	152	316	4,307	4,524	770	581	1,131	3,750	1,125	32,182
RImRA	D	CLAY	334	653	86	152	322	6,251	6,718	866	653	1,270	6,450	1,935	60,315
RImRA	G	CLAY	334	653	86	152	322	6,251	6,718	866	653	1,270	6,450	1,935	60,315
RImRA	A	LOAM	307	538	43	110	329	3,472	4,524	770	581	1,131	3,750	1,125	30,717
RImRA	D	LOAM	320	538	43	110	334	5,038	6,718	866	653	1,270	6,450	1,935	57,538
RImRA	G	LOAM	320	538	43	110	334	5,038	6,718	866	653	1,270	6,450	1,935	57,538
RImRA	A	SAND	319	460	48	101	319	3,046	4,524	770	581	1,131	3,750	1,125	30,867
RImRA	D	SAND	333	460	48	101	324	4,420	6,718	866	653	1,270	6,450	1,935	58,346
RImRA	G	SAND	333	460	48	101	324	4,420	6,718	866	653	1,270	6,450	1,935	58,346
RIm	A	CLAY	115	461	86	94	270	2,894	0	770	523	696	2,250	1,125	13,995
RIm	D	CLAY	116	461	86	94	275	4,200	0	866	588	782	3,870	1,935	24,829

RIm	G	CLAY	116	461	86	94	275	4,200	0	866	588	782	3,870	1,935	24,829
RIm	A	LOAM	118	360	43	40	283	1,962	0	770	523	696	2,250	1,125	13,242
RIm	D	LOAM	120	360	43	40	288	2,847	0	866	588	782	3,870	1,935	23,881
RIm	G	LOAM	120	360	43	40	288	2,847	0	866	588	782	3,870	1,935	23,881
RIm	A	SAND	116	288	48	48	273	1,763	0	770	523	696	2,250	1,125	12,902
RIm	D	SAND	117	288	48	48	278	2,559	0	866	588	782	3,870	1,935	23,274
RIm	G	SAND	117	288	48	48	278	2,559	0	866	588	782	3,870	1,935	23,274
RIfmWHf	B	CLAY	186	489	41	157	288	3,499	848	830	751	951	3,675	1,125	20,955
RIfmWHf	E	CLAY	191	489	41	157	302	5,078	1,260	934	844	1,069	6,321	1,935	38,112
RIfmWHf	H	CLAY	191	489	41	157	302	4,864	1,260	934	844	1,069	6,321	1,935	37,897
RIfmWHf	B	LOAM	186	478	43	152	288	3,360	848	830	751	951	3,675	1,125	20,840
RIfmWHf	E	LOAM	191	478	43	152	304	4,876	1,260	934	844	1,069	6,321	1,935	37,968
RIfmWHf	H	LOAM	191	478	43	152	304	4,696	1,260	934	844	1,069	6,321	1,935	37,787
RIfmWHf	B	SAND	185	795	45	198	288	5,117	848	830	751	951	3,675	1,125	22,561
RIfmWHf	E	SAND	191	795	45	198	301	7,426	1,260	934	844	1,069	6,321	1,935	40,431
RIfmWHf	H	SAND	191	795	45	198	301	7,129	1,260	934	844	1,069	6,321	1,935	40,134
RIfmRAf	B	CLAY	302	447	41	123	313	3,044	4,524	770	581	1,131	3,750	1,125	30,043
RIfmRAf	E	CLAY	316	447	41	123	316	4,417	6,718	866	653	1,270	6,450	1,935	56,525
RIfmRAf	H	CLAY	316	447	41	123	316	4,273	6,718	866	653	1,270	6,450	1,935	56,382
RIfmRAf	B	LOAM	324	490	43	145	318	3,330	4,524	770	581	1,131	3,750	1,125	31,425
RIfmRAf	E	LOAM	341	490	43	145	330	4,833	6,718	866	653	1,270	6,450	1,935	59,605
RIfmRAf	H	LOAM	341	490	43	145	330	4,702	6,718	866	653	1,270	6,450	1,935	59,473
RIfmRAf	B	SAND	313	628	45	186	313	4,453	4,524	770	581	1,131	3,750	1,125	32,000
RIfmRAf	E	SAND	328	628	45	186	323	6,462	6,718	866	653	1,270	6,450	1,935	59,902
RIfmRAf	H	SAND	328	628	45	186	323	6,122	6,718	866	653	1,270	6,450	1,935	59,562
RIfm	B	CLAY	108	252	41	79	267	1,765	0	770	523	696	2,250	1,125	12,544
RIfm	E	CLAY	110	252	41	79	270	2,562	0	866	588	782	3,870	1,935	22,485
RIfm	H	CLAY	110	252	41	79	270	2,479	0	866	588	782	3,870	1,935	22,403
RIfm	B	LOAM	108	258	43	85	267	1,833	0	770	523	696	2,250	1,125	12,611
RIfm	E	LOAM	110	258	43	85	270	2,660	0	866	588	782	3,870	1,935	22,583
RIfm	H	LOAM	110	258	43	85	270	2,556	0	866	588	782	3,870	1,935	22,479
RIfm	B	SAND	108	330	45	78	267	2,122	0	770	523	696	2,250	1,125	12,900
RIfm	E	SAND	110	330	45	78	270	3,079	0	866	588	782	3,870	1,935	23,003
RIfm	H	SAND	110	330	45	78	270	2,948	0	866	588	782	3,870	1,935	22,871
RIsWHs	C	CLAY	280	234	34	71	357	1,723	1,414	834	754	954	3,525	0	23,181
RIsWHs	F	CLAY	282	257	35	75	366	2,727	2,099	938	847	1,073	6,063	0	44,310

