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Economic Analysis on the Agro-Environmental Impacts of Management and Policy Measures in the North China Plain

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Yannick Kühl
February 2011, Ankara

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List of Abbreviations

CAU	China Agricultural University
CAL	Calcium-acetate-lactate method
CFA	Continuous-Flow-Analysis
CH_4	methane
CO_2	Carbon Dioxide
dt	deciton
EC	electrical conductivity
FAO	Food and Agriculture Organization of the United Nations
GDP	Gross Domestic Product
GIS	Geographical Information System
GPS	Global Positioning System
ha	Hectare (1 ha = 15 mu)
hh	household
hhs	households
HRS	Household Responsibility System
IRTG	International Research Training Group “Sustainable Resource Use in Northern China”
K	Potassium
LP	Linear Programming
L	liter
M	meter
m^3	cubic meter
mln	Million
mg	Milligram
Mg	Magnesium
N	Nitrogen
N_{Min}	mineralized nitrogen
N_2O	nitrous oxide
n.a.	not answered
NCP	North China Plain
NH_3	Methane
NUE	nitrogen use Efficiency
no.	Number
OLS	Ordinary least squares
pers.	Person
P	Phosphorous
SM	Summer Maize
SOC	Soil Organic Content
UoH	Universität Hohenheim
USA	United States of America
WUA	Water User Association
WUE	Water Use Efficiency
WW	Winter Wheat
¥	Yuan, Chinese Currency (1¥ ≈ 0.1€)

1. Introduction

Since the foundation of the Peoples Republic of China in 1949 national policy focused on agriculture as its economic foundation and the transformation to modern agriculture began. The Chinese agricultural production levels were low and characterized by a production deficit which culminated in the famine during “The Great Leap Forward” in the end of the 1950s. However, in the past 50 years the use of agricultural inputs like fertilizers, pesticides, machinery and improved seeds increased dramatically. Furthermore arable land areas were expanded and irrigation facilities were installed on a large scale. These advances made China’s agriculture grow more rapidly than that of the USA or the world as a whole between 1949 and 1999 (SHI and CHENG, 2004). The aim of national policy was to achieve food self-sufficiency in China; in the past 25 years the average staple crop productivity in China has doubled – which outnumbered the 25.00% growth of the population during the same period (BINDER et al., 2007). Nowadays, even though China’s agriculture is characterized by scarce land, abundant labor and small scale-production using little mechanization, China feeds 21.00% of the Earth’s total population with only 10.00% of the world’s arable land and only one quarter of the average global water resources per capita (OECD, 2005). This constellation represents “a great challenge for food security in China” (OSTWLAD and CHEN, 2006). However, China also uses 30.00% of the world’s total N fertilizers (JU *et al.*, 2004). This production intensity indicates that the sharp rise in agricultural and food production might have a downside: environmental degradation. For example “water scarcity has become an increasing constraint to agricultural development in northern China” (YANG *et al.*, 2003) and “problems in the water sector will no doubt affect China’s future trade position in key crops and incomes in the farming sector” (HUANG *et al.*, 2009). In addition the increased use of agricultural inputs like fertilizers and pesticides led to wide-spread negative environmental impacts.

The context of this research is that, due to continued growth of the population and the economy, the demand for agricultural products in China is gradually rising. However resources like land and water are scarce in China. Therefore new strategies which do not put additional strains on the environment but meet the expected demand need to be developed. The research area, the North China Plain (NCP) is regarded as “China’s granary” (PIOTROWSKI and JIA, 2006). The agricultural importance of the NCP, as China’s most important agricultural region, will be outlined in part 2.2 – the data base was provided by own collection in a typical agricultural region: Quzhou County.

This work aims at describing and discussing the environmental effects of agriculture in the NCP. By reviewing literature, the extent of these environmental impacts is presented. An essential part of this work is the in-depth description and analysis of the current cropping systems and farming practices, which is based on the findings a household survey (in part 4). The central hypothesis of this work is that a change of the management systems is able to meet the production goals, to achieve a higher input-output efficiency and to reduce negative environmental impacts. Consequently the objectives of this work are related to reducing negative environmental impacts of agricultural production, ensuring sustainability (through e.g. decreased impacts of pollution or resource depletion) and ensuring high grain production levels which guarantee national food security and grain self-sufficiency. Furthermore, since the income disparities for urban and rural households are large, improving rural household incomes also represents an important aim of this work.

The possibilities of adjusting at the operational level have to be regarded simultaneously and have to be evaluated under consideration of economic and environmental goals. This type of decision guiding is important for political decision makers in the research area and is not available until now. The analysis is taking place in the context of sustainability and food security and the interaction between these two: by means of a linear model the surveyed households are optimized in relevant scenarios (in part 6). Improved management measures and innovative production methods are integrated into the model as optimization options to survey if more efficient options under consideration of the objectives of this work exist. The environmental performance of the optimized results will be assessed according to selected environmental indicators. Hereby the focus lies on factor inputs and resource use efficiency. In addition sensitivity analyses will be conducted to survey the uncertainty of the optimized results.

By integrating findings from the optimization, the descriptive analysis of the survey and literature review, strategies to reduce the environmental impacts of farming will be discussed in chapter 7. Finally, strategic policy recommendations, improved management measures and suggestions for further research will be presented in chapter 8.

Based on the objectives of this work, the main goals are:

- The description of current agricultural practices and related negative environmental impacts;
- The definition of agro-environmental management and policy measures;
- Impact analysis of management and policy measures;
- The development of suggestions for further research.

2. Relations between Agriculture and the Environment in the North China Plain (NCP)

This chapter aims at introducing the background of this research, i.e. the environmental impacts of agriculture. Hereby the focus lies on the characteristic farming practices and the on related institutional setting. Embedded in the concept of sustainability (see 2.3) this part introduces the characteristics of Chinese agriculture which are relevant to this study in 2.1. Then, the specific introduction of the research area, the NCP, and specifically the Hebei Province, will be carried out in 2.2. Finally, the manifold environmental problems which can be related to agriculture will be presented in 2.4.

2.1.Introduction of Chinese Agriculture and Rural Areas

China is the largest food producer and consumer in the world (WANG *et al.*, 2004) and is – for example – the world's largest producer of wheat, silk and tea; the second largest producer of maize and the third largest producer of sugar cane (FAOSTAT, 2010). It is the world's largest country with a total population of over 1.3 billion people. The economic growth alongside with a societal transformation – from communism towards a more market-oriented "socialism with Chinese characteristics" – and continuing population growth were important features of China's development over the past decades. The transformation towards modern agriculture began in 1949 with the foundation of the People's Republic of China. Even though per capita national income doubled between the mid 1950s and late 1970s, chronic malnutrition and widespread low income were persistent within the rural population (LARDY, 1983). The collectivized system with planned economy and communistic features resulted in low resource use efficiency and lacking incentives for the farm workers to work hard. Therefore "The inefficiencies of Chinese agriculture under the commune system were generally recognized. Farmers were more knowledgeable about (…) crops (…) than political leader and economic planners" (CHOW, 2007). However, national grain (and food) self-sufficiency has been a goal of the Chinese government for a long time (PIOTROWSKI and JIA, 2006).

Therefore towards the end of the 1970s the Chinese government implemented extensive reforms in order to introduce market incentives and to increase dynamism and economic efficiency and, thus, to decrease planned economy properties. One major point was the introduction of the "Household Contract Responsibility System" (HRS) in 1979, which shifted the responsibilities for the operations (including gains and losses) towards the households. This resulted in a rapid development of agricultural output: between 1979 and 1985 it increased by 56% (LI *et al.*, 2006). In 1985 wholesale agricultural markets were introduced in order to foster a market-oriented economy and the policy that the state is exclusively purchasing agricultural products according to fixed quotas was abolished (SHI and CHENG, 2004). Another important factor for the Chinese developments was the reform of the "hukou" system in 1988: internal migration was no longer strictly controlled and rural residents were allowed to apply for temporary residence permits in urban areas (McGUIRE *et al.*, 2007). One last major transformation was the WTO (World Trade Organization) membership in 2001, which regarded agriculture as one of the central points. In 2001 the state still controlled the trading of important agricultural commodities (see Table 1) and operated in with planning horizons of 18 months.

Table 1. Products Covered by State trading and Designated Trading in China, 2001

	Imports	Exports
State Trading	Grain, vegetable oils, sugar, tobacco, chemical fertilizers and cotton	Tea, rice, maize, soybeans, (unbleached) silk, cotton (yarns and fabrics)
Designated Trading	Rubber, timber, plywood, wool	Rubber, timber, plywood, wool

Source: MARTIN (2001)

The WTO membership requires the step-wise removal of trade barriers and tariffs as well as the liberalization of the state influence on agricultural trade (SCHÜLLER, 2004). Already before the WTO accession, Chinese markets changed; Table 2 demonstrates the increasing share of market prices which replaced planned prices.

Table 2. Share of Agricultural Goods sold at Market Prices in China, 1978-1999

	1978	1985	1991	1995	1999
Agricultural Goods *(% of total trade volume)*	6%	40%	58%	79%	83%

Source: LARDY (2001)

The increase of agricultural goods sold at market prices illustrates the market reforms and the decreasing state influence in China. However, the WTO accession is seen as “a critical turning point, increasing transparency and introducing disciplines on protection even for the commodities remaining under state trading” (MARTIN, 2001). The transformation processes are still ongoing, as – for example – the government control over fertilizer prices has not been removed until 2009 (CHINA DAILY, 2009).

The reforms resulted in impressive growth, but it “has been accompanied by dramatic increases in inequality, especially in the 1990s” (ZHANG and KANBUR, 2005). Moreover, already China’s policies until the 1980s had a strong urban bias regarding access to food, education, housing and healthcare. Even though total numbers of people living in poverty have strongly declined, poverty in rural areas is still more widespread than in urban China (YAO *et al.*, 2004). Furthermore Chinese rural children spend less time in school than their urban counterparts and the educational system is characterized by a “persistent rural-urban inequality” (McGUIRE *et al.*, 2007). Table 3 displays selected indicators for the inequalities in living conditions in rural and urban areas in China.

Table 3. Inequalities between Rural and Urban Areas in China, 1981-2000

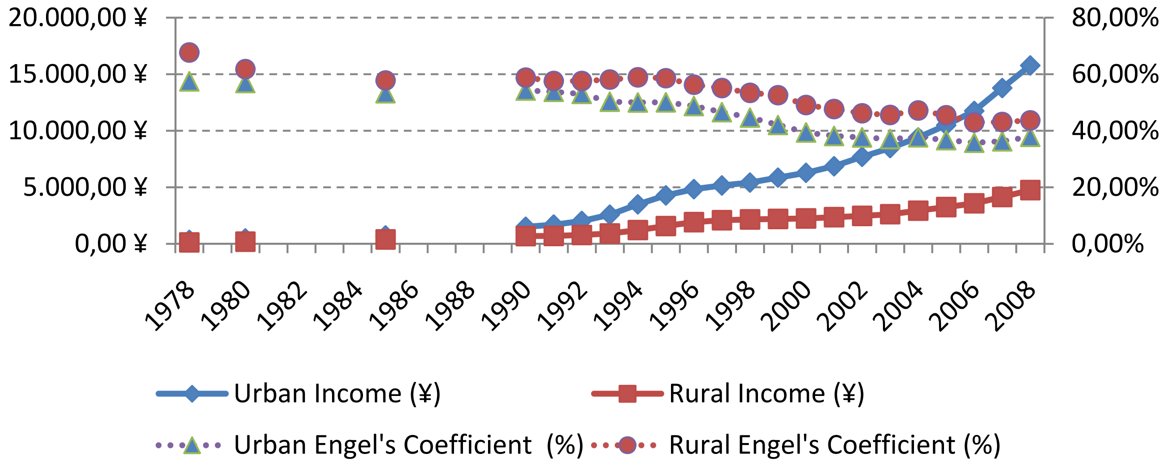
	1981		2000	
	Urban	*Rural*	*Urban*	*Rural*
Illiteracy Rate *(%)*	16.40%	38.40%	8.70%	19.90%
Infant Mortality Rate *(%)**	23.60%	39.10%	11.00%	30.80%
Gini Coefficient	27.0		37.2	

NOTE: *1981: age 12 benchmark, 2000: age 15 benchmark, so data is not totally comparable

Source: ZHANG and KANBUR (2005), modified

Even though the living conditions, based on the selected indicators in Table 3, have improved in urban as well as in rural areas, it is noticeable that social services like health care and education are better developed in the urban areas. Moreover, the Gini coefficient for the urban-rural divide has been rising in the past decades, demonstrating growing income inequalities between rural and urban areas. Figure 2 compares the annual disposable per capita income and the respective Engel's coefficients for rural and urban households in China.

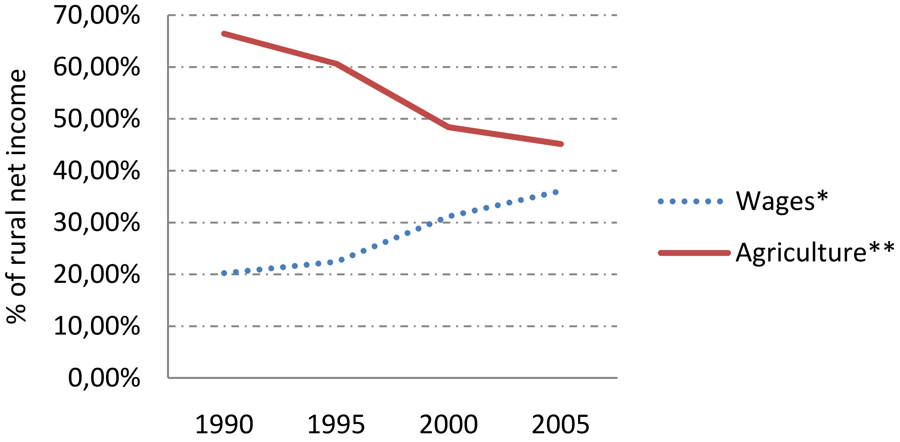
Figure 1. Comparison of Per Capita Annual Disposable Income in Urban and Rural Households and Engel's Coefficient of Urban and Rural Households in China, 1978-2008



Source: NBS (2009)

The Engel's coefficient determines the proportion of income which is spent on food. As can be seen in Figure 1, all Chinese households spend lower shares of their income on food; however the rural households still have a higher Engel's coefficient. The per capita disposable income has risen for both groups. However, especially in the last 20 years, the disposable income of the urban households increased much stronger. In 2008 the annual disposable per capita income of urban households (¥15,780.80) was approximately threefold larger than that of rural households (¥4,760.60). Thus, the "inequality between rural and urban areas in China has risen markedly in recent years" (GALE, 2005). These findings underline the bias toward the urban areas. Due to better and higher income possibilities, migration into the urban areas has been strong over the past decades. For this work it is also important to notice that – due to the better income opportunities in the cities – agricultural income is also under increasing competition with off-farm income. Due to a lack of employment opportunities in Chinese rural areas, rural-urban migration became the fastest growing element of off-farm labor (McGUIRE *et al.*, 2007). The continuing migration from rural into urban areas might become a threat to the sustainability of agriculture in the future, however nowadays labor in the rural areas is still abundant. Figure 2 illustrates the increasing importance of off-farm income for the rural population.

Figure 2. Net Income Share from Agriculture and Wages of Rural Households in China, 1990-2005



NOTE: *The definition "Wages" refers to off-farm income
**Agriculture includes net income from farming, forestry, animal husbandry and fishery

Source: NBS (2008)

Figure 2 represents the rising importance of off-farm income for rural households in China over the past decades. Where as in 1990 66.45% of the net income of China's rural household was derived from agriculture and only 20.22% were originating from wages; until 2007 the share of agriculture decreased to 42.15% while the share of wages increased to 38.50% of the net income of Chinese rural households (NBS, 2008). If the trends continue gradually, wages might soon become the main income source in rural China.

Food expenditures in urban China more than double those in rural areas, where the levels of absolute food expenditure are very low, but the share of total households expenditure are high – "such levels of food expenditure suggest extreme poverty, yet rural people in China are generally not malnourished" (GALE *et al.*, 2005a). Consequently household food self-sufficiency represents a common strategy to minimize food expenditure, and thus saving resources for other expenditures. Table 4 presents the source and quantity of food consumed by rural households.

Table 4. Source and Quantity of Food Consumed by Rural Household Members, 2003

Food Item	Consumed *(kg)*	Purchased *(kg)*	Self-Produced *(kg)*	Self-Produced *(%)*
Grains, Beans and Potatoes	223.1	38.9	184.8	83%
Vegetables	107.4	32.1	75.3	70%
Beef and Mutton	1.3	0.6	0.7	54%
Poultry and Eggs	8.0	4.2	3.9	48%
Pork	13.8	7.8	6.0	44%
Fruits and Nuts	18.3	11.2	7.1	39%
Edible Oil	6.3	4.3	2.0	32%

Source: GALE *et al.* (2005a), modified

As can be seen in Table 4 rural Chinese households strongly rely on self-produced crops, especially for staple crops. It is noteworthy that even wealthy rural households rely on self-produced food. This indicates the importance of agricultural production for food security in rural areas in China.

Nowadays “China’s agriculture is characterized by scarce land, abundant labor and small-scale production using little mechanization” and only one quarter of the average world water resources per capita (OECD, 2005). The large and growing population in combination with a higher demand due to economic growth resulted in a high pressure on agricultural land. The characteristics of the Chinese lack of resources for agricultural production, especially water and land, will be explained in more detail in the following parts. The agricultural output per unit of land is high by international comparison, but output per worker is low. The land area per agricultural worker in China (0.39 ha) is small compared to – for example – Europe (9.36 ha/agricultural worker), United States (58.46 ha/agricultural worker) or Australia (107.34 ha/agricultural worker) (GALE *et al.*, 2005b). Even though the share of the rural population decreased sharply over the past decades, in 2008 still 54.32% (721.35 mln people) of the Chinese population lived in rural areas (NBS, 2009). The land scarcity is also expressed in comparably small farms: the average Chinese farm size is 0.13 ha (KAHRL *et al.*, 2005). Such small farm sizes contribute to low levels of mechanization, high input and marketing costs, restricted access to credits and, thus, lead to low investments. In order to increase rural incomes and decrease the urban bias, China introduced new comprehensive agricultural policies in 2004. The main point was that the traditionally heavy tax burden on farmers was lifted; instead grain subsidies (direct subsidies for planted grain areas), seed subsidies (for high quality grain and soybean seeds), machinery subsidies were introduced and rural infrastructure spending was increased by $18 billion (GALE *et al.*, 2005c).

Along with economic development, structural changes and societal transitions in China, the agricultural sector, as introduced in chapter 1, transformed towards a modern and intensive agriculture. The Chinese economic and agricultural development are closely linked: in 2008 the primary industry (including agriculture, forestry, animal husbandry, fishery and services in support of these industries) made up 11.30% of the Chinese Gross Domestic Product (GDP); however the influence of the primary sector decreased over the past decades, as in

1979 primary industries still accounted for 31.30% of GDP (NBS, 2009). This trend reflects the structural change in China towards an industrial country. In the same period the per capita GDP[1] increased from ¥419.00 (1979) to ¥22,698.00 (2008) (NBS, 2009) – indicating China's enormous and fast economic growth. Also the popular example of rising demand for meat as a result of rising incomes of big parts of the society indicates the link with China's agricultural transformation: "as China's consumers grow wealthier and move from rural to urban areas, purchases of all foods will increase, but consumption of meats, fish, fruits, and vegetable oils will rise the fastest" (GALE, 2005). Consequently Chinese meat production grew by 60.05% between 1996 (45.48 mln tons) and 2008 (72.79 mln tons) (NBS, 2001 and NBS, 2009). The transformations also influenced Chinese grain production. Since the late 1960s, the pressure on the land was antagonized with a strategy aimed at increasing inputs and intensification, which resulted in improved and enlarged irrigation technologies as well as increased chemical fertilizer and pesticide application. To highlight the effects of this strategy, Table 5 compares yields of maize and wheat in China, with yields in the United States of America (USA) and the global average in 1978 and 2008.

Table 5. Comparison of Maize and Wheat Yields in China, USA and the Global Average, 1978-2008

	China	USA	Global Average
Maize Yield *(kg/ha)*			
-1978	2803.10	6342.00	3156.30
-2008	5556.10	9658.30	5109.40
Wheat Yield *(kg/ha)*			
-1978	1844.90	2113.50	1932.80
-2008	4761.90	3017.70	3086.10

Source: FAOSTAT (2010)

The developments in Chinese grain production are represented by strong yield increases over the past decades, as represented by maize and wheat (see Table 5). It is noteworthy that in 1978 Chinese maize and wheat yields were below the global average and in 2008 they were above world average. In the same period Chinese wheat yields surpassed the yield levels of the USA, but maize yields are still considerably lower in China compared to the yields in the USA. Simultaneously the fertilizer consumption in China increased gradually over the same period (see Figure 9). The agricultural transformation can also be represented by the use of machinery and irrigated area (see Figure 3).

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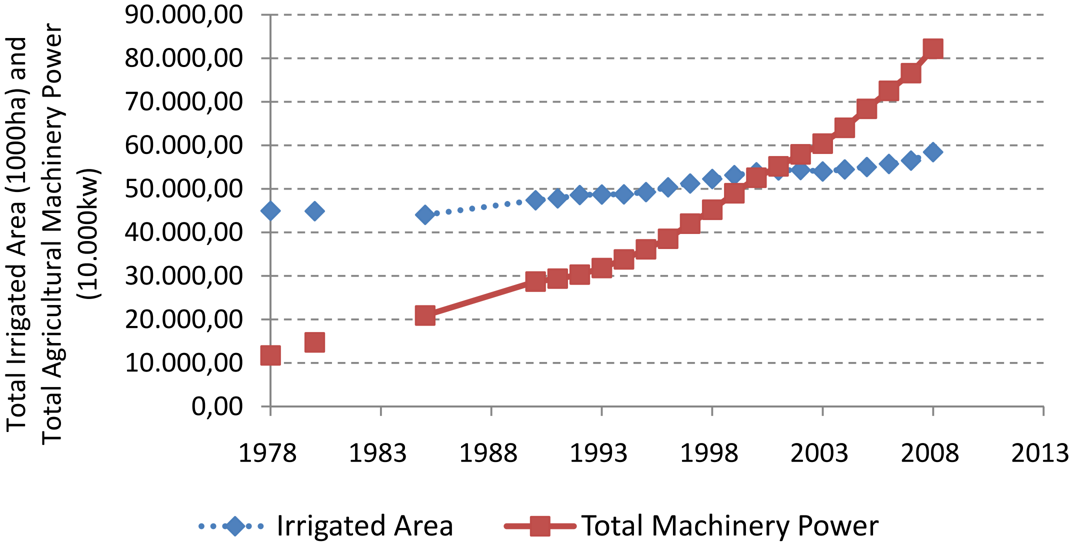
[1] at constant prices

Figure 3. **Total Irrigated Area and Total Agricultural Machinery Power in China, 1978-2008**



Source: NBS (2009)

The intensification and modernization of the Chinese agricultural production is expressed in the gradual increase of irrigated areas and agricultural machinery use (Figure 3). However, the use of machinery is still low compared to developed countries with modern agriculture. As will be demonstrated in the later parts, since collectivized agriculture is decreasing and the average Chinese farm size is small, contractors and their services play a highly important role. For example, contractors are commonly employed for harvesting wheat in the research area (see 4.3.8). This indicates that, apart from large state or private enterprise farms which are not common in the NCP, manual labor and a low level of mechanization – with rather simple processes – is characteristic for Chinese agriculture.

The Chinese state owns all water resources, which are managed by respective authorities which collect payments from (some) users of these resources (YANG *et al.*, 2003). As will be demonstrated in 2.4.2, complex water institutions combined with the influence of private enterprises can impede access to water and soften water rights in China. Similarly agricultural land in China can also not be owned by an individual, which is why it is either owned by a collective or the state. The HRS provided land rental regulations with 15 years of land use rights, which were extended to 30 years in 1993 and in 2002 the "Rural Land Contracting Law" aimed at deepening the security and transferability of contractual land use management rights (PIOTROWSKI and JIA, 2006). However, the use of arable land as collateral is still prohibited – which limits the financial scope of farm households. Recently, the increasing legal protections of the farmer's land use rights, off-farm working opportunities and high rents encouraged Chinese farmers to lease their land (THE WALL STREET JOURNAL, 2009). A study revealed that between 2005 and 2008 the median annual rent for farmland in China nearly doubled to ¥3,675.00 per ha[2] (PROSTERMAN *et al.*, 2009).

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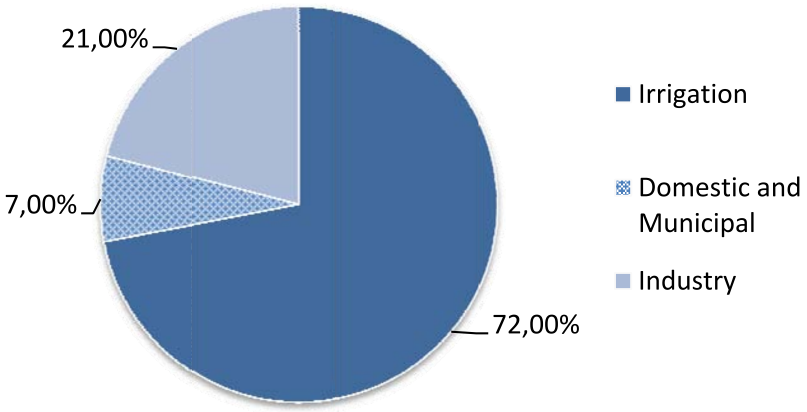
[2] ¥3,675.00 per ha correspond to ¥245.00 per mu

The same study states that, with secure long-term land rights, farmers would be able to make investments and gain a new source of wealth which could amount to up to "1.2$ trillion – in Chinese farmers' hands"; however, the full implementation of land use rights and further "rule of law" measures are necessary in order to achieve these benefits.

In China the availability of water is a crucial factor for agriculture, for crop production in particular. FAO (1999) estimated that in 2000 72.00% of total Chinese water demand could be associated with irrigation (see Figure 4).

Figure 4. Estimated Water Demand in China According to Sectors, 2000



Source: FAO (1999)

Agricultural extension services can play an important role in rural development and processes related to transformation towards modern agriculture, especially in a country like China, where many farmers have not received training (see 4.1.5). Therefore in the mid-1980's the Chinese agricultural extension service network covered vast parts of the agricultural regions, provided high quality services and even became overstaffed (HU *et al.*, 2009). However, in order to reduce governmental expenditure, many agricultural extension services were merged and funding was cut; as a result officers often had to take over other responsibilities within the government or started commercial activities. Within 10 years, from 1996 to 2006, the number of agricultural extension agents decreased by 237,000 (HU *et al.*, 2009). These developments decreased the quality and availability of agricultural extension services in China. The Chinese agricultural sector is also suffering from other structural problems. GUO *et al.* (2005) summarize the main problems of the village government for rural economic development:

- Limited administrative authority and lack of jurisdiction, so it is difficult to manage economic issues efficiently and to control affairs comprehensively and integrated;
- Quality of staff and level of IT applications are limited;
- Lack of financial support;

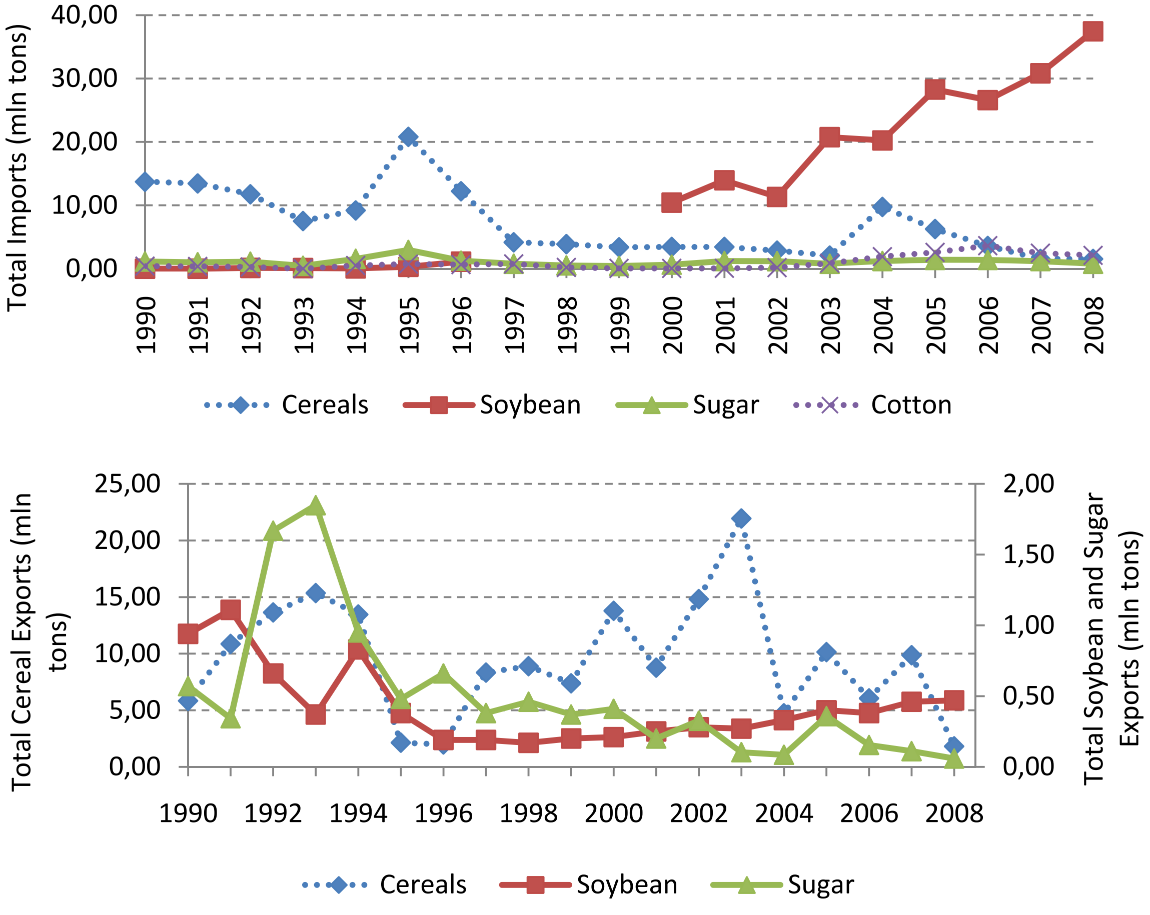
- The speed of agricultural structural adjustments is slow, higher output is not accompanied by higher income and due to imperfect feedback systems local officers often takes short-term actions.

To over-come these structural problems is a complex, comprehensive and long-term task. MAI (2004) outlines the targets of the Chinese government with regards to agriculture:

- To strengthen the market laws and make farmers the dominant position in the market, i.e. to further weaken governmental influence;
- Rule by law: the government should be restricted and confined by legislation;
- Establish a coordinate system of social organizations for the rural population;
- Service government: increase the government's reliability, respectability and efficiency.

The development of imports and exports of agricultural goods in China provide a good overview over the changing Chinese agricultural sector. Therefore Figure 5 displays the imports and exports of selected agricultural products in China.

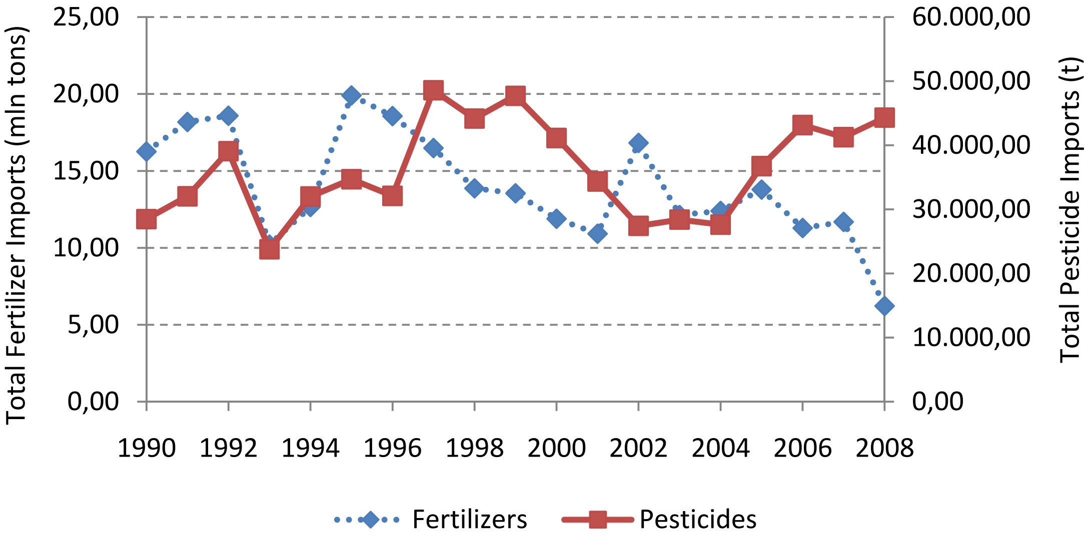
Figure 5. **Import and Export Volumes of Selected Agricultural Products in China, 1990-2008**



Source: NBS (1991), NBS (1993), NBS (1995), NBS (1997), NBS (1999), NBS (2001), NBS (2003), NBS (2005), NBS (2007) and NBS (2009)

Whereas up to the 1990s China used to import grains, Figure 5 shows that the import/export balance of the selected agricultural products is tending to balance out over the past years – imports and exports have decreased. The only exception is soybean, for which the exports have slightly increased, but – more importantly – the imports have grown gradually and strongly. The main reason is the growing demand for meat in the Chinese society. Consequently, whereas the dependence for grain products decreased, a strong dependence on soybean from foreign countries developed over the past years. Moreover, "for a country with nearly 1.3 billion consumers and limited natural resources, China's level of food imports is surprisingly low" (GALE, 2005). However, a strong annual fluctuation can be observed – especially for the exports of these agricultural products. Figure 6 surveys the dependence of the Chinese agriculture in terms of inputs like pesticides and fertilizers.

Figure 6. Import Volumes of Pesticides and Fertilizers in China 1990-2008



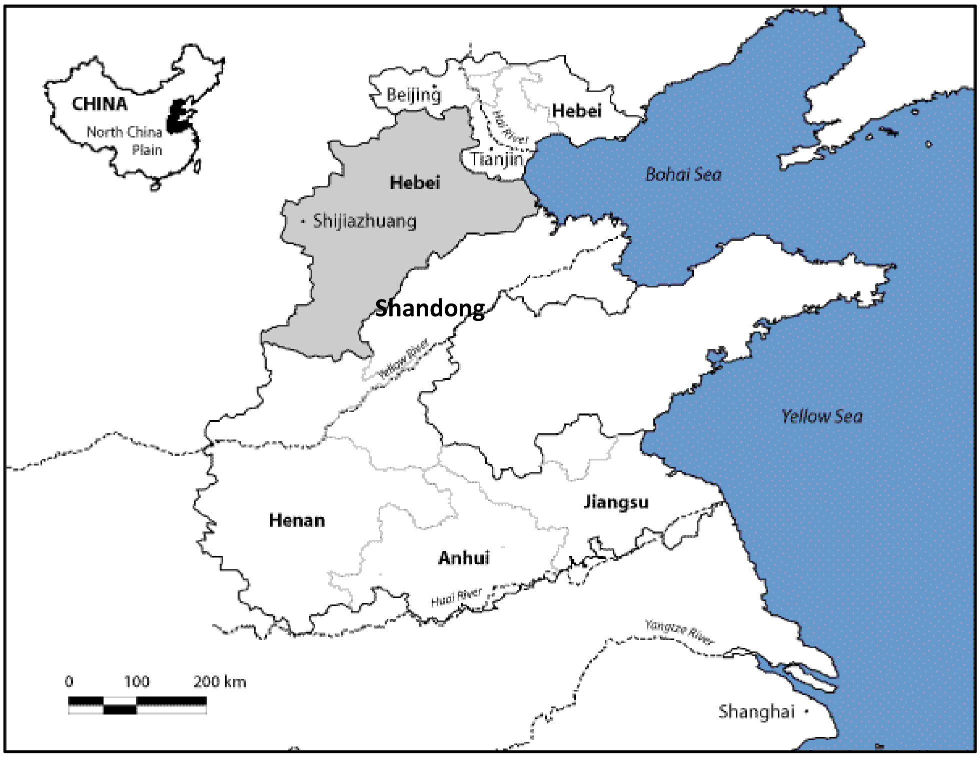
Source: NBS (1991), NBS (1993), NBS (1995), NBS (1997), NBS (1999), NBS (2001), NBS (2003), NBS (2005), NBS (2007) and NBS (2009)

Also the fluctuation of imports of pesticides and fertilizers in China has been strong over the past decades. The total import volume of fertilizers is considerable larger compared to pesticides. Whereas the imports of fertilizers tended to decrease over the past years, also due to the growth of the Chinese fertilizer industry, the imports of pesticide products was growing – indicating a rising dependence on plant protection products. It is remarkable that fertilizer and pesticide export data is not listed in the official yearbooks. This might indicate that these products were not exported on a large scale. However China holds the second biggest global P reserves, which represents 23.7% of the global P resources (DER SPIEGEL, 2010). On a global level Phosphorous is a scarce resource for fertilization, but China is a large global P fertilizer producer.

2.2. Characteristics of the NCP

The North China Plain (NCP) covers seven provinces in the Northern part of Eastern China: Beijing, Tianjin, Henan, Shandong, Hebei and northern parts of Jiangsu as well as Anhui. Figure 7 displays a map of the NCP.

Figure 7. Map of the North China Plain (NCP)



Source: McVicar *et al.* (2002), modified

In Figure 7 the NCP is enclosed by the thick black line. The location of the NCP is displayed by the black shaded area on the inset map. The Hebei Province, the study area, is shaded in grey. The NCP covers 409,500.00 km^2 of which most are below 50 m above sea-level [3]; the relief is monotone and flat (RUMBAUR, 2010). The NCP is one of the most densely populated areas of the world; it covers only about 3% of the total area of the PR China, but it holds around 16% of the total Chinese population (BARNING, 2008). This also leads to small land areas per farm.

The NCP is one of the most important agricultural areas in China and it allows growing of temperate climate crops (BINDER et al., 2007). Quzhou County, the research area, “is a typical county in the NCP” (CHEN *et al.*, 2006); the mean annual temperature is 12.50 ˚C with a mean precipitation of 500 mm/year. Seasonal climate is characterized by distinctly wet (from late June to late October) and dry (from November to early June) periods. Another explicit feature of the NCP is the high variability and strong locality of rainfalls (RUMBAUR, 2010).

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[3] For comparison, total area of Germany: 357,022 km^2 (CIA, 2010)

The pressure on land and improved irrigation technologies as well as increased chemical fertilizer application, since the late 1960s, allowed farmers to operate double cropping systems; nowadays the NCP is dominated by a summer maize – winter wheat (SM-WW) crop rotation system. The grain production in the NCP was intensified and today it is regarded as "China's granary" (PIOTROWSKI and JIA, 2006). As demonstrated in Table 6, the provinces of the NCP supply impressive 73.98% of the total Chinese wheat and 35.27% of the total Chinese maize. Other major crops grown in the NCP, though produced on a considerably smaller scale, also have high shares of the Chinese production and underline the importance of the NCP as an agricultural area.

Table 6. Sown Area and production of major crops in the North China Plain, 2006

	Sown Area *(1000 ha)*	**Wheat** *(mln tons)*	**Maize** *(mln tons)*	**Peanuts** *(mln tons)*	**Cotton** *(mln tons)*
PR China	157 020.6	104.464	145.485	14.666	6.746
NCP provinces*	60 288.2	77.286	51.307	10.142	3.382
Share to whole PR China	**38.40%**	**73.98%**	**35.27%**	**69.15%**	**50.13%**

NOTE: *includes parts of Jiangsu and Anhui which are not in the NCP

Source: CHINA AGRICULTURE PRESS (2007)

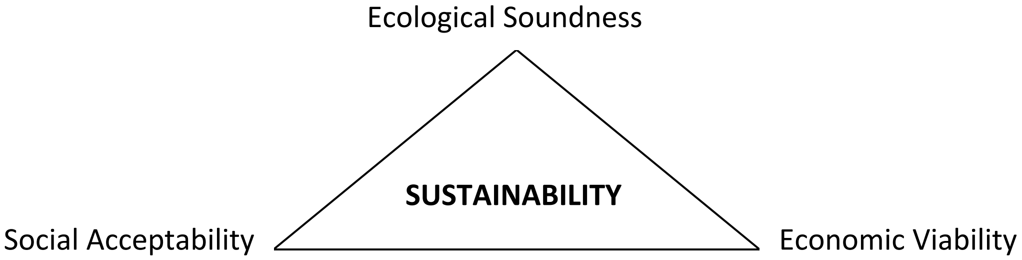
As China's main cultivation area for wheat, maize and peanuts the NCP plays an important role in the objective to achieve food self-sufficiency. Consequently, also considering that poverty still is a threat to parts of the rural population, the area is crucial for Chinese food security and grain sufficiency. The NCP is also China's main cotton producing region – cotton represents an important cash crop for the farmers. Besides the typical SM-WW double cropping system, cotton represents the other characteristic cropping system. Even though a large share of peanuts is grown in the NCP, its total production is less important.

As explained in 2.1, Chinese agriculture – especially in the NCP – is characterized by a low degree of mechanization and a high degree of manual labor. Since many households do not have the financial resources to invest in machinery, the use of contractors is common (as will be demonstrated in 4.3).

2.3.Definition of Sustainability in the Context of the NCP

The concept of sustainability is highly discussed and many definitions exist. The aspects of sustainability are manifold and complex. In this work sustainability is generally referring to the 3 basic dimensions of sustainable agriculture (ZHEN et al., 2005). The 3 dimensions are: ecological soundness (i.e. preservation and improvement on the natural environment), economic viability (i.e. maintenance of yields and productivity) and social acceptability (i.e. self-reliance, equality and improved quality of life) – see Figure 8.

Figure 8. The Three Dimensions of Sustainability



Source: based on ZHEN *et al.* (2005)

More specifically, this work follows the concept of ZHEN and ZOEBISCH (2006) is followed, where agricultural sustainability in the NCP is defined as “the farming practices that grow crops at a profit while minimizing negative impact on the environment. Moreover, sustainable agriculture should also emphasize the ability of the system to continue into the future.” This more specific concept encompasses five dimensions of agricultural sustainability in the NCP, based on the particular setting and situation:

- Crop intensification, respecting the land’s carrying capacity;
- A rational use of inputs;
- Profitable and stable production;
- Strengthened institutional support;
- Improved conservation knowledge and technologies.

This definition of sustainability will be followed throughout this work.

2.4. Environmental Impacts of Agriculture in the NCP

Traditional ancient Chinese agriculture could be characterized by a philosophy and sustainability between nature, physical materials and humans (SHI and CHENG, 2004). Historically Chinese agriculture has been of low intensity and relied on organic fertilizers, such as manure and the return of crop residues (THOMSON *et al.*, 2006). These characterizations are remarkable, considering the current environmental problems of agriculture in the NCP. As described above, the growing population, the growing pressure on land and the lack of resources forced transformation towards a modern high-input high-output agriculture, with related environmental impacts. This high intensity, as will be shown in 2.4.1, led to unbalanced and widely spread over-use of fertilizers and resulting environmental consequences.

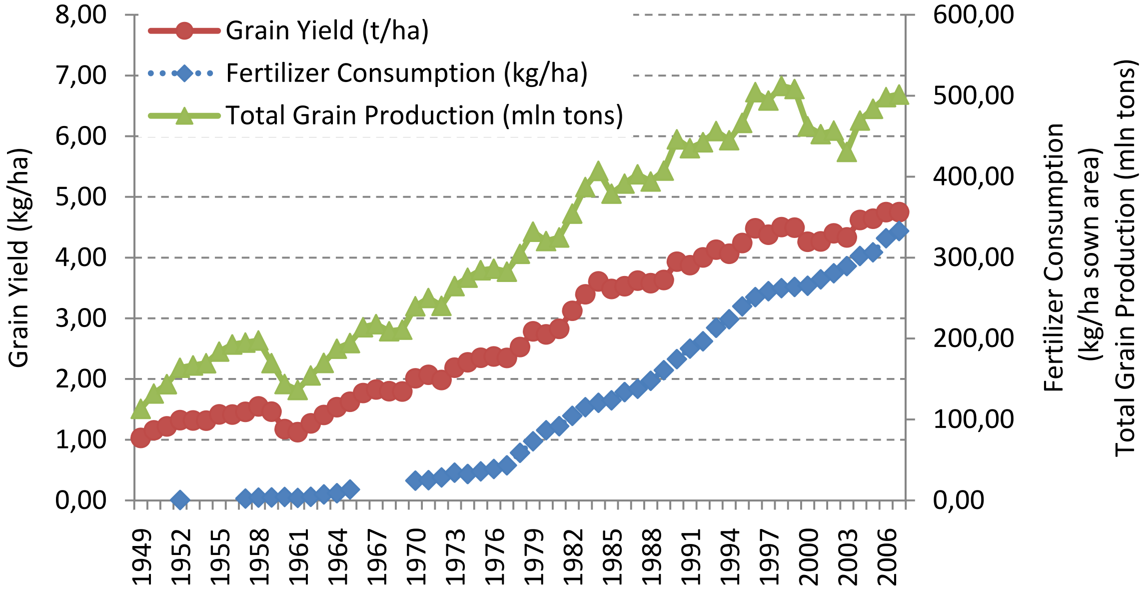
The main source of surface water in the NCP is (diverted) water from the Yellow River (PIOTROWSKI and JIA, 2006). Water is essential for agricultural production, particularly the highly intensive production in the NCP. Therefore any reduction of water supply or quality might threaten the sustainability of agriculture in the NCP, which, for one of China’s most important agricultural regions, poses a risk to food security in China. However, agriculture is also the biggest consumer of water in the NCP and thus the current situation represents a dilemma: farming threatens its own existence. Therefore the following parts describe the problems related to water and farming the NCP – divided into sub-chapters dealing with water scarcity (2.4.2) and water pollution (2.4.3). Other environmental impacts related to agriculture are combined in 2.4.4.

2.4.1. Fertilization

Several studies show that over-fertilization and unbalanced fertilization with large variations are typical for the NCP (GAO *et al.*, 2009 and ZHEN *et al.*, 2006). Consequently, the "lack of science based fertilization has prevented farmers from obtaining their attainable yields and profits" (GAO *et al.*, 2009).

At present China is the world's biggest consumer of nitrogen (N) fertilizers. However, the N efficiency of the prevailing crop rotations in the NCP is often below 30% (KOPSCH *et al.*, 2006). This means that up to 70% of the applied N cannot be used by crops and considerable amounts of N are lost or deposited. Over-fertilization and inadequate practices are the main reasons for these inefficiencies. A notable excess in the N balance leads to a considerable leaking of N and to significant contaminations of air and water (ZILKENS, 2004). Therefore, the present agricultural system in the NCP cannot be regarded sustainable.

Figure 9. Grain Production, Grain Yields and Fertilizer Consumption in China, 1949-2007



Source: BARNING (2008) and NBS (2008), modified

As indicated in Figure 9, China achieved impressive growth rates of total grain production and grain yields between the 1960s and the early 1980s, by expanding the irrigation systems and by applying modern technologies and inputs. Then, however, the growth rates of total grain production slowed down and even started to develop negatively at the turn of the millennium. In the first years of the new millennium total grain production recovered, but it seems like grain yields and total grain production are stagnating over the past years. Fertilizer consumption, though, continued to increase steadily – indicating decreasing nitrogen use efficiency (NUE) and probably rising over-fertilization. HUANG and ROZELLE (1995) already revealed the negative effects of environmental stresses, like soil erosion, increasing natural disasters, salinization of land and the deterioration of soil quality, on yields in China; moreover, they warned about the dynamic characteristics of this problem – if the agricultural practices were continued in the same way, the environmental stresses would increase. However, indicated in Figure 9, fertilizer consumption in China continued to increase since then, which represents a further intensification of farming practices with increased negative environmental stresses: the degradation of natural resources (soil and water) and contaminations (input residues). These environmental stresses can reduce yields and thus can threaten China's food-security.

In a survey by JU *et al.* (2006) the N-balance[4] of intensive cropping systems in the NCP were compared. The mean annual N surplus for the cropping systems in the NCP was estimated at: 349 kg N per ha (cereal crop rotation) and 3,327 kg N per ha (vegetable greenhouse production). These large surpluses are significant considering that already an excess of 100 kg N/ha could be regarded as a baseline for nitrate leaching into the ground or surface water on a regional scale (SCHLEEF and KLEINHANß, 1994). Therefore N is causing environmental damage through i.e. leaching or deposition in the ecosystems. Furthermore, long term application of large amounts of fertilizers may lead to soil acidification and fluxes of nitrous oxide are strongly affected by excessive N application rates (BARNING, 2008). Atmospheric N deposition mainly from over-fertilization, but also from intensive livestock keeping and combustion of fossil fuels, in the NCP is large (HE *et al.*, 2007). The impact of this additional input on the natural ecosystems is causing changes by eutrophication which affects the balance of aquatic and terrestrial systems. HU and CAO (2008) also revealed that the use of chemical fertilizers in the NCP, even with lower levels than the current farming practice, had negative impacts on soil biodiversity, soil health and nutrient cycles. These findings indicate that the current practice have severe impacts on the sustainability of agriculture in the NCP.

The quality of crops is affected by the overuse of N fertilizers. For example, the nitrate concentration of chives (1,533mg/kg) exceeds the threshold value of 700mg/kg more than twice (HU *et al.*, 1996). The relation between the amount of applied N fertilization and the nitrate concentration in field crops poses a threat to human health. Studies in the NCP showed that high application rates of N fertilizers are also linked to a deterioration of crop quality and to occurrences of stomach and esophagus cancer (ZHANG *et al.*, 1996).

Reasons for N overuse in the NCP are: the lack of a formal fertilizer recommendation system, weaknesses of the local extension services, the lack of knowledge transfer to the farmers, low level of education of farmers, low price of N fertilizers, distraction of off-farm activities, obsolete fertilization techniques and many farmers do not take N inputs of manure and water into account (BARNING, 2008; JU *et al.*, 2006).

Numerous studies showed that yields do not increase significantly when fertilizer application rates exceed a certain value, but residual N increases sharply. Hence, it is alarming that

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[4] Nitrogen balance = input components (fertilizer + manure + nitrogen from seed + wet deposition + nitrogen from irrigation) – output components (N removed by aboveground plant parts)

according to JU *et al.* (2006) over-fertilization, with its negative environmental impacts, is representative for the NCP.