RIsWHs	I	CLAY	313	311	40	102	406	3,306	2,099	938	847	1,073	6,063	0	48,254
RIsWHs	C	LOAM	284	335	46	115	372	2,483	1,414	834	754	954	3,525	0	24,139
RIsWHs	F	LOAM	286	363	48	121	382	3,897	2,099	938	847	1,073	6,063	0	45,929
RIsWHs	I	LOAM	313	362	44	115	406	3,774	2,099	938	847	1,073	6,063	0	48,722
RIsWHs	C	SAND	277	294	39	87	346	2,168	1,414	834	754	954	3,525	0	23,484
RIsWHs	F	SAND	279	315	40	90	354	3,385	2,099	938	847	1,073	6,063	0	44,646
RIsWHs	I	SAND	313	393	49	128	406	4,172	2,099	938	847	1,073	6,063	0	49,120
RIsRAs	C	CLAY	434	191	35	82	350	1,464	5,089	774	583	1,134	3,600	0	34,336
RIsRAs	F	CLAY	441	207	36	87	358	2,268	7,558	871	656	1,274	6,192	0	66,534
RIsRAs	I	CLAY	506	281	41	115	397	3,082	7,558	871	656	1,274	6,192	0	74,374
RIsRAs	C	LOAM	449	299	47	126	374	2,255	5,089	774	583	1,134	3,600	0	35,861
RIsRAs	F	LOAM	457	322	49	133	384	3,502	7,558	871	656	1,274	6,192	0	69,519
RIsRAs	I	LOAM	506	327	45	128	397	3,526	7,558	871	656	1,274	6,192	0	74,818
RIsRAs	C	SAND	437	255	40	97	344	1,934	5,089	774	583	1,134	3,600	0	34,944
RIsRAs	F	SAND	444	270	41	101	352	3,040	7,558	871	656	1,274	6,192	0	67,663
RIsRAs	I	SAND	506	359	49	140	397	3,881	7,558	871	656	1,274	6,192	0	75,173
RIs	C	CLAY	190	140	35	69	291	1,133	565	774	526	699	2,100	0	15,286
RIs	F	CLAY	191	148	36	73	294	1,720	840	871	591	786	3,612	0	29,049
RIs	I	CLAY	212	190	41	95	318	2,179	840	871	591	786	3,612	0	31,782
RIs	C	LOAM	194	214	47	109	305	1,717	565	774	526	699	2,100	0	16,057
RIs	F	LOAM	194	225	49	115	308	2,580	840	871	591	786	3,612	0	30,329
RIs	I	LOAM	212	215	45	107	318	2,437	840	871	591	786	3,612	0	32,039
RIs	C	SAND	187	167	39	83	282	1,358	565	774	526	699	2,100	0	15,375
RIs	F	SAND	188	173	40	86	284	2,023	840	871	591	786	3,612	0	29,043
RIs	I	SAND	212	240	49	118	318	2,712	840	871	591	786	3,612	0	32,314
WHs	C	CLAY	90	116	23	0	23	704	848	60	228	255	1,425	0	8,009
WHs	F	CLAY	92	130	26	0	25	1,133	1,260	67	257	287	2,451	0	15,387
WHs	I	CLAY	102	138	29	0	29	1,252	1,260	67	257	287	2,451	0	16,597
WHs	C	LOAM	90	141	29	0	23	869	848	60	228	255	1,425	0	8,186
WHs	F	LOAM	92	158	33	0	25	1,374	1,260	67	257	287	2,451	0	15,658
WHs	I	LOAM	102	163	34	11	29	1,460	1,260	67	257	287	2,451	0	16,805
WHs	C	SAND	90	144	35	4	23	915	848	60	228	255	1,425	0	8,214
WHs	F	SAND	92	159	39	11	24	1,494	1,260	67	257	287	2,451	0	15,734
WHs	I	SAND	102	165	40	29	29	1,610	1,260	67	257	287	2,451	0	16,955
WHs	C	UCLAY	90	116	23	0	23	704	848	60	228	255	1,425	0	8,009
WHs	F	UCLAY	92	130	26	0	25	1,133	1,260	67	257	287	2,451	0	15,387

WHs	I	UCLAY	102	138	29	0	29	1,252	1,260	67	257	287	2,451	0	16,597
WHs	C	ULOAM	90	141	29	0	23	869	848	60	228	255	1,425	0	8,186
WHs	F	ULOAM	92	158	33	0	25	1,374	1,260	67	257	287	2,451	0	15,658
WHs	I	ULOAM	102	163	34	11	29	1,460	1,260	67	257	287	2,451	0	16,805
WHs	C	USAND	90	144	35	4	23	915	848	60	228	255	1,425	0	8,214
WHs	F	USAND	92	159	39	11	24	1,494	1,260	67	257	287	2,451	0	15,734
WHs	I	USAND	102	165	40	29	29	1,610	1,260	67	257	287	2,451	0	16,955
RAs	C	CLAY	244	65	7	0	60	363	4,524	0	58	435	1,500	0	19,082
RAs	F	CLAY	252	74	10	0	64	637	6,718	0	65	489	2,580	0	37,744
RAs	I	CLAY	294	100	17	0	72	879	6,718	0	65	489	2,580	0	42,568
RAs	C	LOAM	255	98	17	0	66	576	4,524	0	58	435	1,500	0	19,842
RAs	F	LOAM	264	112	20	0	72	934	6,718	0	65	489	2,580	0	39,411
RAs	I	LOAM	294	121	23	0	72	1,065	6,718	0	65	489	2,580	0	42,754
RAs	C	SAND	250	98	23	0	63	629	4,524	0	58	435	1,500	0	19,621
RAs	F	SAND	258	109	25	0	68	1,010	6,718	0	65	489	2,580	0	38,803
RAs	I	SAND	294	126	29	5	72	1,160	6,718	0	65	489	2,580	0	42,849
RAs	C	UCLAY	244	65	7	0	60	363	4,524	0	58	435	1,500	0	19,082
RAs	F	UCLAY	252	74	10	0	64	637	6,718	0	65	489	2,580	0	37,744
RAs	I	UCLAY	294	100	17	0	72	879	6,718	0	65	489	2,580	0	42,568
RAs	C	ULOAM	255	98	17	0	66	576	4,524	0	58	435	1,500	0	19,842
RAs	F	ULOAM	264	112	20	0	72	934	6,718	0	65	489	2,580	0	39,411
RAs	I	ULOAM	294	121	23	0	72	1,065	6,718	0	65	489	2,580	0	42,754
RAs	C	USAND	250	98	23	0	63	629	4,524	0	58	435	1,500	0	19,621
RAs	F	USAND	258	109	25	0	68	1,010	6,718	0	65	489	2,580	0	38,803
RAs	I	USAND	294	126	29	5	72	1,160	6,718	0	65	489	2,580	0	42,849
RIsmWHs	C	CLAY	215	272	40	93	341	2,002	848	830	751	951	3,675	1,125	20,952
RIsmWHs	F	CLAY	218	296	41	98	350	3,134	1,260	934	844	1,069	6,321	1,935	39,114
RIsmWHs	I	CLAY	245	378	51	142	391	4,034	1,260	934	844	1,069	6,321	1,935	42,906
RIsmWHs	C	LOAM	216	327	45	109	342	2,404	848	830	751	951	3,675	1,125	21,367
RIsmWHs	F	LOAM	218	353	46	114	351	3,777	1,260	934	844	1,069	6,321	1,935	39,786
RIsmWHs	I	LOAM	245	430	55	155	391	4,549	1,260	934	844	1,069	6,321	1,935	43,421
RIsmWHs	C	SAND	215	360	50	124	341	2,679	848	830	751	951	3,675	1,125	21,623
RIsmWHs	F	SAND	218	385	51	129	349	4,126	1,260	934	844	1,069	6,321	1,935	40,092
RIsmWHs	I	SAND	245	461	59	167	391	4,867	1,260	934	844	1,069	6,321	1,935	43,739
RIsmRAs	C	CLAY	370	228	41	104	363	1,782	4,524	770	581	1,131	3,750	1,125	32,147
RIsmRAs	F	CLAY	376	245	42	110	370	2,712	6,718	866	653	1,270	6,450	1,935	61,374

RIsmRAs	I	CLAY	437	347	52	155	406	3,768	6,718	866	653	1,270	6,450	1,935	68,984
RIsmRAs	C	LOAM	381	290	46	120	371	2,213	4,524	770	581	1,131	3,750	1,125	33,125
RIsmRAs	F	LOAM	389	310	47	125	380	3,382	6,718	866	653	1,270	6,450	1,935	63,376
RIsmRAs	I	LOAM	437	394	56	167	406	4,209	6,718	866	653	1,270	6,450	1,935	69,424
RIsmRAs	C	SAND	375	319	50	134	367	2,426	4,524	770	581	1,131	3,750	1,125	33,064
RIsmRAs	F	SAND	383	338	52	140	375	3,783	6,718	866	653	1,270	6,450	1,935	63,111
RIsmRAs	I	SAND	437	427	60	179	406	4,665	6,718	866	653	1,270	6,450	1,935	69,881
RIsm	C	CLAY	126	170	40	86	299	1,382	0	770	523	696	2,250	1,125	13,028
RIsm	F	CLAY	126	179	42	91	302	2,060	0	866	588	782	3,870	1,935	23,785
RIsm	I	CLAY	143	250	51	128	326	2,789	0	866	588	782	3,870	1,935	26,315
RIsm	C	LOAM	126	198	45	101	299	1,595	0	770	523	696	2,250	1,125	13,241
RIsm	F	LOAM	126	207	46	106	302	2,388	0	866	588	782	3,870	1,935	24,113
RIsm	I	LOAM	143	276	55	140	326	3,052	0	866	588	782	3,870	1,935	26,578
RIsm	C	SAND	126	227	49	115	299	1,808	0	770	523	696	2,250	1,125	13,454
RIsm	F	SAND	126	236	51	120	302	2,700	0	866	588	782	3,870	1,935	24,425
RIsm	I	SAND	143	303	59	151	326	3,364	0	866	588	782	3,870	1,935	26,891
FALL	A	CLAY	0	0	0	0	169	0	0	0	0	0	0	0	0
FALL	D	CLAY	0	0	0	0	169	0	0	0	0	0	0	0	0
FALL	G	CLAY	0	0	0	0	169	0	0	0	0	0	0	0	0
FALL	A	LOAM	0	0	0	0	169	0	0	0	0	0	0	0	0
FALL	D	LOAM	0	0	0	0	169	0	0	0	0	0	0	0	0
FALL	G	LOAM	0	0	0	0	169	0	0	0	0	0	0	0	0
FALL	A	SAND	0	0	0	0	169	0	0	0	0	0	0	0	0
FALL	D	SAND	0	0	0	0	169	0	0	0	0	0	0	0	0
FALL	G	SAND	0	0	0	0	169	0	0	0	0	0	0	0	0
FALL	A	UCLAY	0	0	0	0	169	0	0	0	0	0	0	0	0
FALL	D	UCLAY	0	0	0	0	169	0	0	0	0	0	0	0	0
FALL	G	UCLAY	0	0	0	0	169	0	0	0	0	0	0	0	0
FALL	A	ULOAM	0	0	0	0	169	0	0	0	0	0	0	0	0
FALL	D	ULOAM	0	0	0	0	169	0	0	0	0	0	0	0	0
FALL	G	ULOAM	0	0	0	0	169	0	0	0	0	0	0	0	0
FALL	A	USAND	0	0	0	0	169	0	0	0	0	0	0	0	0
FALL	D	USAND	0	0	0	0	169	0	0	0	0	0	0	0	0
FALL	G	USAND	0	0	0	0	169	0	0	0	0	0	0	0	0