2.4.2. Water Scarcity

When analyzing water scarcity in the NCP it should be noted that “the water shortage could have a worldwide impact if China’s ability to produce sufficient food to feed a large and growing population is restricted” (JIANG, 2009). Therefore water scarcity in the research area might have global implications.

As described in 2.1, in order to ensure food production, irrigation facilities in the agricultural areas in China have been extended over the past decades. Moreover, the demand for high crop yields led to an increased use of irrigation water for winter wheat: from 100 mm in the 1950s to 300 mm in the 1980s (WANG *et al.*, 2001). Nowadays, the irrigation system in the NCP covers 71.00% of the arable land and consumes more than 70.00% of the total water supply (BARNING, 2008). This illustrates the impact of agriculture on water in the NCP – which is also representative for China (see Figure 4). Furthermore it emphasizes the importance of water for Chinese food security. However the situation is problematic as the basins of the NCP “have less than half of the water per capita in relation to Egypt or Java, which are recognized as water-scarce regions” (VARIS and VAKKILAINEN, 2001). Therefore the Hebei Plain ”is estimated to be the largest groundwater drawdown area in the world” (XU *et al.*, 2005). The situation becomes more dramatic when considering that “increasing demand for China’s limited water resources from rapidly growing industry, urban populations and agriculture implies potentially dire consequences for the sustainability of water resources, especially in northern China” (HUANG *et al.*, 2009).

Surface water dominated China’s irrigation development until the 1960s, when gradually groundwater became the main source of irrigation water – especially in Northern China. During the 1990s also private tubewell ownership evolved: from collectively owned and operated to private tubewells; the share of private tubewells rose from almost nothing in the 1970s to 70.00% in 2004 (ZHANG *et al.*, 2008). These privately run decentralized pumping facilities complicate controls, monitoring and quantification of amounts of pumped groundwater. Furthermore questions regarding the fair access to water resources arise. Another study showed that so-called Water User Associations (WUA), which represent farmer-based participatory organizations which manage water resources of villages, have also emerged at the same time. WUAs and private tubewell ownership emerged in order to mitigate effects of water scarcity because “in contrast to the government’s slow response, water users have been more active” (HUANG *et al.*, 2009)

Monitoring of actual water use in the research area is difficult as often volumetric measurement equipment is lacking (YANG *et al.*, 2003). Furthermore the farms in the NCP are characteristically fragmented and small-scale – which also complicates accurate volumetric measuring and monitoring (HUANG *et al.*, 2009). Consequently it is difficult to control the used amounts of water and monitoring costs are high. Water pricing strategies differ strongly across China, also due to the increasing importance of private pumping facilities. Due to the difficulties related to monitoring and measuring of volumetric water use, some regions with surface water irrigation charge per area flat-rate fees – for example ¥330.00 per ha in parts of the Henan Province (YANG *et al.*, 2003).

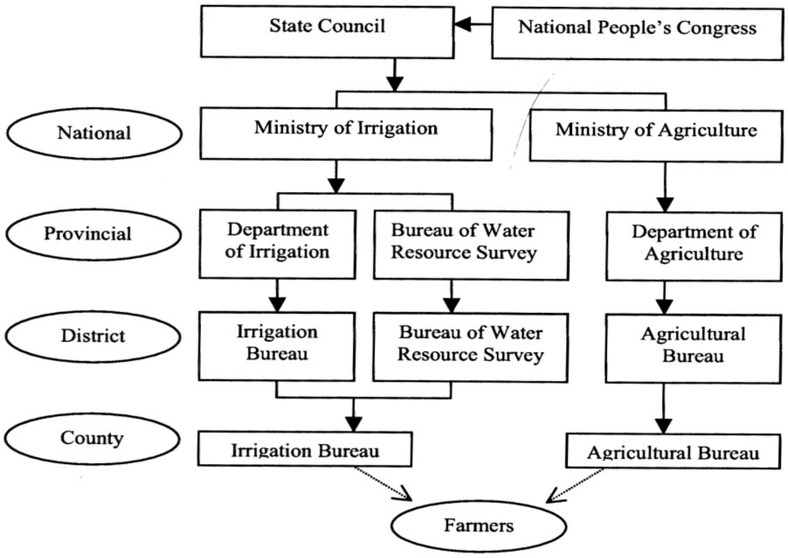
For the Chinese agricultural production, it is challenging that around 81.00% of the water resources are in the country's Southern parts, whereas 64.00% of the arable lands lie in the Northern parts. Consequently the natural characteristics of the water resources are inconsistent with spatial water needs. The present situation in the NCP is dramatic: it holds a considerable share of China's arable land - with a high need of water, but only 6.00% of China's surface water (VARIS and VAKKILAINEN, 2001). In 2003 the available amount of water per person in the NCP was often less than 1,000.00 cubic meters (m^3) – which was the lowest in China (WORLD BANK, 2007). Irrigated arable land in the NCP relies on groundwater, which causes groundwater levels to drop up to 1 meter annually and even led to land subsiding (BINDER *et al.*, 2007). In HENRY (2004) it is estimated that water tables in the NCP are declining between 0.125m and even up to 3m per year. The situation in the Hebei Province is dramatic as around 78.00% of the water used for irrigation stems from groundwater resources (ZHANG *et al.,* 2008). Also for other provinces in the NCP the contribution of agricultural irrigation to the depletion of groundwater is high: around or above 50.00% (WORLD BANK, 2007).

According to GALE (2005) low marginal prices of water in China lead to overuse. Several approaches to value water are presented in WORLD BANK (2007); for the NCP the value of one cubic meter of water is estimated to be up to 5.20¥ (using the method of marginal value). Many studies call for the introduction of (adjusted) water prices in the NCP, whereas other studies oppose approaches related to water pricing. The controversial subject of water pricing will be further discussed in (chapter 7). However, as also shown in 4.3.7, many farmers are already paying (indirect) volumetric water prices through costs related to pumping - the more they pump, the higher the running/rental costs of the pump (WEBBER *et al.*, 2008). However, in order to deliver water to the scarce agricultural regions in China's North, irrigation infrastructure has to be developed, operated and maintained – which creates costs. Current water prices do not cover the full costs of operating and maintaining the irrigation system and also do not regard a resource fee or extraction costs.

The need to utilize groundwater resources for irrigation is even further accelerated by other factors: competition for water with urban and industrial users, increased demand for food, continuous decline of precipitation, overexploitation of surface water resources and drying up of rivers. Considering that the estimated increase of annual groundwater use for irrigation is already 6.42% - the future situation looks tense as the gap between water supply and demand will widen (ZHEN and ROUTRAY, 2002). Already nowadays' high water consumption levels led to water shortages in many places of the NCP. The depletion of groundwater tables is most severe in the Hebei Province (on which this study focuses). Deep-aquifers depleted by more than 50 meters between 1970 and 2005 (WORLD BANK, 2007). It was shown that between 2000 and 2003, 74.50% of the depletion in groundwater tables in the Hebei Province (in total 6,109.00 mln m^3) can be associated with irrigation (WORLD BANK, 2007). Therefore agriculture and especially intensified irrigation represent the major reason for declining groundwater levels. It is a vicious circle as the farmers in NCP endanger their own future existence. Furthermore, the exploitation of groundwater resources in the NCP leads to an increase of irrigation costs, an increase of soil salinity, compacted/hardened soil, an intrusion of salt-water, an increase of land subsistence and the creation of water logging – therefore it threatens the sustainability of farming and, thus, China's food security. The threat for food security is emphasized by the fact that LIU *et al.* (1995) estimated – already in 1995 – that due to water shortages annual Chinese grain production has decreased by more than 10 mln tons and that yields are increasingly uncertain – which increases the economic risks of the farmers.

A challenge of the Chinese water sector is the institutional set-up. The weak implementation of laws and policies in the rural areas is often criticized (WANG *et al.*, 2008). Furthermore HENRY (2004) disapproves of the complex Chinese institutional framework and calls for government action and policy changes. Also VARIS and VAKKILAINEN (2001) state that the Chinese institutional set-up lacks unified water administration and management and that it is "overly complex and prone to rivalries and inefficiencies". Moreover, KOLBE and ZHANG (2000) call for the introduction of state regulations and legislations to control ground and surface water through specific farming and fertilization standards and restrictions for water areas. In order to illustrate the complex structures in Chinese groundwater management, its institutional set-up is displayed in Figure 10.

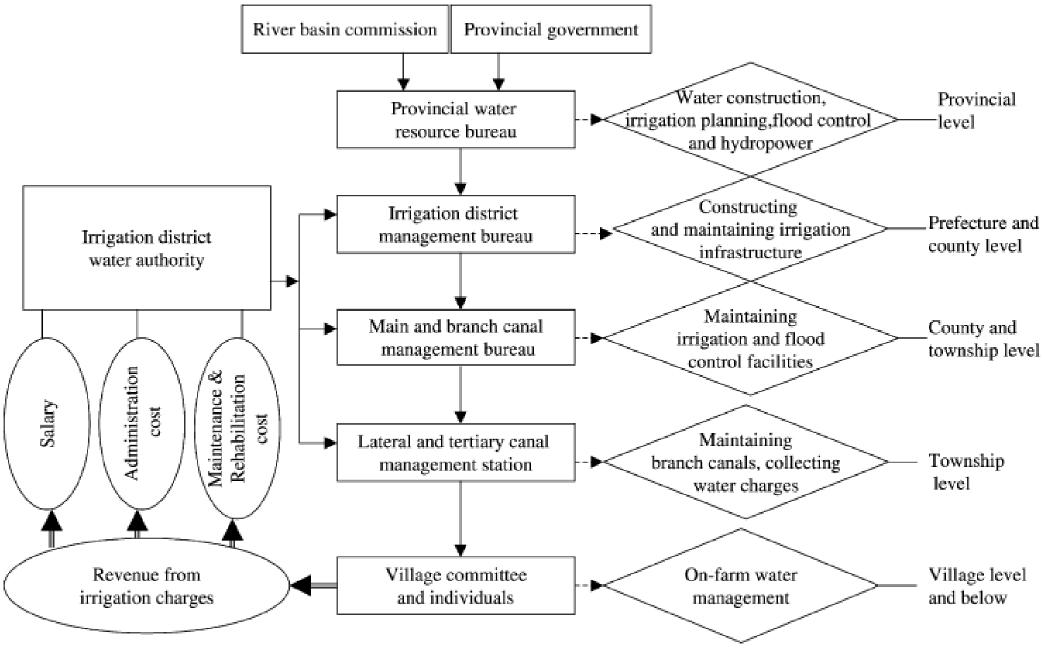
Figure 10. Institutional Arrangements for Groundwater Management in China



Source: ZHEN and ZOEBISCH (2006)

Moreover, the institutional structures regarding water management differ strongly across regions in China (HUANG *et al.*, 2009) – which further complicates the introduction of national policies. Consequently the local conditions and the role of the local government are not uniform across the NCP. Figure 11 demonstrates that comparably complex structures also exist for the Chinese surface water system.

Figure 11. Administrative Structure and Finance of the Surface Water Irrigation System



Source: YANG *et al.* (2003)

The complex structures in the Chinese water sector are additionally complicated by private enterprises which are offering services such as pumping or maintenance and WUAs (see above). This limits control mechanisms and creates unclear responsibilities. Furthermore, clearly defined and legally enforceable water rights are lacking in China (YANG *et al.,* 2003). Therefore several studies call for the coordinated establishment of institutions regulating water use and withdrawal through (clearly defined and legally enforceable) water rights; moreover policies in various areas are not integrated with each other and, thus, might exacerbate issues concerning water resources (JIANG, 2009). Also the irrigation infrastructure represents a source of water loss: “in agriculture on the NCP the principal source of inefficiency is the loss of water in irrigation canals” (WEBBER *et al.*, 2008).

Even though water is a scarce resource in the NCP, farmers are not using it efficiently. The predominant flood irrigation method results in low water use efficiencies and applications of sprinklers and drip irrigation are almost negligible (YANG *et al.*, 2003). ZHEN and ROUTRAY (2002) calculated the water use efficiency (WUE) for the NCP at only 0.70 kg farm produce per m^3 water; the average in developed countries lies at 2.00 kg/m^3. Another study estimated the WUE for grains in China with ≤ 1 kg/m^3 (KANG and LI, 1997 in: WANG *et al.*, 2004). Besides inefficient water use, flood irrigation can also cause soil erosion and degradation. For the dominant SM-WW crop rotation irrigation is essential, because summer maize consumes about 70.00% of the total rainfall during its growth period in the rainy summer season – leaving insufficient soil moisture for producing subsequent winter wheat. Therefore irrigation is necessary for winter wheat during the dry winter months, which puts additional stress on the groundwater resources in the NCP (BINDER *et al.*, 2007). Moreover YANG *et al.* (2003) criticize that even water saving methods which are not capital and energy intensive (e.g. canal lining, border irrigation, hose water conveyance, water quantity and timing control or plastic mulch) are not widely used in Northern China.

2.4.3. Water Pollution

Another major environmental problem in the NCP is ground and surface water pollution from agriculture. It should be noted that water pollution can significantly contribute to water scarcity, as polluted water resources might no longer be used or consumed – these interactions threaten China's food security, economic development and quality of life (JIANG, 2009). Problems with water pollution affect people's living and health via the intake or contact with polluted water (LI *et al.*, 2001). Water quality in the river systems in North China worsened between 2001 and 2005 (WORLD BANK, 2007).

A significant positive relationship between the amount of N fertilization and the N content in groundwater exists in the NCP. Hence a study on water quality showed that 16 out of 20 wells contained N levels exceeding the maximum allowable limit for nitrate in drinking water (ZHEN *et al.*, 2005). Another study in the NCP revealed that about 45.00% of over 600 groundwater samples exceeded WHO and European limits for nitrate in drinking water (ZHANG *et al.,* 2004). Another study in the provinces Beijing, Tianjin, Hebei and Shandong revealed that 47% of 102 groundwater samples contained nitrate above the drinking water standards (LI *et al.*, 2003). Moreover an analysis of samples from irrigation water in the Hebei Province produced remarkable results: irrigation water samples had a nitrate content of over 80 mg/l – which significantly exceeds the threshold of 50 mg/l in Western countries (KOLBE, 2009). In addition, high amounts of applied pesticides also led to contaminations of groundwater resources. This poses threats to human health.

Varieties of cancer, which are suspected of being related to high concentrations of nitrites or nitrate in groundwater (MORALES-SUAREZ-VARELA *et al.*, 1995) or related to the concentration of other chemical pollutants in the groundwater, occur more often in the NCP than in other regions in China (LU *et al.*, 1986 and ZHANG *et al.*, 2000); and the rate of occurrence is also higher than the world average (WORLD BANK, 2007).

Agricultural activities as a major source of non-point pollution contribute a large share to the recent increase in surface and groundwater pollution. Residues of chemical fertilizer are considered a main agricultural source of water pollution. Between 1995 and 2007 the amount of chemical fertilizers used in the Hebei Province rose by nearly 41.32% (NBS, 1996 and 2008). In the regions with intensified agriculture of the NCP the highest concentrations of ammonia in water in China are reported (WORLD BANK, 2007). Non-agricultural rural industries in China contribute strongly to water pollution: 70% of monitored river sections were unfit for human consumption (WANG *et al.*, 2008). Consequently agricultural production is also suffering from water pollution from industrial sectors (e.g. through untreated waste water).

Chemical fertilizers are often not used effectively in China. In the NCP nitrogen fertilizer is applied in too high doses, too early or with an unbalanced ratio of N to P and K. LIEW (2004) highlights that an imbalance in nutrient management in China contributes to pollution of water sources such as lakes and rivers. Furthermore, the increased use of irrigation water and N applications led to encroachment of seawater combined with subsiding land surfaces and groundwater pollution (WANG *et al.*, 2004).

Around 70.00% of the annual precipitation in the NCP is concentrated between July and September. These heavy rainfalls or flood irrigation – which is typical for the NCP – cause nitrate to move into deeper soil layers, as spreading of solid fertilizers with following flooding of the field to dissolve the fertilizers represents a common practice in the NCP. This nitrate is either causing pollution by leaching into the groundwater or it is lost in the deeper layers of the soil where the N cannot be utilized by crops (JU *et al.*, 2004).

Currently, to fight water shortages, farmers in some areas of the NCP are using municipal waste water for irrigation (KENDY *et al.*, 2003). The N concentration in municipal waste waters is rising due to China's economic growth: changing Chinese diets increase the amount of N in human waste and the advancement of flush toilets and sewerage systems increases the amount of municipal waste water which is discharged untreated into rivers and lakes. The expansion of animal production and consequently the increased amount of animal waste, further adds to the N load in China's waters, causing health and environmental problems (LIU *et al.*, 2008). Nevertheless municipal waste water is nutrient-rich (thus can further increase over-fertilization when used for irrigation), but might pose sanitary and hygienic threats.

2.4.4. Other Environmental Impacts

Agriculture is not only creating negative environmental effect, the agricultural sector is also negatively affected by industrialization, urbanization and the growth of China's economy. Large areas of arable lands are claimed for industrial use and are no longer available for agricultural production. The massive conversion of agricultural land to non-agricultural uses represents another threat to the sustainability of farming in China (LI *et al.*, 2009). The conversion of agricultural land, i.e. the loss of agricultural land, can result in urban sprawl, environmental degradation in suburban areas, loss of open space and food security (TAN *et al.*, 2009). Despite administrative attempts to restrict farmland conversion, LICHTENBERG and DING (2008) regard it "as the chief threat to the nation's capacity to produce adequate levels of staple cereals" – institutional and policy failures are regarded as main reasons for the continuing loss of agricultural land. Another factor are significant levels of illegal farmland conversions (TAN *et al.*, 2009). In addition more than 100,000.00 ha are affected by industrial solid waste, which pose further threats to the quality and quantity of agricultural production (YI, 2006).

The grasslands in Northern China suffer from serious degradation due to overstocking of livestock and improper grazing management. Consequently, about 50.00% of the grassland is threatened by desertification, wind erosion and serious quality and productivity degradation (ZHEN and ZOEBISCH, 2006). Also the croplands in the NCP are suffering from erosion, which, thus, poses a thread for the productivity and sustainability. The main reasons are wide-spread mono-cultures and long-repeated crop rotations.

In the NCP, not only the emissions from over-fertilization of crops, but also emissions of animal husbandry and exhausts from traffic and industry generate high atmospheric concentrations of reactive N species and high amounts of N deposition, which are closely related to particulate matter emissions. In the NCP these emissions (i.e. dust from agricultural activities) are creating particulate matter concentrations which exceed the European[5] and the Chinese[6] thresholds by far (KOPSCH *et al.*, 2006). Findings of the same study indicate that air pollution in the NCP is strongly affected by agricultural activities.

The intensification of agricultural practices led to a decline of soil organic matter contents, the main reasons are: intensified tillage and removal of crop residues (THOMSON *et al.*, 2006). This resulted in lower levels of soil nutrients and, consequently, in higher fertilization needs – which further aggravate the environmental problems described in 2.4.1. In traditional Chinese agriculture manure played a central role; people were aware of positive effects on workability, water holding capacity and soil fertility and therefore used to say that "farming is a joke without manuring" (YANG, 2006) – however in the past years the use of manure declined and its positive effects on soils are increasingly lacking. The total loss of soil organic carbon (SOC) in China due to land use is estimated to represent ~9.5% of the total global loss of SOC (WU *et al.*, 2003). In 1990 Chinese croplands lost 1.6% of SOC, whereas U.S. cropland only lost 0.1% in the same year – the main reason is the low return rate of crop residues (LI *et al.*, 2003). Soil carbon sequestration is a possible strategy to mitigate concentrations of greenhouse gases and, thus, climate change – that is why it is a component of the Kyoto strategy for reducing threats of global warming. Vice versa: "net loss of carbon from agricultural soils contributes to the growth of atmospheric CO_2 concentration and the potential for global warming" (LI *et al.*, 2003). Consequently the relations between agriculture, greenhouse gases and climate change in the research area are of importance. A study by LI *et al.* (2006) demonstrated that carbon dioxide (CO_2) fluxes in the SM-WW cropping system in the NCP fluctuate strongly as they are affected by climatic conditions and management measures. Also nitrous oxide (N_2O) emissions from agricultural soils in the NCP showed a strong temporal fluctuation – mostly due to the timing of fertilization (DONG *et al.*, 2001). The same study states, for example, that the combined application of organic manure and fertilization increases the N_2O emissions by 20%, therefore the study concludes that continued intensive land management "will ensure that N_2O emissions from agricultural soils continue to increase in China, affecting stratospheric chemistry and increasing global warming potential". N fertilizers can limit the sink function (i.e. absorption) of soils for atmospheric methane (CH_4); CHEN *et al.* (1997) showed that the

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[5] The EU limit for particulate matter (PM10) concentration in air: 50.00 µg/m^{-3}

[6] The Chinese limit for particulate matter (PM10) concentration in air: 150.00 µg/m^{-3}

soils with the typical cropping systems of the research area are a weak sink of CH_4. Ammonia (NH_3) volatilization is the biggest process for gaseous N loss in the research area: it accounts for 95.6% of the total gaseous N losses and might be cause low efficiencies of N fertilizers (ZANG *et al.*, 2004b).

Most farmers in the NCP use cheap and freely available pesticides. In order to increase effectiveness, high dosages are applied: the average application rates are two to three times higher than the recommended dosage (ZHEN *et al.*, 2005). The high application rates combined with inappropriate handling have negative effects on the farmers' health. Considering that residues of most pesticides can accumulate in human and animal bodies it is alarming that the concentration of pesticide residues in drinking water is high. A study revealed that the EU limits for pesticide residues in drinking water for specific substances[7], as well as for total values[8] were exceeded in the NCP (GUO, 1995). Moreover, about 24.00% of total cropland is already polluted by pesticides (ZHEN and ZOEBISCH, 2006). Pesticide residues could also be detected in other Chinese agricultural products from intensive farming areas, especially in vegetables and fruit.

Another important point is that in China – due to the specific climatic and geographic conditions – "climate change and variation (…) have significant effects on agriculture and land use" (OSTWALD and CHEN, 2006). These effects relate to changes in vegetation or land use, but also in the decreasing dependence on rain fed agriculture and resulting irrigation needs. Climate change is expected to continue on a global level; consequently these effects can be expected to intensify.

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[7] The EU limit for pesticide residues of specific substances in drinking water: 0.10 µg/l.

[8] The EU limit for total pesticide residues in drinking water: 0.50 µg/l.

3. Data Basis and Data Collection

This part describes the processes of data acquisition and data handling for this work. It is divided into a section which describes the secondary data sources and another section which outlines the practices of own data collection, the primary data.

3.1. Primary Data

As sub-project 3.1, this work is embedded in the interdisciplinary International Research Training Group "Sustainable Resource Use in Northern China" (IRTG) which aims "at developing cropping systems and management practices for the North China Plain that will ensure high intensities and will at the same time be environmentally, economically, and socially sustainable" (IRTG, 2009). The IRTG represents a collaborative research project between the University of Hohenheim, Stuttgart, Germany (UoH) and China Agricultural University, Beijing, PR China (CAU). The project defines the NCP as the study area. Data and information were exchanged with other sub-projects of the IRTG. The internal IRTG data base offered a wide range of data concerning agricultural production in the NCP (IRTG, 2010).

3.1.1. Questionnaire Design

Based on intensive literature research, the questionnaire was designed in Stuttgart and Beijing. Experts from the UoH and CAU were consulted for designing the questionnaire. Furthermore literature on quantitative research methods was reviewed to guide the construction process (e.g. BABBIE, 2007 and BLACK, 1999). The questionnaire focuses on quantitative data on the operations of the farm households. The questionnaire consists of open- and closed-ended questions. Most questions have codes for the answers in order to facilitate data entry. In order to control the questionnaire for errors, it was pre-tested on eight farm households in June 2008. The pre-test was conducted in Beijing (北京) Province, in the prefecture-level city of Haidian (海淀) in the village of Cheerying (车耳营村) which belongs to the county of Sujiatuo (苏家坨镇). Then, according to the findings of the test, the questionnaire has been modified. It is divided into six main parts: household characteristics, farm resources, farm production data, further training and information transfer and household balance, subsidies and credits. The survey was conducted in July 2008, therefore the questionnaire refers to the year 2007 in order to cover a complete growing circle of the crops it includes all crops sown in autumn 2006 which are harvested in 2007 and all other crops which are harvested in 2007. The entire questionnaire can be found in the annex (see Annex 3). The translation of the questionnaire into Mandarin was cross-checked by experts from the CAU, in order to avoid translation errors.