1.2 Output table

Table 2 gives several outputs for different kind of rotations, techniques and soil types:

1) Rotation
2) Technique
3) Soil

For the following outputs:

4) Bio Residue Index (-)
5) N surplus (kg N/ha/year)
6) N denitrification (kg N/ha/year)
7) N volatilization (kg N/ha/year)
8) N leaching (kg N/ha/year)
9) P surplus (kg P/ha/year)
10) P run-off (kg P/ha/year)
11) K surplus (kg K/ha/year)
12) K leaching (kg K/ha/year)

Table 2. Outputs for different rotations coupled different techniques and different soil types for Wuxi

1	2	3	4	5	6	7	8	9	10	11	12
R	T	S	BRI	N surplus	N den	N vol	N leaching	P surplus	P run-off	K surplus	K leaching
RIWH	A	CLAY	641	48.7	204	175	152	12.8	1.8	87.6	95
RIWH	D	CLAY	641	43.4	199	172	147	9.8	1.8	77.3	96
RIWH	G	CLAY	641	43.4	199	172	147	9.8	1.8	77.3	96
RIWH	A	LOAM	641	0	147	131	140	0	1.0	59.4	63
RIWH	D	LOAM	641	0	140	126	133	0	0.9	44.4	67
RIWH	G	LOAM	641	0	140	126	133	0	0.9	44.4	67
RIWH	A	SAND	641	29.8	129	164	101	23.9	2.5	29.4	102
RIWH	D	SAND	641	24.6	122	160	92	23.2	2.5	14.1	106
RIWH	G	SAND	641	24.6	122	160	92	23.2	2.5	14.1	106
RIRA	A	CLAY	516	73.3	191	167	139	18.4	1.7	120.9	72
RIRA	D	CLAY	516	59.4	191	167	140	16.4	1.7	115.1	70
RIRA	G	CLAY	516	59.4	191	167	140	16.4	1.7	115.1	70
RIRA	A	LOAM	516	30.1	128	119	117	15.6	1.4	104.7	57

RIRA	D	LOAM	516	22.9	126	116	115	14.4	1.3	94.9	58
RIRA	G	LOAM	516	22.9	126	116	115	14.4	1.3	94.9	58
RIRA	A	SAND	516	39.6	162	182	145	30.9	2.8	82.7	81
RIRA	D	SAND	516	26	162	182	145	28.8	2.8	77.1	79
RIRA	G	SAND	516	26	162	182	145	28.8	2.8	77.1	79
RI	A	CLAY	476	42.7	132	138	84	4.4	1.0	0	49
RI	D	CLAY	476	37.5	132	138	84	3.7	1.0	0	46
RI	G	CLAY	476	37.5	132	138	84	3.7	1.0	0	46
RI	A	LOAM	476	0	80	93	56	0	0.5	0	20
RI	D	LOAM	476	0	78	91	54	0	0.5	-1.8	19
RI	G	LOAM	476	0	78	91	54	0	0.5	-1.8	19
RI	A	SAND	476	25.4	118	158	85	23.6	2.3	0	57
RI	D	SAND	476	20.2	118	158	85	22.9	2.3	0	55
RI	G	SAND	476	20.2	118	158	85	22.9	2.3	0	55
WH	A	CLAY	165	0	82	42	77	6	0.8	56.6	58
WH	D	CLAY	165	0	77	40	72	3.7	0.9	46.2	62
WH	G	CLAY	165	0	77	40	72	3.7	0.9	46.2	62
WH	A	LOAM	165	0	73	40	92	0	0.5	30.5	56
WH	D	LOAM	165	0	69	37	86	0	0.5	19.2	61
WH	G	LOAM	165	0	69	37	86	0	0.5	19.2	61
WH	A	SAND	165	0	20	11	26	0	0.4	1.8	60
WH	D	SAND	165	0	13	7	17	0	0.3	0	57
WH	G	SAND	165	0	13	7	17	0	0.3	0	57
WH	A	UCLAY	165	-53.4	8	4	7	-6	0.1	0	56
WH	D	UCLAY	165	-66.5	9	4	8	-8.3	0.1	0	53
WH	G	UCLAY	165	-66.5	9	4	8	-8.3	0.1	0	53
WH	A	ULOAM	165	-63.7	7	4	9	-9.6	0.1	0	50
WH	D	ULOAM	165	-77.9	8	4	9	-12	0.1	0	47
WH	G	ULOAM	165	-77.9	8	4	9	-12	0.1	0	47
WH	A	USAND	165	-83.1	7	4	9	-14.7	0.1	-1.5	38
WH	D	USAND	165	-103.1	8	4	10	-18.1	0.1	-16.5	44
WH	G	USAND	165	-103.1	8	4	10	-18.1	0.1	-16.5	44
RA	A	CLAY	40	22.8	70	36	66	12.1	0.8	91.6	37
RA	D	CLAY	40	11.8	70	36	66	10.3	0.8	83.3	39
RA	G	CLAY	40	11.8	70	36	66	10.3	0.8	83.3	39
RA	A	LOAM	40	25.2	57	31	72	13.9	0.9	85.3	46

RA	D	LOAM	40	16	57	31	72	12.4	0.9	78.2	48
RA	G	LOAM	40	16	57	31	72	12.4	0.9	78.2	48
RA	A	SAND	40	8.4	54	31	71	5.8	0.6	55.7	40
RA	D	SAND	40	0	53	30	70	4.1	0.6	47.5	42
RA	G	SAND	40	0	53	30	70	4.1	0.6	47.5	42
RA	A	UCLAY	40	-15.7	7	4	7	0	0.1	0	57
RA	D	UCLAY	40	-26.7	8	4	7	-0.9	0.0	0	54
RA	G	UCLAY	40	-26.7	8	4	7	-0.9	0.0	0	54
RA	A	ULOAM	40	-10.4	6	3	8	-0.2	0.0	0	56
RA	D	ULOAM	40	-19.6	7	3	8	-1.7	0.0	0	53
RA	G	ULOAM	40	-19.6	7	3	8	-1.7	0.0	0	53
RA	A	USAND	40	-26.1	6	3	8	-4.7	0.0	0	42
RA	D	USAND	40	-36.9	6	3	8	-6.5	0.0	0	38
RA	G	USAND	40	-36.9	6	3	8	-6.5	0.0	0	38
RIfWHf	B	CLAY	641	40.8	186	155	142	4.9	1.1	92.7	103
RIfWHf	E	CLAY	641	35.7	182	152	137	2.7	1.1	83.3	104
RIfWHf	H	CLAY	641	35.7	182	152	137	2.7	1.1	83.3	104
RIfWHf	B	LOAM	641	5.8	167	161	148	0	0.9	74.6	88
RIfWHf	E	LOAM	641	0	162	157	142	0	0.8	65.4	88
RIfWHf	H	LOAM	641	0	162	157	142	0	0.8	65.4	88
RIfWHf	B	SAND	641	90.5	247	237	256	0	1.1	63.7	138
RIfWHf	E	SAND	641	73.5	248	237	257	0	1.1	54.2	140
RIfWHf	H	SAND	641	73.5	248	237	257	0	1.1	54.2	140
RIfRAf	B	CLAY	516	68.4	172	147	128	8.8	0.9	118.7	66
RIfRAf	E	CLAY	516	55.1	172	147	128	7.5	0.9	113.1	65
RIfRAf	H	CLAY	516	55.1	172	147	128	7.5	0.9	113.1	65
RIfRAf	B	LOAM	516	20.7	173	163	156	3.8	0.8	96.7	64
RIfRAf	E	LOAM	516	8.1	171	161	155	2.2	0.8	90.2	61
RIfRAf	H	LOAM	516	8.1	171	161	155	2.2	0.8	90.2	61
RIfRAf	B	SAND	516	85.8	201	209	194	10.2	1.3	87.9	110
RIfRAf	E	SAND	516	72.5	201	209	194	8.7	1.3	81.6	109
RIfRAf	H	SAND	516	72.5	201	209	194	8.7	1.3	81.6	109
RIf	B	CLAY	476	34.6	113	117	72	0	0.6	0	49
RIf	E	CLAY	476	29.6	113	117	72	0	0.6	0	47
RIf	H	CLAY	476	29.6	113	117	72	0	0.6	0	47
RIf	B	LOAM	476	0.8	111	131	76	0	0.5	0	37