3.1.2. Survey

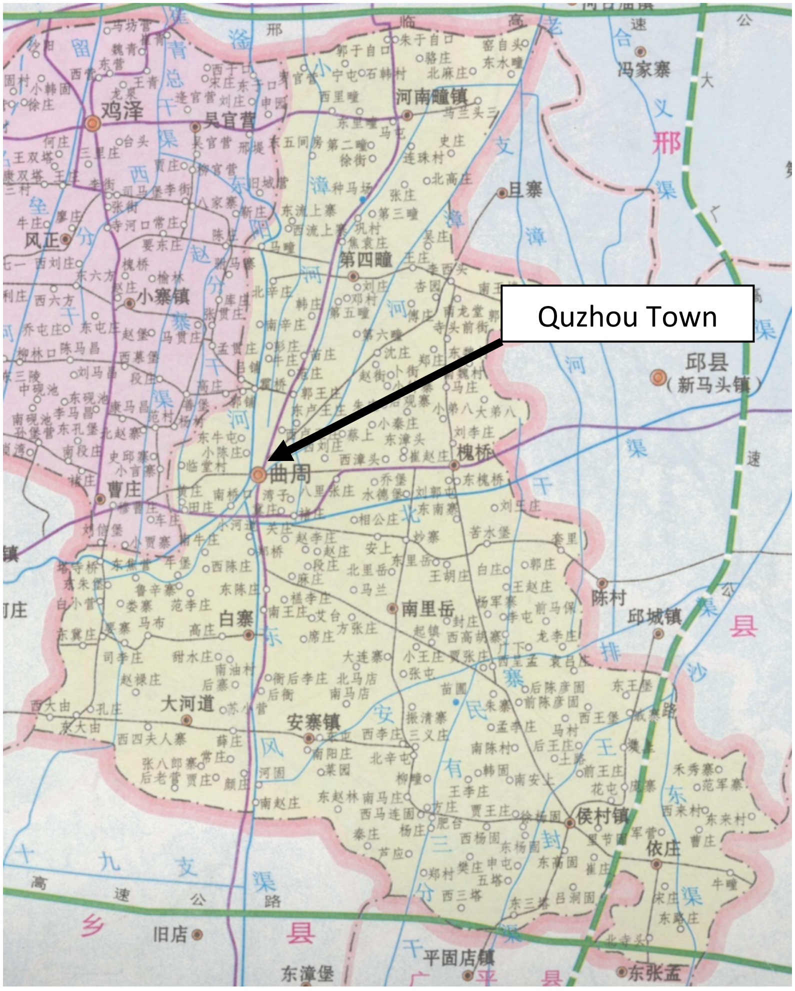
The survey was conducted in July 2008. It was conducted in Quzhou (曲周) County which belongs to the administration of the prefecture-level city Handan (邯郸), which lies in the Hebei (河北) Province. Quzhou is divided into 10 towns (see Table 7) and lies in the NCP.

Table 7. Towns in Quzhou County

Name in Mandarin	Name in English
曲周镇	Quzhou
安寨镇	Anzhai
侯村镇	Houcun
河南疃镇	Henantuan
槐桥乡	Huaiqiao
南里岳乡	Nanliyue
白寨乡	Baizhai
大河道乡	Dahedao
依庄乡	Yizhuang
第四疃乡	Disituan

Figure 12 displays a map of Quzhou County.

Figure 12. Map of Quzhou County



Source: WANG and QIN (2008)

In both towns, the agricultural officer (主管农业的副乡长) provided lists of all villages within the area of authority (see Annex 1 and Annex 2). Based on these lists, the villages were selected in a simple random selection process. Analogous to the processes described in RUSSELL (2000), the names of all villages were written on same-sized pieces of paper, which were then mixed. In each of the two towns of Nanliyue and Baizhai, two villages were randomly selected (by means of “blind selection”); these villages are displayed in Table 8.

Table 8. Randomly Selected Villages of the Survey

	Mandarin	English	Mandarin	English
Town	南里岳乡	Nanliyue	白寨乡	Baizhai
Villages	王胡庄	Wanghuzhuang	后寨	Houzhai
	永胜村	Yongshengcun	苏胡寨	Suhuzhai

In the villages, the village officials provided documents with the names of all households. A simple random selection process selected 16 households per village: an online random number generator provided numbers between one and the number of households per village (HAARH, 2008). These numbers were compared to the documents of the village officials and the corresponding household was contacted. This process was repeated until 16 household heads in each village agreed to participate in the survey. Each respondent received a brief explanation about the purpose of the survey and was ensured confidential treatment of his answers (see Annex 4). After completion of the questionnaire, each respondent received ¥30.00. In total 64 households were surveyed.

Not only due to random sampling representativeness can be assumed: the surveyed households are – in terms of important characteristics like e.g. the number of household members and the size of land areas – comparable to the averages in Quzhou County (as indicated in 4.1.1 and 4.2.1). Also the cropping structure of the surveyed households is typical for the research area (see 4.3.1).

The interviews were conducted by students from the CAU. The interviews were surveyed by experts from the UoH and CAU. In addition to the survey, the locations of the farm houses as well as the locations of up to five plots per household were determined by Global Positioning System (GPS) devices. Furthermore, soil samples from at most 5 plots per household were collected. Thus 204 soil samples were collected and GPS data points for 205 plots and 64 households were identified. In order to facilitate the collection of the location data and the soil samples, each respondent completed a “Field Map” which indicates the names of the fields and the crops which are currently grown on these fields (Annex 5). The codes of the “Field Map” correspond with the codes of the questionnaire. The location data and the soil samples were collected by the support of household members and village officials.

3.1.3. Data Entry

The survey data has been entered into Microsoft EXCEL spreadsheet software. Every step of data entry was cross-checked in order to avoid data entry errors. Still, various error potentials remain in household survey data; therefore it was screened and checked intensively to identify unrealistic values and obvious errors, also by using SPSS Statistics 17 software tools. Whenever justifiable, these values and errors have been replaced by realistic values. If a replacement was not justifiable, the identified value was deleted for the corresponding household. No household needed to be completely excluded from the data set.

3.2. Secondary Data

Besides own collected data, secondary data sources were essential for this research. Review of existing literature represents a main part of this work. The main secondary data sources were scientific publications. Intensive literature research created the data foundation for this work. Mainly English and German literature was considered but also – to a lesser extent – also translated Chinese publications. Moreover, online data bases and other websites were reviewed. Furthermore, exchange with experts on international scientific conferences provided valuable information.

4. Descriptive Analysis of Surveyed Farm Households

This chapter aims at describing the characteristics of the surveyed farm households. It presents the findings from the survey in July 2008. It is divided into 5 sub-chapters: the household characteristics, the characteristics of farm resources, the characteristics of crop production, the environmental characteristics of farming practices and the economic characteristics of the surveyed households.

4.1. Household Characteristics

In order to be able to reveal the socio-economic background of the surveyed households, this part focuses on the description and analyses of the household characteristics and of the members living in those households. The respective sections deal with household size, members and education, off-farm income, agricultural labor structure, non-farm household enterprises and further training and information transfer.

4.1.1. Household Size, Members and Education

“Household head” is a self-defined attribute by the households. The average household size in China in 2007 was 3.17 persons (NBS, 2008); Quzhou County, where the survey was conducted, has a mean rural household size of 4.38 persons (SBHC, 2009). As demonstrated in Table 9, the average household size of this survey is comparable to other studies which estimated with 4.3 persons/hh for the NCP and 4.2-4.4 persons/hh for Quzhou (BARNING, 2008).

Table 9. Size, Members and Education of Surveyed Households

Village *(Number of hhs)*:	**ALL VILLAGES (64)**	Suhuzhai (16)	Houzhai (16)	Yong-shengcun (16)	Wang-huzhuang (16)
Mean hh Size *(pers./hh)*	**4.14**	3.81	4.63	4.44	3.69
Total hh-members	**268**	61	77	71	59
Category *(no. and % of total hh members)*:					
-Hh Head	**64 (23.88%)**	16(26.23%)	16(20.78%)	16(22.54%)	16(27.12%)
-Spouse	**60 (22.39%)**	12(19.67%)	16(20.78%)	16(22.54%)	16(27.12%)
-Children	**86 (32.09%)**	21(34.43%)	16(20.78%)	27(38.03%)	22(37.29%)
-Grandparents	**12 (4.48%)**	4(6.56%)	3(3.90%)	4(5.63%)	1(1.69%)
-Grandchildren	**25 (9.33%)**	5(8.20%)	4(18.18%)	6(8.45%)	0(0.00%)
- Other	**21 (7.84%)**	3(4.92%)	12(15.58%)	2(2.82%)	4(6.78)
Education *(no. and % of total hh members)*:					
-No education	**54 (20.15%)**	6(9.84%)	27(35.06%)	12(16.90%)	9(15.25%)
-Primary School	**77 (28.73%)**	18(29.51%)	20(25.97%)	21(29.58%)	18(30.51%)
-Middle School	**111 (41.42%)**	26(42.62%)	27(35.06%)	32(45.07%)	26(44.07%)
-High School	**20 (7.46%)**	7(11.48%)	3 (3.90%)	5(7.04%)	5(8.47%)
-College	**6 (2.24%)**	4(6.56%)	0 (0.00%)	1 (1.41%)	1(1.69%)

The categorization of household members is based on the perspective of the respective household head. As can be concluded from Table 9, Houzhai has a substantial higher share of household members who obtained no education (35.06%), than the other villages. This can be explained by the fact that more grandchildren and other persons are living in the surveyed households in Houzhai than in the other 3 villages. Of all persons aged 6 and over in 2007 in China, 91.99% (Hebei Province: 93.77%) had schooling (NBS, 2008). The surveyed data also includes persons under the age of six who have not yet started schooling; therefore the surveyed figures for people with at least primary education (79.85%) are lower than the official statistics. However, considering that 18 of the surveyed children or grandchildren (6.72% of total household members) have not yet started schooling, one can assume that the level of school education in the surveyed villages is still slightly lower than the official data of the Hebei Province. In addition the fact that nearly half of the surveyed household members have no or only primary school education demonstrates a low level of education. In addition, not even 10.00% of the surveyed household members have high school or college education.

Table 10. External Family Members of Surveyed Households

	Hhs which support Family Members*	**Hhs supported by Family Members***
Total no. *(and % of all hhs)*	14 (21.88%)	15 (23.55%)
Mean Support *(¥/year)***	¥4,609.29	¥5,846.67

NOTE: *who are not living in household
**of households which support/are supported by family members

As Table 10 shows, the interviewed households have family members who are not living in the household, but who are supported by or who are supporting the household income. Most of the people who are financially supported by the household are students who study away from home (usually in middle or high school or college). Those who support the household are often family members who permanently left the household to work in other regions of China (as migrant workers) or family members who married and, thus, live in a new household. Since these family members do not live in the households anymore, this type of income is distinguished from off-farm income. The income and the expenses of these family members are a considerable factor: 6.15% of mean household revenue and 11.81% of mean household expenses (see Table 68).

4.1.2. *Off-farm Income*

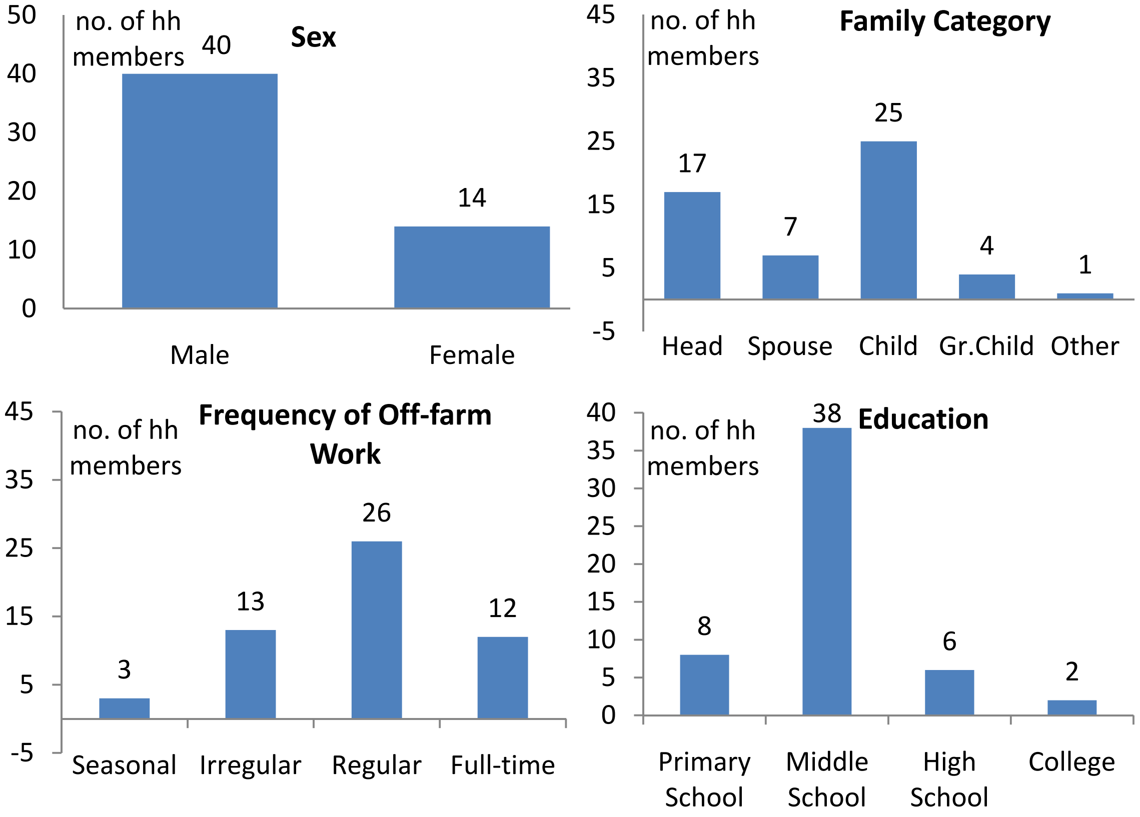
The rural employment structures have been changing over the last decades. As introduced before, many farm households diversify their structures and no longer rely solely on agricultural production; they seek off-farm income sources as e.g. entrepreneurs or workers in bigger cities or factories. Nearly half of the surveyed households have at least one member who obtains off-farm income (see Table 11). Off-farm income can only be generated by people living for a substantial period of the year inside the household, family members who are constantly living outside of the household are registered in Table 10.

Table 11. Off-Farm Income

Village *(Number of hhs)*:	**ALL VILLAGES (64)**	Suhuzhai (16)	Houzhai (16)	Yong-shengcun (16)	Wang-huzhuang (16)
Hhs with Off-farm Income *(total no. and % of all hhs)*	**31** **(48.44%)**	8 (50.00%)	9 (56.25%)	8 (50.00%)	6 (37.50%)
Hh-members with Off-farm Income *(pers. and % of all surveyed hh members)*	**54** **(20.15%)**	15 (24.59%)	16 (20.78%)	13 (18.31%)	10 (16.95%)
Share of Off-farm Income from Total Hh-income *(%)*	**28.73%**	-	-	-	-

Even though nearly half of the surveyed households have off-farm income, only 20.15% of the surveyed household members obtain off-farm income. Off-farm income generates 28.73% of mean net household income of the surveyed households. As was shown in 2.1, the official data states a higher share of income from wages in rural Chinese households, but this work separates off-farm income, support from family members and income from private enterprises – thus the figures are different. The combined mean net revenue from these 3 factors is 46.15% of total mean household revenue – which is even higher than the official data. As demonstrated in Table 68, off-farm income is the biggest single item in the composition of mean net income of the surveyed households. Selected characteristics of the 54 household members who have off-farm income are displayed in Figure 13.

Figure 13. Characteristics of Surveyed Household Members with Off-farm Income



NOTE: *total n=55

For this work, the frequency of off-farm work is characterized as follows:

- Person works 0% of available annual working time outside of the farm and the household: no off-farm work;
- Person works approximately 25% of available annual working time outside of the farm and the household: seasonal off-farm work;
- Person spends approximately 50% of available annual working time outside of the farm and the household: irregular off-farm work;
- Person spends approximately 75% of available annual working time outside of the farm and the household: regular off-farm work;
- Person spends approximately 100% of available annual working time outside of the farm and the household: full-time off-farm work.

Full-time work is defined as 6 days per week, 52 weeks a year, 8 hours per day working on farm. Figure 13 shows that the majority of household members with off-farm income are male. Furthermore, they tend to be from the younger generations (i.e. children or grandchildren). All household members with off-farm income have at least primary school education; more than 85% have at least middle school education. The majority of household members with off-farm income spend approximately 50% or more of their available annual working time outside of the farm. It should be noted that these figures only include those persons who still live in the households; there are also family members with non-agricultural income who have left the household permanently. For the village communities and the future of farming in the NCP it could bear a risk if large numbers of educated persons from the young generation are continuously leaving the villages. Therefore, also to fight that risk, in 2009 approximately 130,000 university graduates are being employed as “studied village officers” to support the villages with administrative issues and to develop new ideas (DER SPIEGEL, 2009).

4.1.3. Agricultural Labor Structure

Not all members of the surveyed households are working full-time on the farm. Table 12 displays the responsibilities of the household members on the farm.

Table 12. Farm Work Responsibilities and Time of Household Members

Village *(Number of households)*:	**ALL VILLAGES (64)**	Suhuzhai (16)	Houzhai (16)	Yong-shengcun (16)	Wang-huzhuang (16)
Farm Work Time *(no. and % of total hh members)*:					
-never	**77(28.73%)**	14(22.95%)	21(27.27%)	27(38.03%)	15(25.42%)
-only seasonal	**47(17.54%)**	18(29.51%)	25(32.47%)	15(21.13%)	9(15.25%)
-most of the time	**67(25.00%)**	9(14.75%)	13(16.88%)	16(22.54%)	9(15.25%)
-everyday	**77(28.73%)**	20(32.79%)	18(23.38%)	13(18.31%)	26(44.07%)
Responsibilities *(no. and % of total hh members)*:					
-no farm work	**75(27.99%)**	14(22.95%)	20(25.97%)	26(36.62%)	15(25.42%)
-only seasonal	**68(25.37%)**	18(29.51%)	26(33.77%)	15(21.13%)	9(15.25%)
-administration	**3(1.12%)**	0(0.00%)	2(2.60%)	1(1.41%)	0(0.00%)
-livestock	**1(0.37%)**	0(0.00%)	0(0.00%)	1(1.41%)	0(0.00%)
-crops	**9(3.36%)**	2(3.28%)	3(3.90%)	3(4.23%)	1(1.69%)
-everything	**112(41.79%)**	27(44.26%)	26(33.77%)	25(35.21%)	34(57.63%)

For this work, the farm work time is characterized as follows:

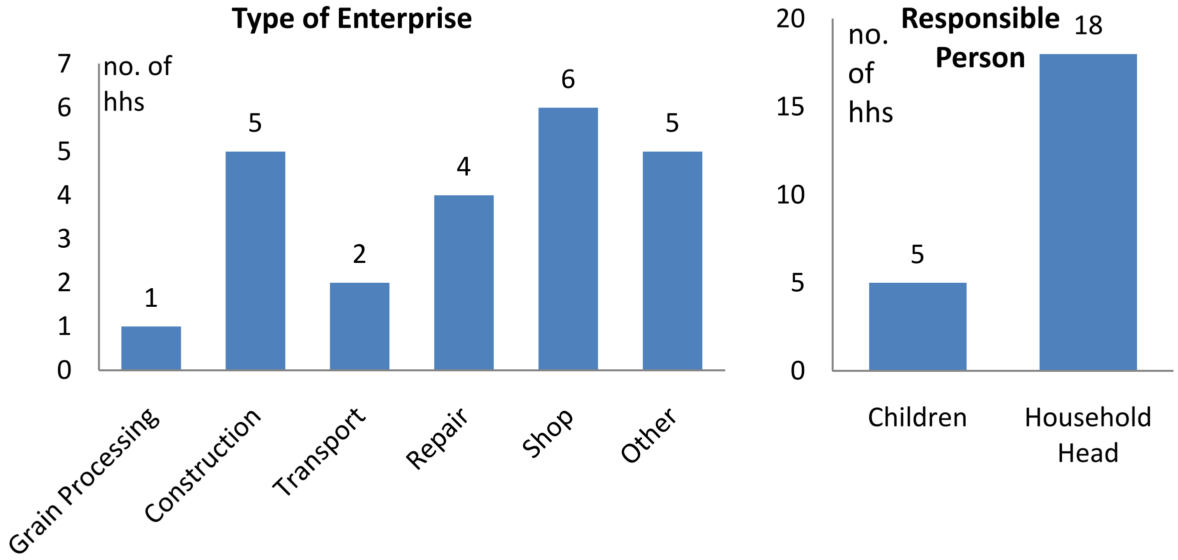
- Person works 0% of available annual working time on the farm: no farm work;
- Person works approximately 25% of available annual working time on the farm: seasonal farm work;
- Person spends approximately 75% of available annual working time on the farm: most of the time farm work;
- Person spends approximately 100% of available annual working time on the farm: full-time off-farm work.

In Table 12 it is noteworthy that 77 household members are never working on the farm, but only 75 have no farm work responsibility. This disparity can be explained, because one household member who is responsible for the administration and another one who only has seasonal responsibilities were classified as “never working on the farm”. From those household members who have no or only seasonal responsibilities on the farm, 72.03% are children, grandchildren or grandparents – these groups are mostly either too old or too young to constantly work on the farm.

4.1.4. Non-farm Household Enterprises

Of the surveyed households 35.94% (23 households) run another enterprise besides farming. These enterprises represent another strategy for rural households to diversify their income away from relying on agriculture as the only source of income. Figure 14 displays selected characteristics of those non-farming enterprises of the surveyed households.

Figure 14. Characteristics of Non-farming Enterprises of the Surveyed Households



The categorization “other” in Figure 14 refers to e.g. teaching or renting out machinery (as contractors) or houses. The majority of these enterprises are run by the household head. These enterprises generate 12.27% of mean household revenue of the surveyed households (see Table 68) and, thus, represent an important share of mean household income. Along with off-farm income and support from family members, these enterprises demonstrate a further diversification of income sources of the surveyed household, which are no longer solely relying on agriculture.

4.1.5. Further Training and Information Transfer

As shown in 4.1.1 the surveyed households seem to have a slightly lower level of school education than the official statistics for the Hebei Province. However, in order to analyze farming practices, the degree of specific agricultural knowledge and training is important. Therefore this part focuses on the specific training for agriculture and information transfer from and to the surveyed farmers.

The vast majority of the surveyed households (54 households which corresponds to 84.38%) never received specific agricultural training. Furthermore, only one household (1.56% of total households) has been visited by an extension officer in the last 36 months. Moreover, only two households (3.13% of total households) have been visited by other specialists who are offering agricultural support. These findings are in accordance with another study which also showed that the vast majority of households in the NCP have not been visited by extension officers and have not visited extension officers; however the contact between farmers and extension officer were not uniform across the research area (ZHEN *et al.*, 2005).

Also, only 15.63% (10 households) of the surveyed households participated in village meetings where agricultural practices were explained. Table 13 presents selected characteristics of these meetings.

Table 13. Organizer, Topics and Frequency of Village Meetings

	Households
Organizer of Meetings *(no. and % of total meetings)**:	
-Officials	1 (11.11%)
-Research Institution	2 (22.22%)
-Extension Officer	6 (66.66%)
Addressed Topics *(no. and % of total meetings)***:	
-Environmental Problems	0 (0.00%)
-Fertilization	4 (28.57%)
-Irrigation	2 (14.29%)
-Pesticide Application	1 (7.14%)
-Sowing/Planting	4 (28.57%)
-Other Agricultural Practices	3 (21.43%)

Note: *not all households answered
**more than one answer per household possible

Considering the environmental problems of agriculture in the NCP it is remarkable that none of the meetings addressed environmental problems. Furthermore the surveyed data indicate that the level of specific agricultural training and knowledge transfer to the farmers is low. This is in accordance with JU *et al.* (2004) who state that knowledge transfer systems are deficient – leading many farmers to unconsidered over-fertilization, resource use or pollution. Fundamental agricultural and environmental knowledge is essential to understand and consider basic agronomic, economic or environmental criteria. Extension services can play a vital role by supporting knowledge transfer to farmers. However the surveyed households received hardly any information services from the extension officers.

In addition, the data also indicates that the majority of households do not look for external help when they are in need of information about agricultural practices; 17.19% (11 households) of the surveyed households do not contact others when they have an agricultural problem and another 45.31% (29 households) rely on their own experience (see Table 14).

Table 14. Information Seeking for Agricultural Problems

	Households
Contacted Person *(no. and % of total hhs)*:	
-Officials	3 (4.69%)
-Research Institution	2 (3.13%)
-Extension Officer	0 (0.00%)
-Cooperative	0 (0.00%)
-Neighboring Farmers	11 (17.19%)
-Agribusiness in Village	8 (12.50%)
-No contact with Others	11 (17.19%)
-Own experience	29 (45.31%)

It is remarkable that no household is contacting the extension officers when seeking information. The agribusinesses in the villages might not be a dependable source for information, as they can have an interest to sell products instead of offering reliable consultancy. Therefore, considering the low degree of agricultural training and knowledge transfer of the surveyed households, it is doubtful that these information seeking strategies lead to optimized and adequate farming methods. In addition it is noteworthy that the options to answer “no contact with others” and “own experience” were not listed in the questionnaire, they were created by the farmers. So the findings indicate a need for knowledge and information transfer systems.

To survey the knowledge base of the households, they were asked if they consider themselves informed about the quality of the soil; 60.94% (39 households) of the surveyed households answered “Yes” (see Table 15).

Table 15. Perception of Surveyed Households towards Soil Quality

	Households
Informed about soil quality *(no. of hhs and % of answers)*:	
-“Yes”	39 (60.94%)
-“No”	25 (39.06%)
If informed *(no. of hhs and % of answers)*	
-“Informed based on own experience”	37 (94.87%)
-“Informed based on exchange with neighbors”	1 (2.56%)
-“informed based on soil samples”	1 (2.56%)
If not informed *(no. of hhs and % of answers)*	
-“Not necessary”	7 (28.00%)
-“No possibility for soil testing”	7 (28.00%)
-“Do not know soil testing”	6 (24.00%)
-“Lack of knowledge/education”	4 (16.00%)
-“Too expensive”	1 (4.00%)

From those households which consider themselves informed, 94.87% (37 households) base their information on own experience or the exchange with neighbors. However, without the possibility to analyze soil methodological it is difficult to assess its quality reliably. Only one household (2.56% of surveyed households) bases its information on soil samples.