RIf	E	LOAM	476	0	108	128	74	0	0.5	0	34
RIf	H	LOAM	476	0	108	128	74	0	0.5	0	34
RIf	B	SAND	476	52.7	123	165	88	0	0.5	0	55
RIf	E	SAND	476	48.4	123	165	88	0	0.5	0	53
RIf	H	SAND	476	48.4	123	165	88	0	0.5	0	53
WHf	B	CLAY	165	0	84	43	78	2.9	0.6	62.3	65
WHf	E	CLAY	165	0	79	40	73	0	0.7	52.2	69
WHf	H	CLAY	165	0	79	40	73	0	0.7	52.2	69
WHf	B	LOAM	165	0	65	35	82	0	0.4	41.1	67
WHf	E	LOAM	165	0	60	33	76	0	0.4	30.8	72
WHf	H	LOAM	165	0	60	33	76	0	0.4	30.8	72
WHf	B	SAND	165	29.1	135	78	180	0	0.7	39.7	95
WHf	E	SAND	165	16.2	135	78	181	0	0.7	29.6	99
WHf	H	SAND	165	16.2	135	78	181	0	0.7	29.6	99
WHf	B	UCLAY	165	-51.5	8	4	7	-5.7	0.1	0	56
WHf	E	UCLAY	165	-64.2	9	4	8	-7.9	0.1	0	54
WHf	H	UCLAY	165	-64.2	9	4	8	-7.9	0.1	0	54
WHf	B	ULOAM	165	-58.6	7	4	9	-8.8	0.1	0	51
WHf	E	ULOAM	165	-71.6	7	4	9	-11	0.1	0	48
WHf	H	ULOAM	165	-71.6	7	4	9	-11	0.1	0	48
WHf	B	USAND	165	-61.9	7	4	9	-11.2	0.1	0	41
WHf	E	USAND	165	-74.5	7	4	9	-13.3	0.1	0	38
WHf	H	USAND	165	-74.5	7	4	9	-13.3	0.1	0	38
RAf	B	CLAY	40	26.1	71	36	66	7.1	0.4	90.3	31
RAf	E	CLAY	40	15.6	71	36	66	5.4	0.4	82.2	32
RAf	H	CLAY	40	15.6	71	36	66	5.4	0.4	82.2	32
RAf	B	LOAM	40	12.7	73	39	92	2	0.4	64.7	45
RAf	E	LOAM	40	0	73	40	92	0	0.4	54.9	47
RAf	H	LOAM	40	0	73	40	92	0	0.4	54.9	47
RAf	B	SAND	40	27.5	88	51	117	9	0.8	64.9	68
RAf	E	SAND	40	15.9	88	51	118	7.1	0.8	55.9	70
RAf	H	SAND	40	15.9	88	51	118	7.1	0.8	55.9	70
RAf	B	UCLAY	40	-13	7	4	7	0	0.1	0	58
RAf	E	UCLAY	40	-23.4	8	4	7	-0.4	0.0	0	55
RAf	H	UCLAY	40	-23.4	8	4	7	-0.4	0.0	0	55
RAf	B	ULOAM	40	-33.8	7	3	8	-4	0.0	0	48

RAf	E	ULOAM	40	-46.5	7	3	8	-6.1	0.1	0	44
RAf	H	ULOAM	40	-46.5	7	3	8	-6.1	0.1	0	44
RAf	B	USAND	40	-32.2	6	3	8	-5.7	0.0	0	40
RAf	E	USAND	40	-43.7	6	3	8	-7.6	0.0	0	36
RAf	H	USAND	40	-43.7	6	3	8	-7.6	0.0	0	36
RImWH	A	CLAY	638	53.7	217	190	162	15.2	2.0	84	108
RImWH	D	CLAY	638	48.5	212	188	157	12.3	2.0	74.3	109
RImWH	G	CLAY	638	48.5	212	188	157	12.3	2.0	74.3	109
RImWH	A	LOAM	638	9.9	173	164	158	0	1.0	46.4	63
RImWH	D	LOAM	638	3.6	168	161	152	0	0.9	31.3	68
RImWH	G	LOAM	638	3.6	168	161	152	0	0.9	31.3	68
RImWH	A	SAND	638	0	92	114	76	0	0.8	21.5	66
RImWH	D	SAND	638	0	84	108	66	0	0.8	-9.5	80
RImWH	G	SAND	638	0	84	108	66	0	0.8	-9.5	80
RImRA	A	CLAY	514	78	204	183	149	20.8	1.9	117.1	85
RImRA	D	CLAY	514	64.1	204	183	149	18.8	1.9	111.4	84
RImRA	G	CLAY	514	64.1	204	183	149	18.8	1.9	111.4	84
RImRA	A	LOAM	514	36.9	155	153	136	15.4	1.3	91.9	57
RImRA	D	LOAM	514	23.4	155	153	136	14.2	1.3	81.9	59
RImRA	G	LOAM	514	23.4	155	153	136	14.2	1.3	81.9	59
RImRA	A	SAND	514	12.2	124	131	120	7.1	1.1	66.3	51
RImRA	D	SAND	514	3.8	122	129	119	5.8	1.1	56	52
RImRA	G	SAND	514	3.8	122	129	119	5.8	1.1	56	52
RIm	A	CLAY	473	50.6	145	153	93	7.3	1.2	0	64
RIm	D	CLAY	473	45.3	145	153	93	6.6	1.2	0	62
RIm	G	CLAY	473	45.3	145	153	93	6.6	1.2	0	62
RIm	A	LOAM	473	7.4	108	128	74	0	0.5	-5	18
RIm	D	LOAM	473	1.1	108	129	75	0	0.5	-9.8	19
RIm	G	LOAM	473	1.1	108	129	75	0	0.5	-9.8	19
RIm	A	SAND	473	0	80	107	59	0	0.5	0	18
RIm	D	SAND	473	0	78	104	58	0	0.5	-3.9	19
RIm	G	SAND	473	0	78	104	58	0	0.5	-3.9	19
RIfmWHf	B	CLAY	638	17.2	157	124	124	4.5	1.1	88.9	108
RIfmWHf	E	CLAY	638	12.1	152	122	120	2.4	1.1	79.5	109
RIfmWHf	H	CLAY	638	12.1	152	122	120	2.4	1.1	79.5	109
RIfmWHf	B	LOAM	638	7.7	135	124	128	0	0.9	66.7	108

RIfmWHf	E	LOAM	638	2.6	131	121	122	0	0.9	57	109
RIfmWHf	H	LOAM	638	2.6	131	121	122	0	0.9	57	109
RIfmWHf	B	SAND	638	44.7	218	197	237	0	1.2	64.3	123
RIfmWHf	E	SAND	638	26.9	218	197	238	0	1.1	54.9	124
RIfmWHf	H	SAND	638	26.9	218	197	238	0	1.1	54.9	124
RIfmRAf	B	CLAY	514	44.6	143	116	111	8.5	0.9	114.9	71
RIfmRAf	E	CLAY	514	31.3	143	116	111	7.2	0.9	109.4	70
RIfmRAf	H	CLAY	514	31.3	143	116	111	7.2	0.9	109.4	70
RIfmRAf	B	LOAM	514	21.9	142	127	137	3.3	0.9	88.8	83
RIfmRAf	E	LOAM	514	6.8	142	127	137	1.7	0.9	81.9	82
RIfmRAf	H	LOAM	514	6.8	142	127	137	1.7	0.9	81.9	82
RIfmRAf	B	SAND	514	40.7	172	169	175	10.2	1.3	88.5	95
RIfmRAf	E	SAND	514	26.5	172	169	175	8.8	1.3	82.2	93
RIfmRAf	H	SAND	514	26.5	172	169	175	8.8	1.3	82.2	93
RIfm	B	CLAY	473	13.9	83	86	54	0	0.6	0	56
RIfm	E	CLAY	473	8.9	83	86	54	0	0.6	0	54
RIfm	H	CLAY	473	8.9	83	86	54	0	0.6	0	54
RIfm	B	LOAM	473	5	79	93	56	0	0.5	0	55
RIfm	E	LOAM	473	0	79	93	56	0	0.5	0	53
RIfm	H	LOAM	473	0	79	93	56	0	0.5	0	53
RIfm	B	SAND	473	9.5	93	125	68	0	0.5	0	43
RIfm	E	SAND	473	4.4	93	125	68	0	0.5	0	41
RIfm	H	SAND	473	4.4	93	125	68	0	0.5	0	41
RIsWHs	C	CLAY	641	0	48	41	36	0	0.6	0	96
RIsWHs	F	CLAY	641	0	52	44	40	0	0.6	0	96
RIsWHs	I	CLAY	641	0	52	46	39	0	0.6	0	95
RIsWHs	C	LOAM	641	0	67	65	59	0	0.7	0	108
RIsWHs	F	LOAM	641	0	72	70	64	0	0.8	0	109
RIsWHs	I	LOAM	641	0	60	58	53	0	0.7	0	93
RIsWHs	C	SAND	641	0	53	56	52	0	0.6	0	83
RIsWHs	F	SAND	641	0	57	59	56	0	0.7	0	82
RIsWHs	I	SAND	641	0	61	68	56	0	0.7	0	84
RIsRAs	C	CLAY	516	0	41	38	30	0	0.4	0	98
RIsRAs	F	CLAY	516	0	45	41	32	0	0.5	0	99
RIsRAs	I	CLAY	516	0	49	45	35	0	0.6	0	93
RIsRAs	C	LOAM	516	0	62	63	51	0	0.6	0	107

RIsRAs	F	LOAM	516	0	66	67	56	0	0.7	0	109
RIsRAs	I	LOAM	516	0	56	56	47	0	0.6	0	91
RIsRAs	C	SAND	516	0	48	53	44	0	0.6	0	83
RIsRAs	F	SAND	516	0	51	56	47	0	0.6	0	83
RIsRAs	I	SAND	516	0	57	66	51	0	0.6	0	81
RIs	C	CLAY	476	0	38	37	25	0	0.4	0	37
RIs	F	CLAY	476	0	40	39	27	0	0.4	0	39
RIs	I	CLAY	476	0	43	43	29	0	0.5	0	39
RIs	C	LOAM	476	0	51	58	37	0	0.5	0	52
RIs	F	LOAM	476	0	54	62	39	0	0.6	0	55
RIs	I	LOAM	476	0	45	51	33	0	0.5	0	42
RIs	C	SAND	476	0	39	49	30	0	0.4	0	40
RIs	F	SAND	476	0	40	50	31	0	0.4	0	41
RIs	I	SAND	476	0	48	61	36	0	0.5	0	44
WHs	C	CLAY	165	0	26	13	24	0	0.3	0	52
WHs	F	CLAY	165	0	28	14	26	0	0.3	0	50
WHs	I	CLAY	165	0	23	11	21	0	0.3	0	46
WHs	C	LOAM	165	0	29	16	37	0	0.3	0	46
WHs	F	LOAM	165	0	32	17	41	0	0.4	0	45
WHs	I	LOAM	165	0	27	14	34	0	0.3	0	48
WHs	C	SAND	165	0	28	16	36	0	0.3	0	39
WHs	F	SAND	165	0	30	17	40	0	0.4	0	42
WHs	I	SAND	165	0	25	14	33	0	0.3	0	50
WHs	C	UCLAY	165	0	26	13	24	0	0.3	0	52
WHs	F	UCLAY	165	0	28	14	26	0	0.3	0	50
WHs	I	UCLAY	165	0	23	11	21	0	0.3	0	46
WHs	C	ULOAM	165	0	29	16	37	0	0.3	0	46
WHs	F	ULOAM	165	0	32	17	41	0	0.4	0	45
WHs	I	ULOAM	165	0	27	14	34	0	0.3	0	48
WHs	C	USAND	165	0	28	16	36	0	0.3	0	39
WHs	F	USAND	165	0	30	17	40	0	0.4	0	42
WHs	I	USAND	165	0	25	14	33	0	0.3	0	50
RAs	C	CLAY	40	0	17	9	16	0	0.1	0	50
RAs	F	CLAY	40	0	19	10	18	0	0.1	0	48
RAs	I	CLAY	40	0	18	9	17	0	0.2	0	39
RAs	C	LOAM	40	0	23	12	28	0	0.2	0	41