Considering that the “own experience” of the surveyed farmers and their neighbors is often not based agricultural training or knowledge transfer systems, the answers in Table 14 and Table 15 seem to indicate the risk of randomness in the farmers’ knowledge base. So these answers indicate a lack of methodological knowledge and arbitrariness in the decision making process. Most of the answers of the farmers who consider themselves not informed reveal similar tendencies: “not necessary”, “do not know soil test” or “lack of education”. The answer “no possibility for soil testing” also indicates structural shortcomings in the surveyed area and the need for information and technological transfer.

4.2. Characteristics of Farm Resources

In order to be able to analyze the agricultural performance of the farms, this sub-chapter describes the characteristics of the farming operations of the surveyed households. It is divided into sections dealing with land resources, land market, livestock, greenhouses, private machinery, tools and equipment as well as the spatial dimension.

4.2.1. Land Resources

None of the surveyed households is member of a cooperative and all farms (64 households) are solely managed by family members. This indicates that the de-collectivization process of China's rural household structures (see 2.1) is completed in the surveyed villages. Furthermore it also indicates that the farm households make free decisions about the management and allocation of their resources. As described, the pressure on the agricultural land in China is strong. Table 16 presents the land resources of the surveyed households.

Table 16. Farm Land Resources

Village *(Number of households)*:	**ALL VILLAGES (64)**	Suhuzhai (16)	Houzhai (16)	Yong-shengcun (16)	Wang-huzhuang (16)
Total Area *(ha)*	**33.49**	6.82	5.94	8.13	12,60
Mean Area per hh *(ha)*	**0.52**	0.43	0.37	0.51	0.79
Mean Area per Plot *(ha)*	**0.15**	0.10	0.10	0.17	0.27
Mean Area per hh-member *(ha)**	**0.12**	0.11	0.08	0.11	0.21
Total Plots *(no.)*	**223**	67	62	47	47
Plots per hh *(no.)*	**3.48**	4.19	3.88	2.94	2.94

Note: *hh member=all persons living in the household

The official data for Quzhou County states the mean household with 0.58 ha (SBHC, 2009); also in BARNING (2008) the mean area per household (0.53 ha), the mean area per household member (0.13ha) and the plots per household (3.3) are comparable to the surveyed data in Table 16. However, the villages show some variation. Wanghuzhuang has fewer plots than the other villages, but the fields are bigger. As mentioned before, China – in particular the research area – has little land per person; indicating the pressure on land.

Due to the small size of the surveyed farms, the traditionally and commonly used Chinese area unit mu will be applied in the following parts. Mu represents a more realistic unit for the operations of the surveyed farms. One mu equals 1/15th ha (0.06 ha). The conversion results in the following farm land resources of the surveyed households:

- Total Area: 502.35 mu;
- Mean Area per household: 7.85 mu;
- Mean Area per plot: 2.25 mu;
- Mean area per household member: 1.89 mu.

4.2.2. Land Market

Literature shows that "despite more than decades of market reform, land markets in China still remain underdeveloped" (KIMURA *et al.*, 2010). Therefore, today, the land rental market is small and farmers mostly rely on their own resources and, thus, do not rent or rent out land (PIOTROWSKI and JIA, 2006). The share of rented or rented out land of the surveyed households is presented in Table 17.

Table 17. Land Rental Market

	Renting Land	Renting Land Out
Households *(no. and % of total)*	3 (4.69%)	3 (4.69%)
Plots *(no. and % of total)*	10 (4.48%)	*
Mean Price *(¥/mu/year)***	¥376.67	¥600.00

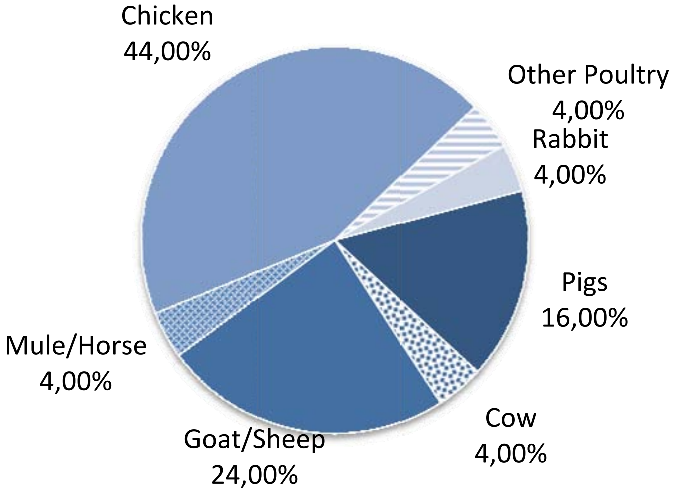
Note: *not answered
**of households renting/renting out land

In accordance with other studies, also the surveyed households do not rent or rent out their land resources on a large scale. However, it should be noted that one of the surveyed households rents all the land from other farms. It is remarkable that the mean price of the surveyed households for renting out land is significantly higher than the price for renting land. One explanation might be that recently urban investors rented land in the surveyed villages in order to produce vegetables and fruits in greenhouses. These investors – having no personal relationship to the farmers – might be forced to pay higher prices than local farmers. Compared to the data in 2.1, which determined the mean price for renting agricultural land in China as ¥245.00/mu, the mean price of the surveyed households for renting land is considerably higher (¥376.67/mu); this can be explained by the effect that the Hebei Province is an agricultural area where the competition for land is high, the study by PROSTERMAN *et al.* (2009) included 17 provinces of China – also areas with less competition for land and far away from consumers in big cities.

4.2.3. Livestock

As described in 2.2, the NCP is dominated by crop production. However, 25.00% (16 households) of the surveyed farms also have livestock resources. Considering the rising demand for meat in China, this share is low. Table 15 displays the share of the type of animals of the surveyed households.

Figure 15. Share of Animal Type of Surveyed Households*' **



NOTE: *% of surveyed households
**households can have more than one type of animal

As can be seen in Figure 15, only chicken, goat/sheep and pig production seem to be common in the surveyed households. All other types of livestock production are carried out by only one of the surveyed households. Table 18 displays the general characteristics of the livestock production of the surveyed households.

Table 18. General Characteristics of the Livestock Production of the Surveyed Households

	Mean no. per hh *(of hhs with that animal)*	**Mean production per animal** *(kg/year)*	**Share of own consumption** *(% of total production)*	**Share of bought feed** (% of total feed)	**Mean area for animals per hh** *(mu)*
Pig	10.25	126.67kg	0.87%	80.00%	0.05
Cattle	4.00	n.a.	0.00%	100.00%	0.03
Goat/Sheep	6.00	n.a.	0.00%	16.77%	0.01
Mule/Horse	1.00	n.a.	n.a.	0.00%	0.03
Chicken:	1,098.00	-	-	33.33%	0.19
-meat	-	1.95kg	47.73%	-	-
-egg	-	9.59kg	16.95%	-	-
Other Poultry	4.00	n.a.	n.a.	0.00%	0.01
Rabbit	3.00	n.a.	0.00%	0.00%	0.01

The share of bought to own feed varies strongly between the different types of animals. Own feed sources can refer to own crops, food leftovers or grazing. Pig and cattle have a high share of bought feed (pig: 80.00% and cattle: 100.00%) and a low share of own consumption (pig: 0.87% and cattle: 0.00%), which indicates that the farmers are producing solely for selling and that they expect high returns for their investments (see Table 19). The households with larger numbers of chicken are mostly producing eggs, which explains the high share of own consumption of chicken meat (47.73%), as it represents a by-product of egg production.

The mule/horse is not held to be consumed as food; it is used for working and transporting purposes. The services of the mule/horse are needed for a long period; therefore the mean annual veterinary costs per animal are the highest of all animals (see Table 19).

Table 19. Economic Characteristics of the Livestock Production of the Surveyed Households

	Mean Selling Price *(¥/kg)*	**Mean price** *(¥/animal)*	**Mean feed costs** *(¥/year/animal)*	**Mean medicine/ veterinary costs** *(¥/year/animal)*
Pig	¥10.73	¥150.00	¥367.88	¥55.53
Cattle	¥17.50	¥8,000.00	¥375.00	n.a.
Goat/Sheep	¥11.75	¥90.00	¥5.00	¥2.83
Mule/Horse	n.a.	n.a.	¥0.00	¥200.00
Chicken:	-	¥3.35	¥16.25	¥1.28
-Meat	¥9.80	-	-	-
-Egg	¥6.52	-	-	-
Other Poultry	n.a.	¥20.00	¥0.00	¥0.00
Rabbit	¥5.00	n.a.	¥0.00	¥0.40

With the available data the gross margin cannot be calculated meaningful, as the data include animals which are either only bought or only sold in 2007. If the whole lifespan of the livestock investments (which is often more than one year) cannot be regarded, the gross margin could create misleading interpretations, as earnings and expenses might not fall in the considered period.

Considering the mean number of held animals, chicken seems to be the only livestock production which is done on a larger scale in the surveyed households (1,098.00 animals per hh which holds chicken). Cattle, regarding the high prices for new animals and feed, as well as chicken, regarding the high mean numbers of held animals per households, require high financial investments. Nevertheless, in terms of mean numbers per household and mean area used for animals, livestock production remains a sideline production in the surveyed households, as agricultural production is dominated by crop production. This is also why this work is focusing on crop production.

4.2.4. Greenhouses

Hebei is one of the major provinces for agricultural production in greenhouses. In 2006, 16.36% of the total Chinese area of greenhouses was in the Hebei Province (CHINA AGRICULTURE PRESS, 2007). As introduced in 4.2.2, urban investors rent land from the surveyed households to invest in greenhouse production. Besides the income from renting out their land, household members are often also employed for operating the greenhouses (which represents a source of off-farm income). The greenhouses which are managed by urban investors and operated by the farm households are not included in the analysis of farming practices, as they are externally managed. However, none of the surveyed households invested in or runs an own greenhouse – so there are no data on the management practices of greenhouses of the surveyed.

4.2.5. Private Machinery, Tools and Cultivation Equipment

Even though agricultural production in China is characterized by low levels of mechanization, the increasing use of machinery for agricultural production was described in 2.1. Also the surveyed households invested in machinery for agricultural production: 85.94% of the households (55 households) have own machinery. However this number also includes motorcycles, electric bicycles and cars, because in the research area they are used to transport goods, workers or tools to support agricultural production. Table 20 displays selected characteristics of this machinery.

Table 20. Characteristics of the Machinery of the Surveyed Households

	Total Number	**Mean Age** *(in years)*	**Mean Purchasing Price** *(¥)*	**Mean Running Costs** *(¥/year)*	**Mean Usage** *(days/year)*
2-wheel Tractor	3	8.00	¥2,833.33	¥116.67	15.00
3-wheel Tractor	30	6.68	¥4,756.67	¥729.33	74.00
4-wheel Tractor	16	7.81	¥5,475.31	¥787.50	48.44
Wheat Cutter	1	8.00	¥54,000.00	¥7,000.00	12.00
Corn Thresher	3	7.67	¥390.00	¥10.67	25.33
Plough	9	11.56	¥456.22	¥22.22	23.11
Sowing Machine	11	5.56	¥1,352.22	¥44.44	32.22
Car	2	1.25	¥25,000.00	¥1,500.00	45.00
Motorcycle	38	4.72	¥4,613.89	¥325.83	138.33
Electric bicycle	1	1.00	¥2,100.00	n.a.	365.00

The most common and most used purely agricultural machinery of the surveyed households are 3-wheel tractors. The wheat cutter is the machine with the highest investment and running costs, but it is not common as only one household owns one. The 2-wheel tractor has the lowest mean purchasing price and running costs of all types of tractors. Furthermore it has the lowest mean costs per day of usage: ¥7.78/day, compared to ¥9.86/day (3-wheel tractor) and ¥16.26/day (4-wheel tractor).

Compared to developed countries the purely-agricultural machinery endowment of the surveyed households is low. Reasons for the low use of machinery might be the lack of capital for many households to be able to invest in machinery, also the land areas per household are small compared to other countries and generally labor is abundant in the research area (as demonstrated in 2.1). That is why manual labor is still widespread in the research area. Furthermore, contractors who rent out and operate machinery play an important role in the research area. Their services represent a strategy which allows households to mechanize certain production steps without investing large amounts of capital. The importance of contractors for the surveyed households can be seen in the description of the farming practices in the following parts. Two of the surveyed households are working as contractors. One household member is working as contractor for planting; from this activity the household earns ¥5,000.00 per year. The other household is renting out a corn thresher; from this activity the household earns ¥600.00 per year.

Besides machinery, 89.06% (57 households) of the surveyed households have costs for other cultivation equipment. Table 21 displays selected characteristics of the cultivation equipment of the surveyed households.

Table 21. Characteristics of Cultivation Equipment

	Plastic Cover	Irrigation Pump	Irrigation Pipes
Households *(no. and % of total hhs)*	50 (53.76%)	5 (5.38%)	38 (40.86%)
Mean Costs *(¥/mu/year)**	¥33.13	**	¥32.26
Crop *(no. and % of hhs producing crop)*:			
-Cotton	48 (96.00%)	4 (8.00%)	29 (58.00%)
-Maize	1 (2.00%)	2 (4.00%)	30 (60.00%)
-Wheat	1 (2.22%)	4 (8.88%)	22 (48.88%)
-Other	3 (13.04%)	0 (0.00%)	9 (39.13%)

NOTE: *of households applying respective cultivation equipment
**not calculated

Plastic cover is used for mulching to keep soil moisture contents high. It is mostly used for cotton; maize and cotton are investment intensive, whereas wheat has a comparable low investment. The low share of costs of cultivation equipment for other crops indicates the importance of cotton, maize and wheat for the surveyed households. The plastic cover has to be replaced every year.

The investment in pipes might indicate a changing irrigation infrastructure; but it also represents an indirect cost factor for irrigation. Other studies showed that these investments are a consequence of dropping water tables and difficulties to obtain water (see 2.4.2). The mean price for the irrigation pipes refers to a purchasing price in 2007; the pipes might also be used in the following years. In addition to machinery and cultivation equipment, the surveyed households spend on average ¥119.69 per year on other tools.

4.2.6. Spatial Dimension

In order to survey the distances between the households' plots and to gain information about the spatial dimension of the research area, GPS data of the 64 houses of surveyed households as well as of up to 5 of their managed plots were collected: thus spatial data of 204 field entry points were collected. A field entry point was defined as the point at which the farmer usually enters the field. The mean distance per household in meters (*MD*) is calculated, as the mean of the sum of the individual distances *(x)* between all plots and also the house:

$$MD(x) = \frac{\sum_{i=1}^{n} x_i}{n}$$

Table 22 presents the mean distances per household of the surveyed households.

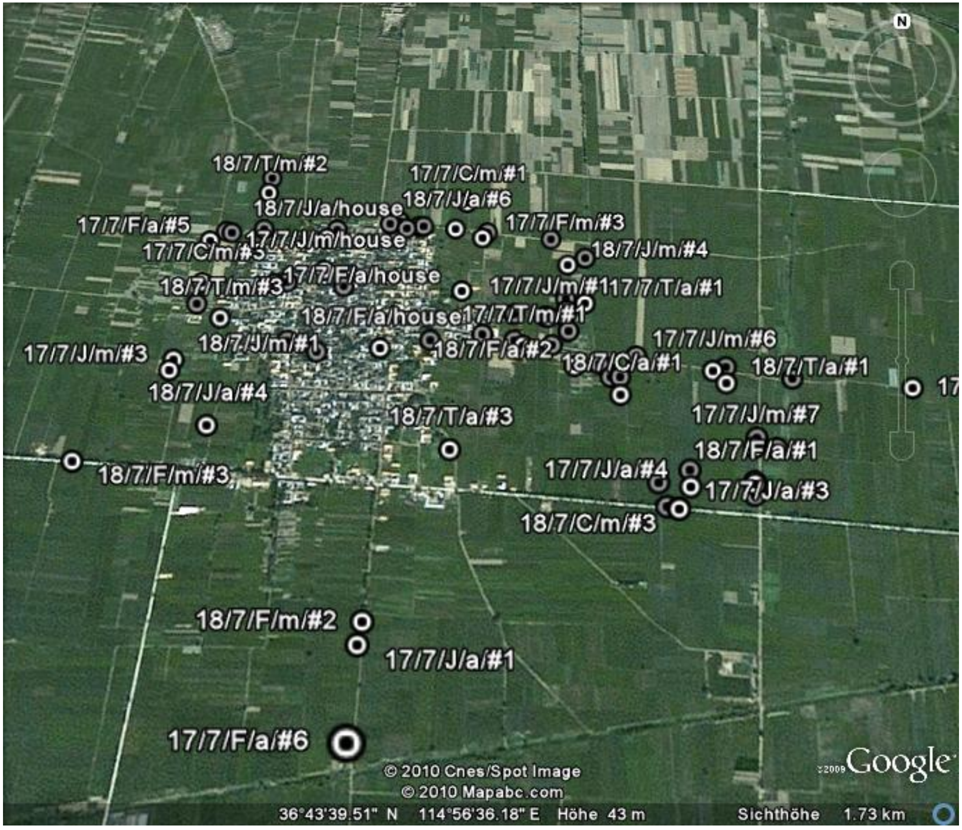
Table 22. Mean Distance per Household of the surveyed households

Village	ALL VILLAGES	Suhuzhai	Houzhai	Yong-shengcun	Wang-huzhuang
Mean *(m)*	**641.35**	612.92	755.86	578.81	617.82
Max *(m)*	**1400.00**	949.93	1400.00	777.83	820.67
Min *(m)*	**137.33**	137.33	159.00	281.00	447.33
Mean Deviation *(m)*	**147.05**	128.01	224.70	120.40	95.82

Considering that the surveyed households have on average 3.48 plots per household, these distances indicate that the households spend a considerable amount of time on the way. This fact legitimates motorcycles, electric bicycles and cars as agricultural machinery, as they are frequently used for transportation purposes. The data in Table 22 shows that the mean distances per household are comparable for the surveyed households, as the mean deviations are rather small (considering the mean distances).

The GPS data of the surveyed households can also be displayed graphically. Exemplary, the house and field locations of Suhuzhai are displayed in Figure 16 (the other villages are displayed in Annex 6 to Annex 8).

Figure 16. Locations of Surveyed Plots and Houses in Suhuzhai Village[9]



As can be seen in Figure 16 and Annex 6 to Annex 8, the plots of the surveyed households are distributed around the respective villages. Land fragmentation refers to a division of a farm into several detached and distinct plots which are managed by the same household. In a global comparison China "is confronting the most severe land fragmentation in rural areas since the land reform initiated more than two decades ago" (TAN et al., 2008). The review of literature shows that land fragmentation can have positive effects (e.g. risk diversion or labor division) and negative effects (e.g. reduced work efficiency or obstructions to application of machinery) on land use and, thus, the operations of a farm. Consequently, related to the surveyed regions or settings, studies either highlighted the beneficial or the adverse impacts, while others even stated that there are no significant impacts of land

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[9] The map was constructed using GOOGLE™ Earth 5.0.1 and GARMIN MapSource® 6.14.1 software tools.

fragmentation on farming practices. The Simpson Index (SI) indicates the degree of land fragmentation (BLAREL et al., 1992). It is calculated as:

$$SI = 1 - \sum_{i=1}^{n} a_i^2 / (\sum_{i=1}^{n} a_i)^2$$

where a_i is the area of each plot and n is the number of plots. The *SI* is located between 0 and 1, whereby higher values indicate a larger degree of land fragmentation. A value of 0 indicates a complete land consolidation, i.e. the household farms only one plot. The *SI* was calculated for each surveyed household and the results are presented in Figure 17.

Figure 17. Simpson Index Range of Surveyed Households

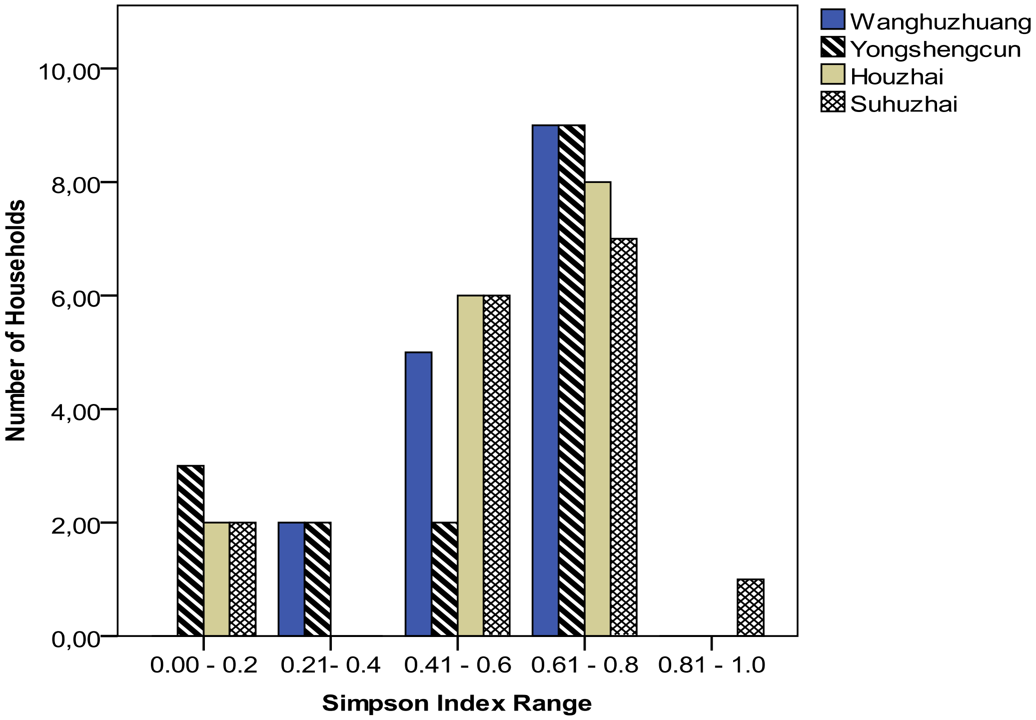


Figure 17 presents a slight tendency towards land fragmentation for the surveyed households. Even more so, when considering that most households in the cluster with a *SI* of 0.00-0.20 are households with only one plot. However, the mean value of the *SI* of 0.55 of all surveyed households is smaller compared to, for example, mean *SI* values in Ghana (0.64) and Rwanda (0.69) (BLAREL *et al.*, 1992).

4.3. Characteristics of Crop Production

This part introduces the farming practices concerning crop production of the surveyed farms. It will first introduce the characteristics of land use and then it will describe step by step the processes of crop production of the main crops including tillage, planting, seeds, crop nutrition, pest and weed control, irrigation until harvest. This part will conclude with a description of the post-harvest processes.

4.3.1. Land Use

The crop production characteristics in the NCP were introduced in 2.2. The pressure on land led many farmers to adopt double-cropping rotations to maximize output from scarce land resources. Table 23 displays how the surveyed households are using their land resources for crop production.

Table 23. Land Use Characteristics of Crop Production of Surveyed Households

	Households *(no. and % of total hhs)*	**Plots*** *(no. and % of total plots)*	**Total Cropped Area** *(in mu)*	**Mean Cropped Area** *(in mu per hh)*
Cotton	50 (78.13%)	124 (51.45%)	271.39	5.43
Winter-Wheat Summer-Maize Rotation	45 (70.31%)	77 (31.95%)	168.45	3.75
Maize**	8 (12.50%)	13 (5.42%)	34.40	4.30
Vegetables	11 (17.19%)	14 (5.81%)	18.60	1.33
Peanuts	6 (9.38%)	6 (2.49%)	3.50	0.58
Sweet Potatoes	4 (6.25%)	5 (2.07%)	2.05	0.51
Apple	2 (3.13%)	2 (0.83%)	6.50	3.25

NOTE: *more than one crop can be grown per plot
**pure Maize plot or more summer maize than winter wheat

As Table 23 displays, in terms of total cropped area and mean cropped area per household, crop production of the surveyed households is dominated by cotton, followed by the SM-WW crops rotation. On 83.40% of the total plots cotton or the WW and SM rotation is grown. In all surveyed households wheat is grown as winter wheat in a SM-WW rotation. This is in accordance with the crop production characteristics of the NCP. Cotton is an important cash crop, but does not play a role in fulfilling the goals of grain self-sufficiency and food security. As will be shown in 4.5.2, most of the vegetable production – which is the fourth largest crop in terms of total cropped area – is used for own consumption and not for sale and the other crops are not grown on a considerable scale. Therefore the following descriptive analysis of this work exclusively focuses on the three main crops cotton, maize and wheat. As described in 2.1 wheat and maize play major roles for China’s food security. It should be noted that the total cropped area is larger (in Table 23) than the total area of the farm resources (in Table 16), as different crops can be grown in different seasons on the same plot, i.e. in a double crop rotation.

Table 24 shows the changes of the surveyed households in production of the main crops compared to the respective previous year.

Table 24. Production of Main Crops of Surveyed Households Compared to Previous Year

	Cotton	Maize	Wheat
2005 *(no. of hhs)**:			
-Decrease	4	4	4
-Increase	9	5	3
-New Production	0	0	0
2006 *(no. of hhs)**:			
-Decrease	4	6	6
-Increase	7	3	4
-New Production	1	0	0

NOTE: *all other households have not changed their production

The data indicates that the past years showed a tendency to increase the production of cotton and to slightly decrease the production of the SM-WW crop rotation. In addition to the data from Table 24, another household – which did not grow it before – began to produce cotton in 2007.

4.3.2. Tillage Operations

Tillage is essential for crop farming. Tillage refers to "specific mechanic influences on the top soil" (DIEPENBROCK *et al.*, 2005). Usually, before planting or sowing of the seeds/seedlings, the soil is loosened, turned, mixed or crumbled. These processes are energy intensive. In traditional agriculture tillage was often performed manually or operated by animals – in modern agriculture the use of machinery is increasingly important. It should be noted that wheat and maize are regarded separately, even if they are grown together in the SM-WW rotation. For the main crops, Table 25 presents how many of surveyed households are tilling their fields and which methods they apply.

Table 25. Tillage Methods for Main Crops of Surveyed Households

	Cotton	Maize	Wheat
Applying Tillage *(no. and % of hhs growing crop)*	48 (96.00%)	6 (12.00%)	44 (97.78%)
Method of Tillage *(no and % of hhs growing crop)**:			
-Ploughing	48 (96.00%)	6 (12.00%)	43 (95.55%)
-Harrowing	20 (40.00%)	4 (8.00%)	21 (46.66%)
-Soil Turning	20 (40.00%)	3 (6.00%)	10 (20.00%)
-Other	12 (24.00%)	4 (8.00%)	12 (24.00%)
Mean Months of Preparation**	March-April	June	September-October

NOTE: *households can apply more than one type of tillage
**calculated as mean value of answers

The majority of the surveyed households tills the fields before planting cotton or wheat; ploughing is the preparation method which is applied most. For wheat and cotton production many households apply more than one tillage method. On the other hand, the majority of the surveyed households does not prepare the fields when growing maize. Table 26 displays how many of the surveyed households are using machinery for tilling the soil for the main crops.

Table 26. Machinery Application for Tillage of Main Crops of Surveyed Households

	Cotton	Maize	Wheat
Usage *(no. and % of hhs producing that crop)*	45 (90.00%)	6 (12.00%)	43 (95.55%)
Type of Machinery *(no. and % of hhs producing that crop)**:			
-2 or 3 Wheel Tractor	3 (6.00%)	0 (0.00%)	0 (0.00%)
-4 Wheel Tractor	25 (50.00%)	2 (4.00%)	22 (48.88%)
-Plough	2 (4.00%)	1 (2.00%)	6 (13.33%)
-Other	15 (30.00%)	3 (6.00%)	20 (44.44%)
Share of Contractors *(% of machine usage per crop)*	66.66%	66.66%	81.40%
Mean Costs *(¥/mu)***:	¥33.67	¥34.00	¥34.53

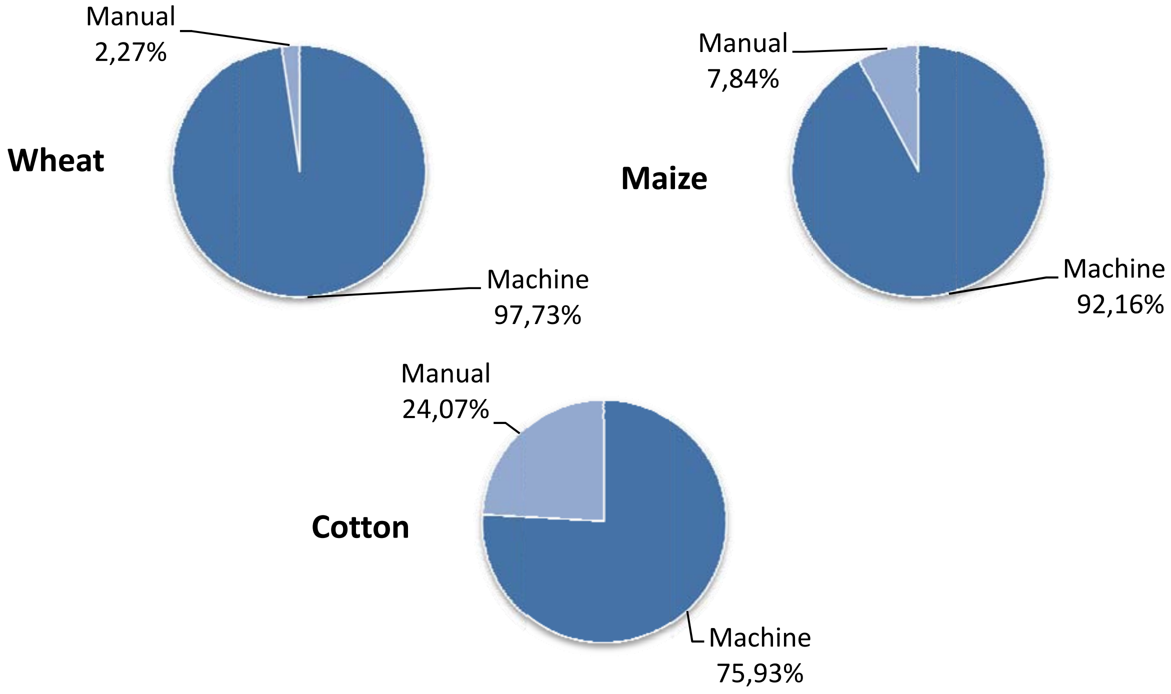
NOTE: *households can apply more than one type of machinery
**of households applying machinery for tillage

The most commonly used machine for wheat (48.88%) and cotton (50.00%) production is a 4-wheel tractor. The high shares of machinery application indicate that traditional ways of field preparations by hand or with animals are no longer common in the research area; only 6.00% (cotton) and 2.22% (wheat) of the surveyed household producing the respective crop are not using machinery for tillage. This reflects the transition from traditional to modern agriculture. Even though only some of the surveyed households are tilling for maize production (12.00%), nearly all of those households are using machinery. Hard work steps, like ploughing, are unlikely to be done manually – but investments for powerful machinery are costly and most households are only operating small plots. Therefore, the use of contractors is very common for tilling in the research area: at least 2/3 of the surveyed households use contractors for the main crops. The high usage of machinery makes tillage one of the cost intensive production steps for cotton and wheat production of the surveyed households (see Table 67).

4.3.3. Planting

All surveyed households (100.00%) are independently responsible for the amount and timing of planting their crops – nobody is interfering in the decision making process about when, what or how to plant. Figure 18 surveys the share of manual work and machinery application for planting of the main crops.

Figure 18. **Share of Manual Work and Machinery Application for Planting of Main Crops of Surveyed Households*, **, *****



NOTE: *% of households growing crop
**households can plant manually and with machinery
***not all households answered

Figure 13 shows that the majority of households are using machinery for planting the main crops. It is, however, evident that for cotton the share of manual planting is higher than for maize and wheat. The mean months for planting the main crops[10] are similar to the periods of field preparation:

- Cotton: March-April;
- Maize: June;
- Wheat: September-October.

Table 27 displays the characteristics of the machinery application for planting main crops of the surveyed households.

Table 27. **Machinery Application for Planting Main Crops of Surveyed Households**

	Cotton	Maize	Wheat
Type of Machinery *(no. and % of hhs growing crop)**:			
-2 or 3 Wheel Tractor	1 (2.00%)	1 (2.00%)	0 (0.00%)
-4 Wheel Tractor	17 (34.00%)	15 (30.00%)	15 (33.33%)
-Sowing Machine	40 (80.00%)	46 (92.00%)	42 (93.33%)
Share of Contractors *(% of machine usage per crop)*	80.95%	91.67%	91.11%
Mean Costs *(¥/mu)***	¥10.81	¥10.10	¥10.85

NOTE: *households can apply more than one type of machinery
**of households applying machinery for planting

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[10] calculated as mean value of answers

As can be seen in Table 27, the majority of the surveyed households are using contractors for planting of the main crops. Even though the machinery application rate is high and contractors are often used, planting does not cover a large share of the mean expenses for all main crops of the surveyed households (see Table 67).

4.3.4. *Seeds*

The selection of seeds and varieties can be an important factor for the yield development of the respective crop. Table 28 displays the answers of the surveyed households regarding the decision making for seed selection and the quantity sown of seeds.

Table 28. Decision Making for Seed Selection and Quantity and Timing of Sowing of Surveyed Households

	Households
Seed Selection *(no. of hhs and % of answers)**:	
-Household	61 (95.31%)
-Government	2 (3.13%)
-Other	1 (1.56%)
Quantity and Timing of Sowing *(no. of hhs and % of answers)**:	
-Crop Variety	16 (25.40%)
-Soil Quality	10 (15.87%)
-Instructions on Seed Package	10 (15.87%)
-Crop Market Price	8 (12.70%)
-Own Experience	8 (12.70%)
-Availability of Space	5 (7.94%)
-Price of Seed	4 (6.35%)
-Weather	1 (1.59%)
-Learn from Neighbors	1 (1.59%)

NOTE: *not all households answered

Considering that in 4.1.5 it was shown that only one households analyzes the soil in a laboratory and that a lack of methodological knowledge and arbitrariness in the decision making process was implied, the high occurrence of the answer “soil quality” indicates that the decision about the quantity and timing of sowing might not be based solely on systematic, methodological or reliable criteria. In addition, bearing in mind that the level of education of the surveyed household is low (see 4.1.1) and that the households need information and knowledge transfer systems (see 4.1.5), the strategies “own experience” and “learn from neighbors” should be classified similarly. Table 29 lists the varieties of the main crops which are grown by the surveyed households.

Table 29. List of Varieties of Main Crops of Surveyed Households

Name *(Mandarin Name)*	Plots* *(% of plots with that crop)*	Planted Area* *(mu)*	Mean Seed Price *(¥/kg)*	Share of Collected Seeds *(% of variety)***
COTTON:				
298 (298)	89 (71.77%)	193.76	¥36.89	7.87%
Guo Xin No. 4 (国新 4 号)	4 (3.23%)	2.90	¥40.00	0.00%
291 (291)	3 (2.41%)	9.00	¥10.60	0.00%
Da Taon 208 (大桃 208)	3 (2.41%)	7.40	¥45.00	0.00%
Han Dan 4849 (邯郸 4849)	3 (2.41%)	3.20	¥20.66	0.00%
Others	18 (14.52%)	34.95	¥71.75	11.11%
Unknown	13 (10.48%)	20.18	¥20.04	7.69%
TOTAL	**-**	**271.39**	**¥29.84**	**7.52%**
MAIZE:				
Nong Da 108 (农大 108)	13 (15.85%)	27.18	¥8.55	0.00%
Zheng Da 958 (正大 958)	8 (9.76%)	16.50	¥7.23	0.00%
Jin Hai No.5 (金海 5 号)	6 (7.31%)	18.80	¥10.83	0.00%
Xian Yu 335 (先玉 335)	6 (7.31%)	9.80	¥34.66	0.00%
335 (335)	5 (6.10%)	15.50	¥15.40	0.00%
An Yu No.6 (安豫 5 号)	5 (6.10%)	10.40	¥10.00	0.00%
Fu You 20 (富友 20)	3 (3.66%)	6.50	¥8.00	0.00%
Jun Dan 20 (俊单 20)	3 (3.66%)	6.44	¥24.33	0.00%
Fu You No. 9 (富友 9 号)	3 (3.66%)	5.80	¥10.00	0.00%
Others	17 (20.73%)	52.60	¥12.01	0.00%
Unknown	24 (29.27%)	33.33	¥10.53	0.00%
TOTAL	**-**	**202.85**	**¥8.41**	**0.00%**
WHEAT:				
Liang Xing 99 (良星 99)	10 (12.99%)	25.20	¥1.85	20.00%
617 (617)	4 (5.19%)	5.10	¥1.70	0.00%
Wen 8 (温八)	3 (3.90%)	6.50	¥2.00	0.00%
5230 (5230)	3 (3.90%)	5.80	¥3.00	0.00%
6172 (6172)	3 (3.90%)	4.30	¥1.60	0.00%
Others	3 (3.90%)	8.30	¥2.40	33.33%
Unknown	54 (70.13%)	113.25	¥2.22	47.27%
TOTAL	**-**	**168.45**	**¥1.56**	**37.50%**

NOTE: *Households can grow more than one variety per plot
**not all households answered

In Table 29 ‘others’ refers to varieties which were grown on less than three plots; whereas ‘unknown’ indicates that the households do not know the name of the variety. Collecting seeds from own plots for cultivation in the following season is a traditional method for obtaining seeds, which implies that the households did recently not benefit from scientific developments in plant breeding and might not be using the latest varieties. However, as can be seen in Table 29, only wheat has a considerable share of collected seeds (37.50% of all used seeds are collected).

The use of transgenic (i.e. genetically modified) cotton varieties is common in the NCP. The varieties 298, Guo Xin No. 4 and Han Dan 4849 are co called Bt-cotton varieties which are resistant against the bacillus thuringiensis – so the majority of cotton varieties of the surveyed households are transgenic[11]. Cotton is dominated by the variety 298. Hybrid maize varieties are also widely applied in the research area.

Prices for wheat seeds per kg are the lowest, but a high degree of households which are not buying wheat seeds remains. This and also the high share of households which do not know which wheat variety they are growing indicate that households are not willing to invest in wheat. But, as shown in 4.5.2, wheat has the highest share of own consumption of the main crops. On the other hand the cash crop cotton: the households are aware of the varieties which they are cultivating and they are willing to pay higher prices. The mean prices of seeds per mu for the main crops of the surveyed households are[12]:

- Cotton: ¥74.98/mu/year;
- Maize: ¥32.03/mu/year;
- Wheat: ¥32.48/mu/year.

Compared to maize, wheat has a much higher seed demand; therefore the seed prices per mu are similar, even though the seed prices of wheat per kilo are clearly lower. Cotton, as an investment intensive cash crop, has the highest seed costs (per kg and area) of the main crops. For wheat seed costs do not cover a large share of the mean expenses, but for cotton and maize seeds are a considerable factor (see Table 67).

In the last years, 79.69% of the surveyed households did not change the varieties of the grown crops. Only the varieties of the three main crops were changed:

- 5 households changed the variety of cotton;
- 6 household changed the variety of maize;
- 5 households changed the variety of wheat.

Table 30 presents the reasons for the surveyed households for changing varieties of the main crops.

Table 30. Reasons for Variety Change of Surveyed Households

	Households
Reason *(no. of hhs and % of answers)**:	
-Expect Higher Yields from New Variety	5 (38.46%)
-Advice from Neighbors	3 (23.08%)
-Official Advice	2 (15.38%)
-New Variety Subsidized	1 (7.69%)
-Old Variety Diseased	1 (7.69%)
-New Variety Higher Quality	1 (7.69%)

NOTE: *not all households which changed varieties answered

In Table 30 most of the surveyed households stated reasons which can be attributed to positive effects on yields or quality. As explained in 4.1.5, knowledge transfer systems

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[11] Other grown cotton varieties of the surveyed households might also be transgenic

[12] of households buying seeds for the respective crop

(including extension services) in the research area are deficient, which is why it is not unexpected that few farmers followed official device and, moreover, that advice from neighbors is more popular than official device.

4.3.5. Crop Nutrition

As described in 2.4.1 crop production in the NCP is suffering from over-fertilization, i.e. farmers fertilize more than the plants are able to take in, but also from unbalanced fertilization. The environmental effects of crop nutrition practices of the surveyed households will be analyzed in 4.4.2. For that reason this part focuses on the description of the practices of nourishing the crops by means of fertilization and manure.

Households which have livestock can nourish their crops by using manure from their own animals. The values for the calculation of the amounts of nutrients in the different types of manure are displayed in Table 31.

Table 31. Nutrient Contents of Dried Manure Types

	Chicken	Sheep	Cattle	Pig
N *(% of dry matter)*	3.0%	0.6%	1.5%	0.6%
P *(% of dry matter)*	3.0%	0.3%	1.5%	0.4%
K *(% of dry matter)*	2.0%	0.2%	1.2%	0.1%

Source: MITCHELL (2008)

11 of the surveyed households (17.19% of total surveyed households) use manure from own animals for crop nutrition; these 11 households represent 68.75% of the surveyed households with livestock. On the contrary 31.25% of the surveyed households with livestock do not apply manure from their own animals to their crops – which indicates that these households are not using freely available nutrient sources and might suggest a lack of agricultural knowledge. Table 32 presents the animal sources, crops and reasons for applying own manure to the crops.

Table 32. Characteristics of Manure from Own Animals for Plant Nutrition of Surveyed Households

	Households
Animal Source *(no. and % of hhs applying own manure)**:	
-Chicken	7 (63.64%)
-Sheep	4 (36.36%)
-Pig	2 (18.18%)
-Cattle	1 (9.09%)
Crop *(no. and % of hhs growing crop)**:	
-Cotton	8 (16.00%)
-Maize	7 (14.00%)
-Wheat	6 (13.33%)
Reasons for Applying Own Manure *(no. and % of hhs applying own manure)**, **:	
-“To Increase Soil fertility”	6 (54.54%)
-“To Increase Yield”	4 (36.36%)
-“Do not Know What Else to Do With It”	1 (9.09%)

NOTE: *more than one answer per household possible
**not all households answered

Chicken is the most common type of animal of the surveyed households (see Figure 15), therefore it is also the most common animal source for own manure. Own manure is not frequently applied to the main crops: cotton, maize and wheat (only 16.00%, 14.00% and 13.33% of all households growing the respective crop). The most common reasons for applying own manure are expected positive effects on soil fertility and yield. The mean applied quantity and the mean nutrient input of own manure for the main crops of the surveyed households are displayed in Table 33.

Table 33. Applied Amount and Nutrient Input of Own Manure for Main Crops of Surveyed Households

	Cotton	Maize	Wheat
Mean Amount per Application *(kg/mu/year)***	751.90	436.57	442.66
Max. Amount per Application *(kg/mu/year)***	2,666.66	1,500.00	1,500.00
Mean Nutrient Input *(kg/mu/year)***:			
-N	12.28	10.83	11.43
-P	11.12	10.60	11.27
-K	7.45	7.03	7.48

NOTE: *calculated with data from Table 31
**of households applying own manure

Cotton has the highest mean and maximum applied amount of own manure and consequently the highest mean nutrient input of N; but wheat has the highest nutrient input of P and K from own manure. This discrepancy can be explained by the fact that more households are applying chicken manure for wheat than for cotton.

Households which do not own livestock can also use manure to nourish crops, by purchasing it from livestock farms – 45.31% of the surveyed households (29 households) buy manure. The mean price for bought manure is ¥0.22 per kg. Table 34 presents the animal sources, crops and reasons for applying own manure to the crops.

Table 34. Characteristics of Bought Manure for Plant Nutrition of Surveyed Households

	Households
Animal Source *(no. and % of hhs applying bought manure)**:	
-Chicken	28 (96.55%)
-Do not Know	1 (3.45%)
Crop *(no. and % of hhs growing crops)**:	
-Cotton	20 (40.00%)
-Maize	13 (26.00%)
-Wheat	11 (24.44%)
-Others	8 (34.78%)
Reasons for Applying Own Manure *(no. and % of hhs applying bought manure)**:	
-“To Increase Yield”	18 (62.07%)
-“To Increase Soil Fertility”	16 (55.17%)
-“Other People’s Suggestion”	1 (3.45%)

NOTE: *more than one answer per household possible

The majority of households which are buying manure for plant nutrition applies manure from chicken (96.55%). Bought manure is applied to the main crops: cotton, maize and wheat (40.00%, 26.00% and 24.44%, respectively of households growing crop). The most common reasons for applying bought manure are as well expected positive effects on yield and soil fertility. The mean applied quantity and mean nutrient input of bought manure for the main crops of the surveyed households are displayed in Table 35.

Table 35. Mean Costs, Applied Amount and Nutrient Input of Bought Manure for Main Crops of Surveyed Households

	Cotton	Maize	Wheat
Mean Costs *(¥/mu)***	¥49.53	¥48.29	¥54.54
Mean Amount per Application *(kg/mu/year)***	292.90	242.31	230.30
Max. Amount per Application *(kg/mu/year)***	1,000.00	550.00	400.00
Mean Nutrient Input *(kg/mu/year)***:			
-N	8.60	6.98	6.57
-P	8.60	6.98	6.57
-K	5.73	4.65	4.38
Mean Nutrient Price *(¥/kg nutrient)**, **,***:			
-N	¥2.22	¥2.48	¥2.85
-P	¥2.24	¥2.50	¥2.83
-K	¥3.36	¥3.76	¥4.24

NOTE: *calculated with data from Table 31
**of households applying bought manure
*** mean nutrient price is corrected for the number of nutrients for the respective manure

Similar to own manure, cotton has the highest mean applied amount of bought fertilizers; cotton also has the highest mean nutrient input. Unlike in the case of own manure, the mean nutrient input of bought manure is closely related to the applied amount, because the surveyed households nearly exclusively apply the same type of manure (chicken). Compared to the use of own manure, the mean nutrient input from bought manure is lower for all main crops, as the mean and maximum applied amounts are considerably smaller. The mean nutrient price for bought manure of the survey (which will also be included in the analysis in chapter 6) is: 2.30 ¥/kg N, 2.33 ¥/kg P and 3.50 ¥/kg K. In total 60.94% of the surveyed households (39 households) are using own or bought manure for nourishing their crops. The respective total mean nutrient input of manure (bought and own manure combined) amounts to[13]:

- Cotton: 10.72 kg N/mu, 10.34 kg P/mu and 6.89 kg K/mu;
- Maize: 8.98 kg N/mu, 8.89 kg P/mu and 5.91 kg K/mu;
- Wheat: 8.18 kg N/mu, 10.34 kg P/mu and 6.89 kg K/mu.

Besides manure, the surveyed households also nourish their crops with straw which is also releasing nutrients into the soil. According to ZHENG *et al.* (2007) maize in China has a straw/grain-ratio of 2.00 and wheat, correspondingly, of 1.336; this means that per 1.00 kg of grains 2.00 kg of maize straw, or, respectively, 1.336 kg of wheat straw, are produced. It

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[13] of households applying manure

should be noted that none of the surveyed households leaves residues from cotton on the fields; therefore Table 36 only displays the characteristics for maize and wheat. 13 households (26.00% of the surveyed households which grow cotton) use or sell the residues of cotton for heating. As mentioned before, even though it is forbidden, a common practice in the NCP is to burn the residues on the field – it has to be noted that no surveyed household answered whether crop residues are burned on the fields. It should be noted that in the SM-WW rotation the straw of WW is nourishing SM and vice versa – as they are grown subsequently on the same plot. In case maize is not grown in combination with wheat, the straw residues will nourish the following season's maize. Table 36 presents the characteristics of straw applications for maize and wheat – assuming that 100% of the produced straw is returned to the fields.

Table 36. Characteristics of Straw Application for Plant Nutrition from Maize and Wheat of Surveyed Households

	Maize	**Wheat**
Share of Households Leaving Straw on Field *(% of hhs growing crop)**	90.00%	95.55%
Nutrient Content of Straw *(%)***,***:		
-N	0.9%	0.5%
-P	0.2%	0.3%
-K	2.00%	1.40%
Mean Possible Nutrient Input *(NIS) (kg/mu/year)****:		
-N	3.42	8.66
-P	1.71	2.00
-K	9.02	19.19

NOTE: *not all households answered
***Source:* LFL (2009)
***of households applying straw for plant nutrition

The possible nutrient input from straw *NIS* in kg per mu is calculated as:

$$NIS = Y * R * NC$$

where *Y* is the yield (kg/mu), *R* represents the straw-grain-ratio and *NC* the nutrient content of the respective crop. As can be seen in Table 36, the mean possible nutrient input from straw is higher for wheat – this is the result of higher nutrient contents and higher mean maize yields of maize. It should be noted that it is unrealistic that all straw can be returned to the fields – so in the following analysis in chapter 6 a possible loss is considered.

98.44% (62 households) of the surveyed households select mineral fertilizers themselves independently. For one household (1.56%), fertilizers are provided by the village work team, which represents a voluntary village solidarity group. However, all households decide autonomously about the timing and quantity of fertilization.

Table 37. Decision Making for Quantity and Timing of Fertilization of Surveyed Households

	Households
Quantity and Timing of Fertilization *(no. of hhs and % of answers)**:	
-Own Experience	22 (40.74%)
-Crop Variety Quality	13 (24.07%)
-Soil Quality	9 (16.67%)
-Instruction of Fertilizer Package	4 (7.41%)
-Price of Fertilizer	4 (7.41%)
-Instructions on Seed Package	2 (3.70%)

NOTE: *not all households answered

It is notable that only 7.41% of the households who answered that question indicated that they base the decision about quantity and timing of fertilization on the price of the fertilizers. This indicates that a change of fertilizer price might not be an efficient tool for the surveyed households. Following the argumentation regarding the decision making process for seed selection (see 4.3.4), the answers “own experience”, “crop variety quality” and “soil quality” indicate that the decision making about the quantity and timing of fertilization might not be based solely on systematic, methodological or reliable criteria.