RAs	F	LOAM	40	0	25	13	31	0	0.2	0	39
RAs	I	LOAM	40	0	21	11	26	0	0.2	0	32
RAs	C	SAND	40	0	21	12	27	0	0.2	0	31
RAs	F	SAND	40	0	23	13	30	0	0.3	0	29
RAs	I	SAND	40	0	20	11	26	0	0.3	0	24
RAs	C	UCLAY	40	0	17	9	16	0	0.1	0	50
RAs	F	UCLAY	40	0	19	10	18	0	0.1	0	48
RAs	I	UCLAY	40	0	18	9	17	0	0.2	0	39
RAs	C	ULOAM	40	0	23	12	28	0	0.2	0	41
RAs	F	ULOAM	40	0	25	13	31	0	0.2	0	39
RAs	I	ULOAM	40	0	21	11	26	0	0.2	0	32
RAs	C	USAND	40	0	21	12	27	0	0.2	0	31
RAs	F	USAND	40	0	23	13	30	0	0.3	0	29
RAs	I	USAND	40	0	20	11	26	0	0.3	0	24
RIsmWHs	C	CLAY	638	0	57	50	42	0	0.6	0	102
RIsmWHs	F	CLAY	638	0	61	53	46	0	0.7	0	103
RIsmWHs	I	CLAY	638	0	66	61	48	0	0.8	0	107
RIsmWHs	C	LOAM	638	0	65	63	58	0	0.7	0	103
RIsmWHs	F	LOAM	638	0	70	67	64	0	0.8	0	103
RIsmWHs	I	LOAM	638	0	73	74	63	0	0.8	0	105
RIsmWHs	C	SAND	638	0	67	75	62	0	0.7	0	97
RIsmWHs	F	SAND	638	0	72	79	67	0	0.8	0	97
RIsmWHs	I	SAND	638	0	73	85	66	0	0.8	0	96
RIsmRAs	C	CLAY	514	0	50	47	36	0	0.5	0	105
RIsmRAs	F	CLAY	514	0	53	50	38	0	0.6	0	106
RIsmRAs	I	CLAY	514	0	62	59	44	0	0.7	0	105
RIsmRAs	C	LOAM	514	0	59	61	51	0	0.6	0	103
RIsmRAs	F	LOAM	514	0	63	64	55	0	0.7	0	103
RIsmRAs	I	LOAM	514	0	68	72	57	0	0.7	0	103
RIsmRAs	C	SAND	514	0	61	72	54	0	0.7	0	97
RIsmRAs	F	SAND	514	0	65	76	58	0	0.7	0	97
RIsmRAs	I	SAND	514	0	69	83	60	0	0.7	0	93
RIsm	C	CLAY	473	0	45	44	30	0	0.5	0	43
RIsm	F	CLAY	473	0	47	47	31	0	0.5	0	45
RIsm	I	CLAY	473	0	55	55	36	0	0.6	0	50
RIsm	C	LOAM	473	0	48	54	35	0	0.5	0	49

RIsm	F	LOAM	473	0	50	57	36	0	0.5	0	51
RIsm	I	LOAM	473	0	57	65	41	0	0.6	0	53
RIsm	C	SAND	473	0	51	66	39	0	0.5	0	53
RIsm	F	SAND	473	0	53	69	40	0	0.5	0	55
RIsm	I	SAND	473	0	59	77	44	0	0.6	0	55
FALL	A	CLAY	0	0	11	4	9	0	0.0	0	2
FALL	D	CLAY	0	0	11	4	9	0	0.0	0	2
FALL	G	CLAY	0	0	11	4	9	0	0.0	0	2
FALL	A	LOAM	0	0	10	4	11	0	0.0	0	2
FALL	D	LOAM	0	0	10	4	11	0	0.0	0	2
FALL	G	LOAM	0	0	10	4	11	0	0.0	0	2
FALL	A	SAND	0	0	9	4	11	0	0.0	0	2
FALL	D	SAND	0	0	9	4	11	0	0.0	0	2
FALL	G	SAND	0	0	9	4	11	0	0.0	0	2
FALL	A	UCLAY	0	0	11	4	9	0	0.0	0	2
FALL	D	UCLAY	0	0	11	4	9	0	0.0	0	2
FALL	G	UCLAY	0	0	11	4	9	0	0.0	0	2
FALL	A	ULOAM	0	0	10	4	11	0	0.0	0	2
FALL	D	ULOAM	0	0	10	4	11	0	0.0	0	2
FALL	G	ULOAM	0	0	10	4	11	0	0.0	0	2
FALL	A	USAND	0	0	9	4	11	0	0.0	0	2
FALL	D	USAND	0	0	9	4	11	0	0.0	0	2
FALL	G	USAND	0	0	9	4	11	0	0.0	0	2