It has to be noted that not all farmers knew the name or the nutrient content of the mineral fertilizer products which they were applying. This indicates – again – a lack of methodological knowledge of the surveyed households. In most cases the nutrient contents of the applied fertilizers could be constructed because farmers knew either the name or the ingredients of the fertilizer product[14]. However, for one wheat, three maize and four cotton producing households the nutrient content could not be researched as the farmer neither indicated name or ingredient nor the nutrient content, so these production processes are not considered in the analysis of fertilization practices. Table 38 presents selected characteristics of the fertilization practices of the main crops of the surveyed households.

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[14] Nutrient contents calculate according to MITCHELL (2008)

Table 38. Characteristics of Fertilization of Main Crops of Surveyed Households

	Cotton	Maize	Wheat
Share of Fertilizing Households *(% hhs growing crop)*	98.00%	98.00%	100.00%
Mean Amount per Application *(kg/mu)**	45.83	44.00	58.87
Mean Fertilizer Content *(% dry matter)*:			
-N	18.03%	19.31%	14.55%
-P	12.44%	9.52%	8.41%
-K	11.13%	7.26%	4.52%
Mean Number of Applications per Year*	1.43	1.30	1.44
Mean NUE *(kg/kg N)*, ***	26.91	69.36	29.91
Mean Fertilizer Costs *(¥/mu/year)**	¥187.50	¥123.65	¥260.45
Mean Fertilizer Price *(¥/kg)**	¥2.20	¥1.83	¥1.61
Mean Nutrient Price *(¥/kg nutrient)*, ****:			
-N	¥4.66	¥4.11	¥3.48
-P	¥4.57	¥4.17	¥4,22
-K	¥4.26	¥3.51	¥1.85

NOTE: *of households applying fertilizers
**of fertilization
***mean nutrient price is corrected for the number of nutrients per respective fertilizer

The data shows a variation in nutrient prices, as prices for various types of fertilizers vary strongly (see Table 39). Mean nutrient prices for fertilizers of the survey (which will also be included in the analysis in chapter 6) are: 3.95 ¥/kg N, 4.35 ¥/kg P and 2.97 ¥/kg K. When comparing the mean nutrient prices of bought manure it is remarkable that the mean prices per kg of N and P in manure are considerably lower than in fertilizers, still – as demonstrated in previous chapters – the intensive use of fertilizers is characteristic for the NCP. Only respectively one household is not using fertilizers for producing cotton and maize; all wheat producing households apply fertilizers. Wheat has the highest mean amount of application and the highest number of applications per year, but the lowest nutrient content – indicating the usage of less expensive fertilizers, which is confirmed by the comparably low fertilization prices. The mean fertilizer content for cotton has the highest levels of P and K and a high share of N indicating the usage of more expensive high performance fertilizers and consequently the mean fertilizer price of cotton is the highest. This emphasizes the role of cotton as a cash crop, for which the surveyed households are willing to invest more. The nitrogen use efficiency (NUE) is following the concept of the WUE and determines the yield in relation to the applied N fertilization; maize has a comparably higher NUE than cotton or wheat.

When calculating the mean ratio of costs of applied fertilizers and revenue from crop sales, the investment of ¥1.00 in fertilization yields in ¥11.21 for cotton, ¥10.10 for maize and ¥5.09 for wheat[15]. The ratios for maize and wheat are similar with findings from BARNING (2008) who calculated ¥10.64 for maize and ¥5.99 for wheat. This indicates that the gains from investing in N fertilization are comparably low for wheat. The types of fertilizers which the surveyed households apply are displayed in Table 39.

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[15] Is should be noted that no other factors were considered for this calculation

Table 39. **Main Fertilizer Types of Surveyed Households**

Name *(Mandarin Name)*	**Plots*** *(% of total plots)*	**Mean Nutrient Content** *(% dry matter)* **N**	 **P**	 **K**	**Mean Price** *(¥/ kg)*
Compound Fertilizers					
TOTAL	**108 (48.43%)**	**16.10**	**14.69**	**14.49**	**¥2.46**
N Fertilizers:					
-Ammonium Bicarbonate (碳酸氢铵)	35 (15.70%)	18.40	0.00	0.00	¥0.94
-Urea Carbamite (尿素)	30 (13.04%)	46.00	0.00	0.00	¥2.16
-Ammonium Hydrogen (氢氨)	5 (2.24%)	28.00	0.00	0.00	¥0.56
-Other	18 (8.07%)	18.94	5.83	0.00	¥1.03
TOTAL	**88 (39.46%)**	**28.51**	**1.31**	**0.00**	**¥1.35**
P Fertilizers:					
-Phosphate (磷肥)	38 (17.04%)	0.00	13.94	0.00	¥1.01
-Calcium Phosphate (过磷酸钙)	5 (2.24%)	0.00	16.40	0.16	¥1.58
TOTAL	**43 (19.28%)**	**0.00**	**14.23**	**0.02**	**¥1.08**
K Fertilizers:					
-Potassium (钾肥)	3 (1.35%)	0.00	0.00	30.00	¥2.50
-Huangjinjia (黄金钾)	1 (0.00%)	14.00	4.00	19.00	¥3.20
TOTAL	**4 (1.80%)**	**3.50**	**1.00**	**27.25**	**¥2.68**
Unknown:					
TOTAL	**14 (6.28%)**	**	**	**	**

NOTE: *households can apply more than one type of fertilizer per plot
**no answer

Compound fertilizers are the most commonly applied type of fertilizers within the surveyed households; also pure N fertilizers are widely applied. P and N fertilizers are less costly compared to compound and K fertilizers. It is remarkable that on 6.28% of the plots the surveyed households apply fertilizers without knowing the nutrient content or fertilizer type – this also indicates a lack of methodological knowledge. Table 40 surveys the distribution of the fertilizer types between the main crops of the surveyed households.

Table 40. **Application of fertilizer Types for Main Crops of Surveyed Households**

	Cotton	**Maize**	**Wheat**
Compound Fertilizers *(% of total applications)**	40.74%	27,78%	21.30%
N Fertilizers *(% of total applications)**	12.50%	27.27%	43.18%
P Fertilizers *(% of total applications)**	14.71%	14.71%	75.53%
K Fertilizers *(% of total applications)**	0.00%	0.00%	75.00%

NOTE: *missing %: other crops

Considering the main crops, K fertilizers are only applied to wheat (and other crops which are not considered in the analysis). Consequently all types of fertilizers are applied to wheat. Inevitably the comparable expensive compound fertilizers are mostly applied to cotton. These practices result in the nutrient inputs from fertilization which are displayed in Table 41.

Table 41. Nutrient Input from Fertilization of Main Crops of Surveyed Households

	Cotton	Maize	Wheat
Mean Nutrient Input *(kg/mu/year)**:			
-N	13.77	12.71	19.11
-P	11.84	6.38	15.15
-K	10.20	4.31	7.02
Max. Nutrient Input *(kg/mu/year)* *:			
-N	43.80	65.70	40.00
-P	34.00	29.00	40.00
-K	34.00	17.00	63.00
Min. Nutrient Input *(kg/mu/year)* *:			
-N	3.00	2.25	0.00
-P	0.00	0.00	0.00
-K	0.00	0.00	0.00

NOTE: *of households applying fertilizers

Table 41 demonstrates a strong variation in mean, max and min nutrient of the main crops. Wheat has the highest mean nutrient input (see Table 41), as it is fertilized more often and with higher amounts than the other main crops (see Table 38). Consequently maize, which is fertilized the least often and with the smallest amounts has the lowest mean nutrient inputs. For wheat and particularly for maize, P and especially K input are considerable smaller compared to N input. The high use of compound fertilizers results in a balanced nutrient supply for cotton. The mean total N input for the main crops is displayed in Table 61. Table 42 displays the characteristics of machinery applications for bringing out fertilizers of the main crops.

Table 42. Machinery Application for Fertilization of Main Crops of Surveyed Households

	Cotton	Maize	Wheat
Usage *(no. and % of hhs producing that crop)*	5 (10.00%)	14 (28.00%)	4 (8.88%)
Type of Machinery *(no. and % of hhs growing crop)**:			
-Sowing Machine	5 (10.00%)	14 (28.00%)	4 (8.88%)
Share of Contractors *(% of machine usage per crop)*	40.00%	100.00%	100.00%
Mean Costs *(¥/mu)**, **:	¥15.00	¥12.06	¥12.66

NOTE: *of households applying fertilizers with machinery
**not all households applying fertilizer with machinery answered

It can be seen in Table 42 that the majority of the households are fertilizing manually; only 8.88% of wheat, 10.00% of cotton and 28.00% of maize producing households are using machinery for fertilization. Farmers in the NCP are often sprinkling fertilizers by hand, which does not allow for an equal distribution of fertilizers and often leaves the fertilizers on the surface of the soil without penetrating it. Furthermore, fertilization is often combined with flood irrigation, which causes nutrients to move into deep soil layers where they cannot be absorbed from plants (see also 2.4.3). In addition, the manual handling of fertilizers also bears health risks. Machinery use can reduce these health risks and might allow a more equal distribution by exact placing of the nutrients. All surveyed households which are using machinery for fertilization are using sowing machines; it is notable that all households which are using machinery for fertilizing maize and wheat are renting it, i.e. they hire contactors. The mean costs for machinery application for fertilization of maize and wheat are similar for the surveyed households (¥12.06/mu and respectively ¥12.66/mu); the mean costs for cotton are slightly higher: ¥15.00/mu.

4.3.6. Pest and Weed Control

This part describes the practices of the surveyed households regarding pest and weed control. 56 of the surveyed households (87.50%) are manually weeding their crops. Table 43 presents the characteristics of the weeding activities of the main crops of the surveyed households.

Table 43. Characteristics of Weeding Activities of Main Crops of Surveyed Households

	Cotton	Maize	Wheat
Performing Weeding *(no. and % of hhs growing crop)*	43 (86.00%)	37 (74.00%)	27 (60.00%)
Weeding Method *(no. and % of hhs growing crop)**:			
-Manual	25 (50.00%)	20 (40.00%)	19 (42.22%)
-Use of Hoe	35 (70.00%)	27 (54.00%)	16 (35.55%)
-Machine	0 (0.00%)	0 (0.00%)	0 (0.00%)

NOTE: *households can apply more than one method of weeding

Table 43 shows that cotton has the highest share of the surveyed households which are weeding. The surveyed households do not use machinery for weeding; they are either using a hoe or their hands (manual weeding). This indicates that weeding the main crops is a time and labor intensive production step for the surveyed households.

The surveyed households also use pesticides. All surveyed households select and by the pesticides themselves. In addition, all surveyed households decide independently about the amount and timing of the pesticide applications. Table 44 presents the reasons for decisions about amount and timing of pesticide applications of the households.

Table 44. Decision Making about Amount and Timing of Pesticide Applications for Surveyed Households

	Households
Quantity and Timing of Pesticide Application *(no. of hhs and % of answers)**:	
-Instructions on Pesticide Package	43 (55.13%)
-Own Experience	11 (14.10%)
-Degree of Pest Infestation	11 (14.10%)
-Crop Variety Quality	6 (7.69%)
-Price of Pesticide	3 (3.85%)
-Other Farmer's Advice	2 (2.56%)
-Specialist Advice	1 (1.28%)
-Soil Quality	1 (1.28%)

NOTE: *more than one answer per household possible

The majority of surveyed households follows the instructions on the pesticide package when deciding about the quantity and timing of the pesticide application. Again, as in 4.3.5, following the argumentation in 4.3.4, the answers “own experience”, “crop variety quality” and “soil quality” indicate that the decision making about the quantity and timing of pesticide applications might not be based solely on systematic, methodological or reliable criteria. It is notable that more households look for other households' advice than for advice from specialists. Table 45 displays the liquid pesticide types which are applied for the main crops of the surveyed households.

Table 45. Applied Liquid Pesticide Types of Surveyed Households

Name *(Mandarin Name)*	**Plots*** *(% of plots with that crop)*	**Mean Amount** *(liter/mu/ year)*	**Mean Price** *(¥/liter)*	**Mean Price** *(¥/mu)*
COTTON:				
Alphacypermethrin (氯氰菊脂)	20 (16.13%)	3.47	¥25.27	¥81.27
Acetamiprid (啶虫脒)	8 (6.34%)	8.12	¥24.93	¥214.56
Fu Lv Ling (氟氯灵)	7 (5.65%)	0.61	¥24.57	¥13.87
Omethoate (氧化乐果)	6 (4.84%)	1.52	¥26.38	¥31.93
Abamectin (阿维菌素)	4 (3.23%)	1.53	¥32.50	¥35.28
Others	38 (30.65%)	3.75	¥25.25	¥89.36
Unknown	35 (28.23%)	4.21	¥28.24	¥38.37
TOTAL	-	**3.76**	**¥26.38**	**¥94.88**
MAIZE:				
Yu Wu You (玉天优)	20 (24.40%)	0.69	¥20.69	¥12.91
Alphacypermethrin (氯氰菊脂)	19 (23.17%)	0.73	¥24.64	¥17.19
1605	6 (7.32%)	0.80	¥18.22	¥15.90
Abamectin (阿维菌素)	4 (4.88%)	0.60	¥59.15	¥14.07
Others	46 (56.10%)	0.76	¥26.67	¥19.74
Unknown	16 (19.51%)	1.31	¥23.83	¥29.93
TOTAL	-	**0.79**	**¥25.55**	**¥18.79**
WHEAT:				
Omethoate (氧化乐果)	13 (16.88%)	0.14	¥22.56	¥2.86
Alphacypermethrin (氯氰菊脂)	9 (11.68%)	0.30	¥24.44	¥8.13
Abamectin (阿维菌素)	4 (5.19%)	0.46	¥41.00	¥6.83
Acetamiprid (啶虫脒)	4 (5.19%)	0.22	¥43.10	¥9.78
1605	4 (5.19%)	0.07	¥16.50	¥1.12
Others	22 (28.57%)	0.31	¥23.14	¥7.37
Unknown	20 (25.97%)	0.76	¥42.07	¥21.09
TOTAL	-	**0.39**	**¥29.82**	**¥10.07**

NOTE: *households can apply more than one type of liquid pesticide per plot

The results in Table 45 show that the surveyed households apply – compared to wheat and maize – large amounts of liquid pesticides for the production of cotton and thus they invest the most per mu in pesticides for cotton. This in accordance with the characteristics of cotton as an input-intensive cash crop and is also expressed in the high share of pesticide in the mean expenses of cotton in Figure 33. The applied liquid pesticide types are similar for all main crops of the surveyed households; therefore the mean prices per liter are comparable. Winter wheat is grown during the dry and cold winter months, so the application of liquid pesticides is lower compared to the other main crops – as the infestations can be expected to be lower.

To a lesser degree, the surveyed households also apply solid pesticides (which are usually diluted before application) to the main crops, the solid pesticide types are displayed in Table 46.

Table 46. Applied Solid Pesticide Types of Surveyed Households

Name *(Mandarin Name)*	**Plots*** *(% of plots with that crop)*	**Mean Amount** *(kg/mu/year)*	**Mean Price** *(¥/kg)*	**Mean Price** *(¥/mu)*
COTTON:				
Pi Chong Lin (蚍虫林)	7 (9.09%)	0.05	¥56.17	¥36.34
Pi Chong Ling (蚍虫灵)	5 (6.49%)	0.11	¥60.00	¥111.46
Others	3 (3.90%)	0.02	¥31.00	¥17.51
Unknown	2 (2.60%)	0.01	¥525.00	¥6.00
TOTAL	**-**	**0.06**	**¥108.10**	**¥51.54**
MAIZE:				
Others	10 (12.20%)	0.10	¥100.20	¥5.93
Unknown	2 (2.44%)	0.02	¥16.00	¥0.64
TOTAL	**-**	**0.09**	**¥86.17**	**¥5.05**
WHEAT:				
Pi Chong Lin (蚍虫林)	8 (10.39%)	0.05	¥55.38	¥3.62
Others	3 (3.90%)	0.05	¥66.67	¥6.83
Unknown	3 (3.90%)	0.05	¥80.00	¥2.75
TOTAL	**-**	**0.05**	**¥63.07**	**¥4.12**

NOTE: *households can apply more than one type of solid pesticide per plot

Table 46 shows that the application of solid pesticides is not common for the surveyed households; of all main crops only a few households apply solid pesticides. The interpretation of the characteristics of the application of solid pesticides is similar to liquid pesticides. Consequently cotton has the noteworthy highest per area pesticide costs (solid and liquid) of the main crops. Table 47 presents the total pesticide applications (of combined liquid and solid pesticides) and the mean total pesticide costs of the main crops.

Table 47. Total Pesticide Applications and Mean Total Pesticide Costs

	Cotton	**Maize**	**Wheat**
Hhs Applying Pesticides *(no. and % of hhs growing crop)*	50 (100.00%)	50 (100.00%)	44 (97.78%)
Mean Pesticide Costs *(¥/mu)**:	¥240.34	¥43.61	¥18.55

NOTE: *of households using applying pesticides

The use of chemical pest control is common for the surveyed households. Simultaneously to the separated analysis of liquid and solid pesticide use, cotton has the highest total pesticide costs and wheat the lowest. Concluding it can be stated that the surveyed households perform the most intensive control for pests and weed (i.e. manual and chemical control) for cotton. The practices of machinery use for pesticide applications are presented in Table 48.

Table 48. Machinery Use for Pesticide Application of Main Crops of Surveyed Households

	Cotton	Maize	Wheat
Usage *(no. and % of hhs growing crop)*	3 (6.00%)	0 (0.00%)	0 (0.00%)
Share of Contractors *(% of machine usage per crop)*	66.67%	0.00%	0.00%
Mean Machinery Costs *(¥/mu)**:	¥23.33	¥0.00	¥0.00

NOTE: *of households using machinery for pesticide applications

The use of machinery is not common for the application of pesticides of the surveyed households; only 6.00% use machinery for the application of pesticides for cotton – no household uses machinery for maize or wheat. The common pesticide application method is, thus, the manual application by means of a knapsack sprayer. This method bears health risks and environmental risks (see also 2.4.4).

4.3.7. Irrigation

Considering the environmental problems related to water management in the research area this analysis is of special importance. All surveyed households decide autonomously about the timing and quantity for irrigation. Table 49 presents the reasons for decisions about amount and timing of irrigation of the households.

Table 49. Decision Making about Amount and Timing of Irrigation for Surveyed Households

	Households
Quantity and Timing of Pesticide Application *(no. of hhs and % of answers)**:	
-Own Experience	51 (77.27%)
-Soil Quality	10 (15.15%)
-Crop Variety Quality	5 (7.58%)

NOTE: *more than one answer per household possible

Again, following the argumentation in 4.3.5 and 4.3.4, all answers regarding the decision making about the quantity and timing of irrigation indicate that the decisions might not be based solely on systematic, methodological or reliable criteria. It should be noted that none of the surveyed households is paying directly for the water used for irrigation.

Table 50 displays selected characteristics of irrigation of main crops of the surveyed households. As described before, flood irrigation is the most common irrigation method in the NCP. In order to bring water from the underground, wells or ditches onto the fields, pumps are applied. Not all households knew the exact amount of water used for irrigation, but all households knew the time the pump was running to irrigate a respective lot. Therefore, by knowing the capacity of the respective pump, the irrigation quantity could be calculated[16].

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[16] In cases in which only the type of pump was known, but not the exact model, the amount of irrigation was estimated by using characteristics of comparable pumps

Table 50. Characteristics of Irrigation of Main Crops of Surveyed Households

	Cotton	Maize	Wheat
Share of Irrigating Households *(% hhs growing crop)*	100.00%	100.00%	100.00%
Irrigation Method *(no. and % of hhs growing crop)**:			
-Pipe Flood Irrigation	45 (90.00%)	48 (96.00%)	43 (95.55%)
-Furrow System Flood Irrigation	3 (6.00%)	1 (2.00%)	1 (2.22%)
Mean Amount per Application *(m^3/mu)****	93.03	94.28	91.06
Mean Number of Applications per Year***	1.67	2.04	2.85
Mean Amount *(m^3/mu/year)****	153.56	192.52	243.13
Max Amount *(m^3/mu/year)****	375.00	537.00	840.00
Mean Machinery Costs *(¥/mu/year)***, ***	¥69.10	¥70.89	¥99.00
Mean Machinery Costs *(¥/m^3)****, ****		¥0.54	

NOTE: *not all households answered
**costs refer to running costs of pump or rental costs
***of households irrigating respective crop
****representing the indirect volumetric water price

The answer "pipe flood irrigation" includes stable pipes and changeable hoses which are attached to pumps (which are often attached to tractors). Consequently it has to be noted that the vast majority of households is applying flood irrigation methods. The amount per application of main crops is similar, as usually the same pumps are used to flood the fields. However, wheat and cotton are irrigated more often per year and are thus irrigated with higher amounts per year. In accordance with other studies (e.g. BARNING, 2008), wheat is irrigated with the largest amounts of all main crops of the surveyed households. This is also due to the climatic conditions during the growing period of wheat. The mean amounts of annual irrigation for maize and wheat are comparable with another study in the Hebei Province which estimates the amount of irrigation for maize with 140.00 – 200.00 m^3/mu and for wheat with 180.00 – 250.00 m^3/mu (YANG *et al.*, 2003).

When calculating the mean ratio of costs of applied water (at ¥0.54 per m^3) and revenue from crop sales (at mean prices from 4.5.3), the investment of ¥1.00 in irrigation yields in ¥6.79 for cotton, ¥3.98 for maize and ¥4.39 for wheat[17]. It is notable that maize has the comparably lowest gains from investments in water.

Many surveyed households do not own pumps and pay contractors for irrigation services or they have to pay running costs for own pumps, so the irrigation costs per area unit and per product unit are rising with the number of applications per year and applied amounts – this is why wheat has the highest irrigation costs per mu and per m^3. It should also be noted that the mean machinery costs (in ¥/m^3) in Table 50 represent an indirect volumetric price for water – the more water the households apply, the more they pay. Compared to the suggested marginal price of water in the NCP of ¥5.20, (see 2.4.2) – reflecting resource, extraction and management costs – the indirect volumetric water price of the surveyed households (¥0.54/m^3) seems to be low. However, this indirect volumetric water price will be included in the analysis in chapter 6.

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[17] Is should be noted that no other factors were considered for this calculation

4.3.8. Harvest

As is demonstrated in Table 51, the main crops are either harvested in the beginning or the end of the summer months.

Table 51. Characteristics of Harvesting of Main Crops of Surveyed Households

	Cotton	Maize	Wheat
Share of Manual Harvest *(% per crop)*	100.00%	100.00%	0.00%
Mean Yield *(kg/mu)***	260.25	480.79	428.00
Max Yield *(kg/mu)*	370.37	700.00	600.00
Mean Labor Costs *(¥/mu)*	¥0.18	¥0.00	¥0.00
Mean Months of Harvest*	August - September	September	May - June

NOTE: *calculated from mean values of answers
**grain yield for maize and wheat

Maize has the highest mean yield of the main crops. The difference between mean and max yield are large for maize and wheat – consequently the standard deviation (in kg/mu) of maize (114.47) and wheat (94.43) are high. The standard deviation (in kg/mu) of cotton yield is comparably small (39.78) – indicating that yield ranges for cotton are small. The mean yields of the surveyed farms are high compared to yields in the official data of the Hebei Province for 2006: 67.20 kg/mu (cotton), 321.13 kg/mu (maize) and 316.67 kg/mu (wheat) (CHINA AGRICULTURE PRESS, 2007). However another study (JIN and JIANG, 2002) determined the yields for cotton at farmer's practice in Handan – which includes Quzhou – with 290.00 kg/mu. Other studies determined the yields in the study area for maize with 430.00 kg/mu and for wheat with 355.00 kg/mu (ZHEN *et al.*, 2005) or for maize with 426.67 kg/mu and for wheat with 382.00 kg/mu (BARNING, 2008). The statistical office in Handan (which is the prefectural city of Quzhou County) states the yields in Quzhou with 423.00 kg/mu for maize and 373.00 kg/mu for winter wheat (SBHC, 200). This indicates that the yield levels in the research area are fluctuating strongly.

Since manual harvest is time intensive and maize and cotton are typically harvested during the same period, labor shortages might occur. However, as indicated in 4.5.1, labor is abundant during the rest of the year. Table 52 surveys the characteristics of the machinery applications for harvesting the main crops.

Table 52. Machinery Application for Harvesting of Main Crops of Surveyed Households

	Cotton	Maize	Wheat
Usage *(no. and % of hhs growing crop)*	0 (0.00%)	0 (0.00%)	45 (100.00%)
Type of Machinery *(no. and % of hhs growing crop)**:			
-Harvester	0 (0.00%)	0 (0.00%)	35 (77.78%)
-Wheat Cutter	0 (0.00%)	0 (0.00%)	10 (22.22%)
Share of Contractors *(% of machine usage per crop)*	0.00%	0.00%	93.33%
Mean Machinery Costs *(¥/mu)*:	¥0.00	¥0.00	¥36.83

As can be seen in Table 52, all surveyed households use machinery for harvesting wheat. The vast majority use contractors for harvest of wheat. All households harvest cotton and maize manually. However, no share of manual harvest exists for wheat.

4.3.9. Postharvest

The characteristics of the postharvest activities of the main crop of the surveyed households are outlined in Table 53.

Table 53. Characteristics of Postharvest Activities of Main Crops of Surveyed Households

	Cotton	Maize	Wheat
Removing Plant Residues from Field *(% of hhs growing crop)*	100.00%	10.00%	4.45%
Type of Work *(no. and % of hhs growing crop)**:			
-Threshing	n.a.	30 (60.00%)	n.a.
-Cutting Residues	n.a.	21 (42.00%)	n.a.
Share of Machinery Use *(no. and % of households growing crop)***	n.a.	35 (70.00%)	n.a.
Mean Machinery Costs *(¥/mu)*:	n.a.	¥26.58	n.a.

NOTE: *not all households answered
**households can do post-harvest work manually and with machinery

As was shown in 4.3.5, all cotton residues are removed after harvest. As can be seen in Table 52, wheat is harvested by contractors with machinery. So wheat is threshed and does not need post-harvest work; however, some farmers are cutting the straw before returning it to the field. The cotton bulbs are harvested manually and do mostly not need post-harvest work, especially when all undesirable plant parts are removed during harvest. Maize is the most intensive crop regarding postharvest; machinery is usually used for threshing and/or cutting residues. All households which have used plastic mulching have to remove the plastic cover after harvest.

4.4. Environmental Characteristics of the Farming Practices

Based on the characteristics of the surveyed households and the general environmental effects of farming in the NCP (see 2.4), this chapter analyses the operations the farm households of the under environmental criteria. This chapter is separated into sub-chapters dealing with soil characteristics, fertilization, water management, other environmental characteristics and environmental awareness.

4.4.1. Soil Characteristics

In July 2008 soil samples from 204 plots of the surveyed households were taken and analyzed in order to study the impacts of the farming practices on soil characteristics at the field level. The samples were taken to a depth of 30 cm and then divided into two equally sized parts. For the respective analyses, one half of each sample was dried for 3 days at controlled room temperature, whereas the other half was dried in an oven for 12 hours at 105.00˚C. All soil samples were classified as silty loam. Due to a lack of a Chinese categorization of plant available nutrients for the soils of the NCP, the soils were categorized according to the classification of the State Institute of Agricultural Chemistry, Universität Hohenheim, Germany (see Table 54).

Table 54. Categorizations of Nutrient Contents for Medium Textured Arable Soils

Class	**P_2O_5*** *(mg/100g)*	**K_2O*** *(mg/100g)*	**Mg**** *(mg/100g)*
A *(very low)*	≤5	≤7	≤4
B *(low)*	6-9	7-14	4-7
C *(optimum)*	10-20	15-25	8-13
D *(high)*	21-34	26-35	14-18
E *(very high)*	≥35	≥35	≥18

NOTE: * P2O5 and K2O were determined using the Calcium-Acetate-Lactate method (CAL)
** Mg was determined by extraction with a 0.0125 mol/l $CaCl_2$-solution

Source: VDLUFA (1991)

The mean pH-value ($CaCl_2$) of the soils of the surveyed households is 7.62 – all analyzed soils are within the slightly alkaline range from 7.30 to 7.80. The pH-value and the Mg contents were determined in a $CaCl_2$ extract; the P_2O_5 and K_2O contents were determined with the Calcium-Acetate-Lactate method (CAL) (VDLUFA, 1991). Table 55 presents the nutrient contents of the soils of the surveyed households according to the classification in Table 54.

Table 55. Categorizations of Nutrient Contents for Soils of the Surveyed Households

Class	**P_2O_5** *(number and % analyzed plots)*	**K_2O** *(number and % analyzed plots)*	**Mg** *(number and % analyzed plots)*
A *(very low)*	0 (0.00%)	3 (1.47%)	0 (0.00%)
B *(low)*	0 (0.00%)	77 (37.75%)	0 (0.00%)
C *(optimum)*	20 (9.80%)	81 (39.71%)	0 (0.00%)
D *(high)*	84 (41.18%)	18 (8.82%)	3 (1.47%)
E *(very high)*	100 (49.02%)	25 (12.25%)	201 (98.53%)

NOTE: * P2O5 and K2O were determined using the Calcium-Acetate-Lactate method (CAL)
** Mg was determined by extraction with a 0.0125 mol/l $CaCl_2$-solution

Table 55 shows a tendency for P_2O_5 and Mg to be high and very high. K_2O seems to be more equally distributed between all 5 categories. N_{min} was determined by Continuous-Flow-Analysis (CFA); the mean value for all analyzed soils is 25.18 mg N_{min}/kg Soil varying widely from 4.00 to 162.00 mg N_{min}/kg Soil. Table 56 displays the mean nutrient contents and the variances of all soils as well as the soils under cotton monoculture and under a SM-WW double crop rotation.

Table 56. Mean Nutrient Contents of Soils from Fields of the Surveyed Households

	All		**Cotton Monoculture**		**SM-WW Rotation**	
	Mean	*(Min-Max)*	*Mean*	*(Min-Max)*	*Mean*	*(Min-Max)*
N_{min} *(mg/kg)*	25.18	(4.00-162.00)	26.05	(4.00-162.00)	22.23	(5.10-103.00)
P_2O_5 *(mg/kg)*	40.48	(11.00-135.00)	37.48	(11.00-129.00)	40.48	(12.00-125.00)
K_20 *(mg/kg)*	21.00	(5.70-79.00)	21.58	(7.30-76.00)	18.58	(6.40-72.00)
Mg *(mg/kg)*	42.30	(15.00-68.00)	47.35	(18.00-68.00)	38.89	(21.00-62.00)

The results in Table 56 do not indicate any noteworthy difference in soil nutrient contents between soils under cotton monoculture and the SM-WW crop rotation. However large variances of nutrient contents are obvious – this is in accordance with the strongly varying fertilization practices, as fertilization impacts soil nutrient contents. The mean P_2O_5 and Mg contents of soils for cotton and for SM-WW production is in class E “very high” indicating excess nutrient input. The mean K_2O content of soils for cotton and SM-WW production lie in class C “optimum” indicating optimal nutrient supply at the time when the soil samples were taken. Table 57 compares the mean N_{min} contents of the soils of the surveyed households and N_{min} recommendations (in kg/ha). The N_{min} contents (in mg/kg) was converted into kg/ha by using factor 4.2 (30 cm depths and the soils in Quzhou have a relative density of 1.4 kg/l soil) (IRTG DATABASE, 2010).

Table 57. Mean N_{min} Contents of the Soils from the Surveyed Households and N_{min} Target Values*

	All	**Cotton Monoculture**	**SM-WW Rotation**	**Target Value Maize****, ***	**Target Value Winter Wheat****, ****
N_{min} *(kg/ha)*	105.24	109.42	91.91	50.00	36.00

NOTE: *Target values for silty loam soils in North Rhine-Westphalia, Germany

*******Source:* NMIN (2010)

***Preceding crop: winter wheat

****Preceding crop: summer maize

When comparing the mean N_{min} contents and the target values, it is apparent that the mean N_{min} contents of the soils of the surveyed households are high. Considering that the variance of the N_{min} contents of the soils of the surveyed households is large (see Table 56), some soils will exceed the target values significantly. However, it should be noted that the samples were taken at random dates during the survey in July, in this period in the SM-WW crop rotation maize is typically in a medium growing stage and cotton is in the final growing period. In addition the samples were only taken once per plot, for more convincing conclusions soil samples should be taken at several important growing stages.

High salt contents in soils can have negative effects on plant growth. The mean salt content of the soils of the surveyed households (measured with 1:10 extract as % KCl) is 0.10%. These results indicate that the salt content in the analyzed soils is low and, thus, has no negative effect on plant growth. The climatic conditions, i.e. seasonally concentrated heavy rainfall, and current farming practice, i.e. flood irrigation, cause nutrients and salt to move into deeper layers of the soil – explaining the low salt content in the samples which were taken from the top soil.

A factor of 1.72 was used for calculating the humus content from the C-content (which was determined by elementary analysis). All analyzed soil samples had a humus content which was lower than 4.00% (of organic matter in the soil). The mean humus content of the surveyed soil samples was 1.36%. Such low humus content might limit soil fertility and should, thus, be increased using adequate farming practices. This is in accordance with other studies in the NCP; for example GAO *et al.* (2009) also determined a low mean organic matter content of soils in the Hebei Province of 0.60% and a mean pH of 8.20.

The contents of micro nutrients were determined according to the CAT method (VDLUFA, 1991). The previous analyses were conducted on plot level, the micronutrient contents were determined by mixed samples on household level. Table 58 displays the desired range of plant available micronutrients for agricultural silty loam soils and the results of the analysis of the soils of the surveyed households according to the CAT method.

Table 58. Desired Range and Measured Mean Contents of Plant Available Micronutrients for Silty Loam Soils – According to the CAT Method

Class	**Boron** *(mg/kg)*	**Copper*** *(mg/kg)*	**Zinc** *(mg/kg)*
Desired Range**	0.40-1.20	1.00-3.00	1.10-3.00
Mean Content of Analyzed Soils	0.58	1.84	4.97

NOTE: *for pH ≥ 7.00
**Source:* LTZ (2010)

The mean contents of Boron and Copper are within the desired level for agricultural soils: boron near the lower end and copper near the center of the desired range. However, the mean content of zinc is distinctly above the desired range.

4.4.2. Fertilization

A definition of over-fertilization is difficult, when not being able to determine specific values like micro-climate, exact growth stage or soil nutrient contents over the whole growing period for each field. Therefore more generalized definitions are needed to analyze the fertilization practices of the surveyed households. In order to do so, several studies have been consulted; LIU *et al.* (2006) measured the nutrient uptakes of maize and wheat in China over several years – fertilization exceeding these maximum amounts is considered a baseline for over-fertilization in this study; JIN and JIANG (2002) developed fertilization recommendations for cotton production in the prefecture Handan (which includes Quzhou) – fertilization exceeding this recommendation are a baseline for over-fertilization in this study. The baselines for N over-fertilization are displayed in Table 59.

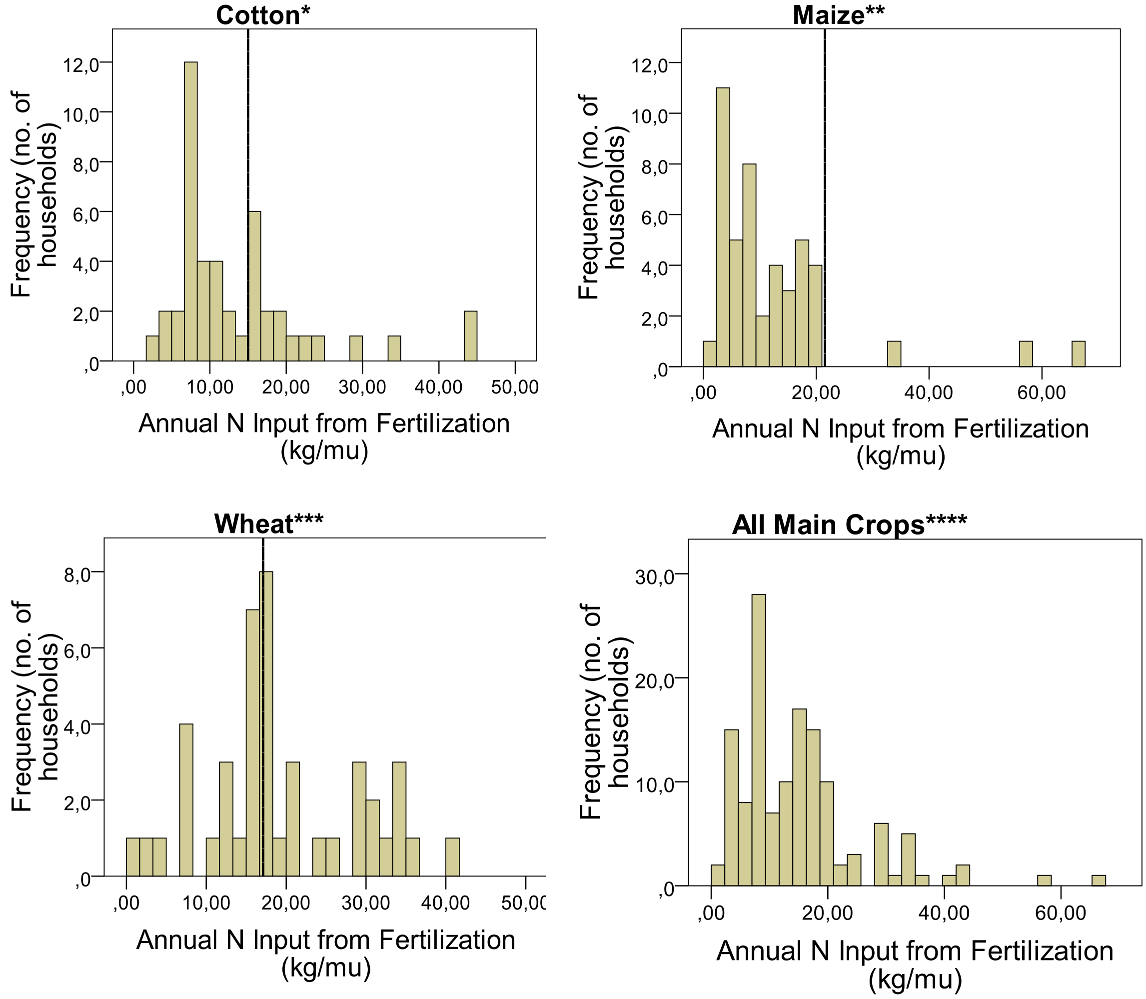
Table 59. Baselines for N Over-fertilization

	Cotton	**Maize**	**Wheat**
Max N Uptake *(kg/mu)**	-	21.65	17.13
N Recommendation *(kg/mu)* **	15.00	-	-

NOTE: *based on LIU et al. (2006)
** based on JIN and JIANG (2002)

The baselines in Table 59 for N over-fertilization are reasonable as another study (ZHEN *et al.*, 2006) estimated the mean annual uptake rates in the NCP with 9.00 Kg/mu for cotton, 10.00 kg/mu for maize and 11.00 kg/mu for wheat. Consequently the selected thresholds are clearly above mean the mean uptake rates in the research area. When comparing these baselines with the mean surveyed fertilization practices of the surveyed households (in Table 41), only wheat exceeds these baselines. So the surveyed households, on average, do not over fertilize maize and cotton. The dashed line in Figure 19 represents the baseline for over-fertilization according to the definitions in Table 59.

Figure 19. Baseline for N Over-fertilization and Histograms of N Input from Fertilization of Main Crops of Surveyed Households



NOTE: *Standard Deviation: 9.25, Mean: 13.77, n=45
**Standard Deviation: 12.49, Mean: 12.51, n=46
***Standard Deviation: 9.47, Mean: 19.04, n=44
****Standard Deviation: 10.83, Mean: 15.06, n=135

The histograms in Figure 19 illustrate a great variation in fertilizer application practices of the surveyed households: some households are using large amounts of fertilizers whereas others are applying too small amounts. As described in 2.4.1, this unbalanced fertilization usage is in accordance with recent studies. Cotton and wheat have the lowest standard deviations of all main crops, but the standard deviations are still high – indicating a strong variation in fertilizer use. Wheat has the highest mean annual N input from fertilization. According to this baseline for cotton 28.00% (14 households), for maize only 6.00% (3 households) and for wheat 48.89% (22 households) of households producing the respective crop are over-fertilizing.

Liebig's law of the minimum assumes proportional linear yield increases according to variations of inputs until the point is reached in which no further yield increase can be achieved (WAGNER, 1995). Therefore the resulting production function is often referred to as a fractional linear production function. The basic form of the Liebig function for N input is:

$$Y = a * N + c$$

where *Y* is the obtainable yield (in kg/mu) and *N* the respective N input (in kg/mu); *a* is a coefficient and *c* the constant. Based on the surveyed data a Liebig production functions for maize and wheat are estimated by means of a regression[18] – see Table 60.

Table 60. Estimated Liebig Production Functions for Maize and Wheat

	Maize	Wheat
R^2	0.45	0.02
a	1.32	0.34
c	464.81	417.89
Resulting Production Functions	Y=1.32*N+464.81	Y=0.34*N+417.89

The yield at the maximum nitrogen input can be considered the maximum yield level. So, if the maximum N uptake levels according to Table 60 for maize (21.65 kg N/mu) and wheat (17.13 kg N/mu) are entered into the function, the maximum yield levels can be determined. The resulting maximum yield for maize is 493.39 kg/mu and for wheat it is 423.71 kg/mu. The resulting maximum yield levels match the mean yield levels of the survey (see Table 51) – moreover the maximum yield levels of the survey clearly exceed this calculated maximum yield. Even though the R^2 value for maize is acceptable, the estimation for wheat results in a low R^2 value. Therefore it can be concluded that the estimated Liebig functions do not represent the relation between N input and maximum yields and thus they cannot be consulted in further analyses of N fertilization of maize and wheat. Since no data on maximum uptake rates of cotton in the research area exist, this calculation could not be calculated for cotton.

In order to survey the effects of N nutrient management on yields of the main crops, Figure 20 compares the N-use-efficiency with the respective N input for the main crops of the surveyed households. The N-Use-Efficiency is calculated as:

N-Use-Efficiency (kg product/kg N) = Yield (kg/mu)/N input fertilization (kg/mu).

The mean N-Use-Efficiency (NUE) of the main crops of the surveyed households are: 26.91 kg cotton per kg N, 69.26 kg maize per kg N and 29.91kg wheat per kg N – maize has the noticeably highest NUE of the main crops.

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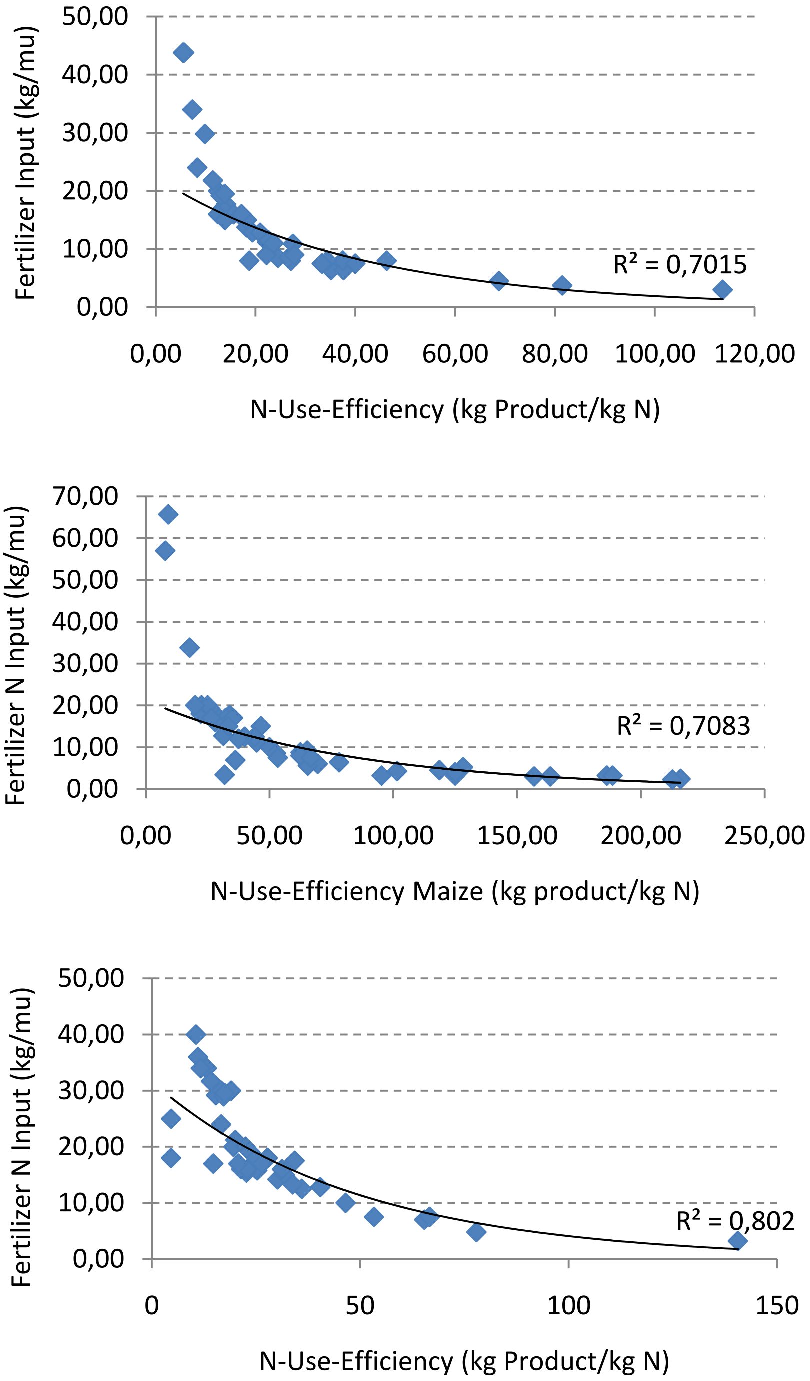
[18] With the SPSS Statistics 17 software

Figure 20. **Comparison of N Input from Fertilization and N-Use-Efficiency of Main Crops of Surveyed Households**



Cotton

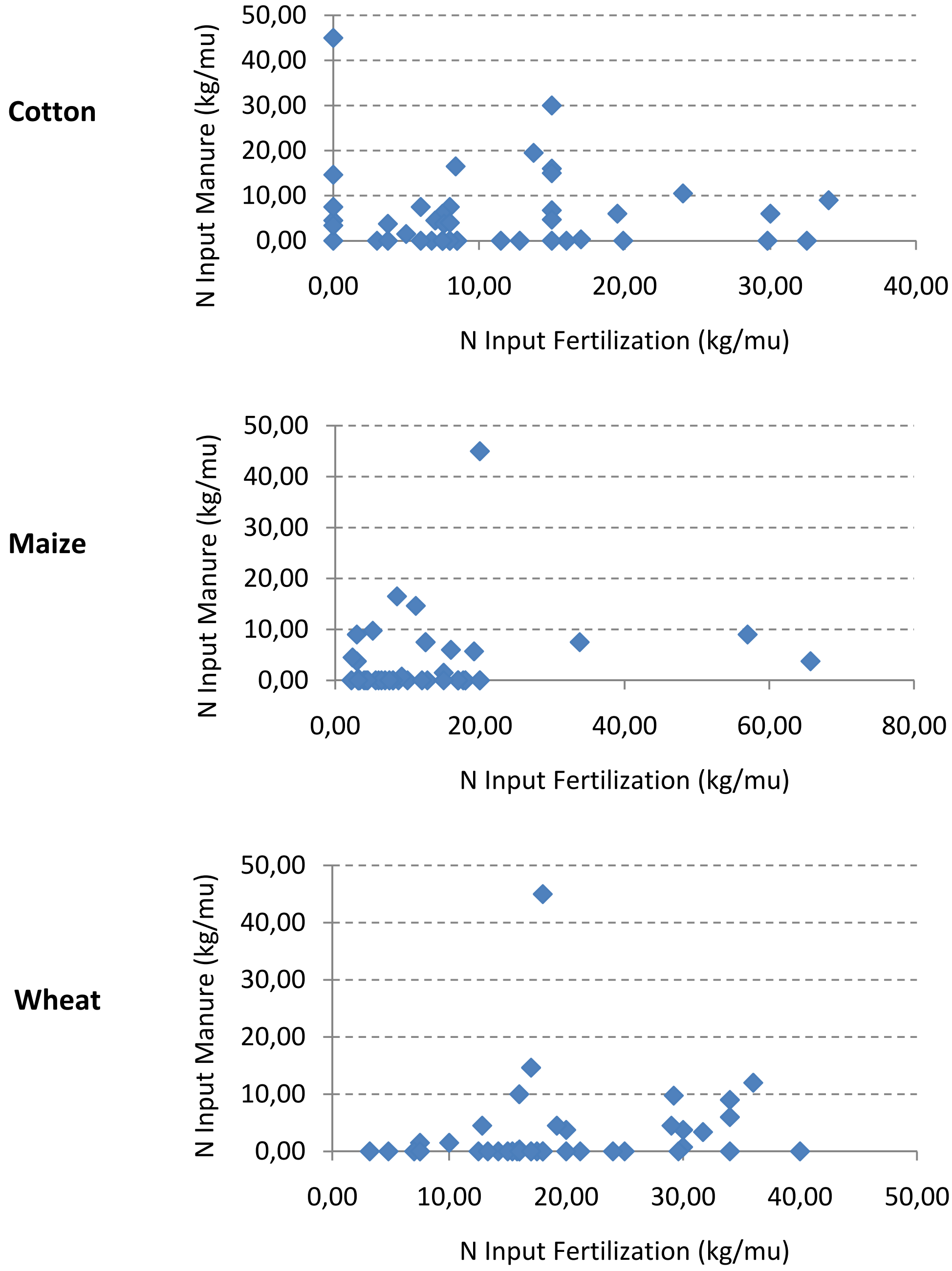
Maize

Wheat

Figure 20 demonstrates that the N-Use-Efficiency is the highest for low N input rates for all main crops. The fitted exponential trend lines for the main crops have significant coefficients of determination (R^2) values, so the relation between the N input and the N-Use-Efficiency can be explained by these exponential trend lines. These trend lines represent reversed production functions with diminishing returns. These findings show that – for the surveyed main crops – high N input rates do not yield in high NUEs and, thus, seem to be not efficient. This is in accordance with ZHEN *et al.* (2006) who state that for the research are that "popularly and overly used N did not appear to be a significant factor affecting the yield".

However, as described in 4.3.5, besides fertilization, the main crops are also nourished through plant residues (i.e. straw) and manure. The scatter plot in Table 21 illustrates the relations between N input from fertilization and manure for the main crops of the surveyed households.

Figure 21. Relations of N Input from Fertilization and Manure for Main Crops of the Surveyed Households

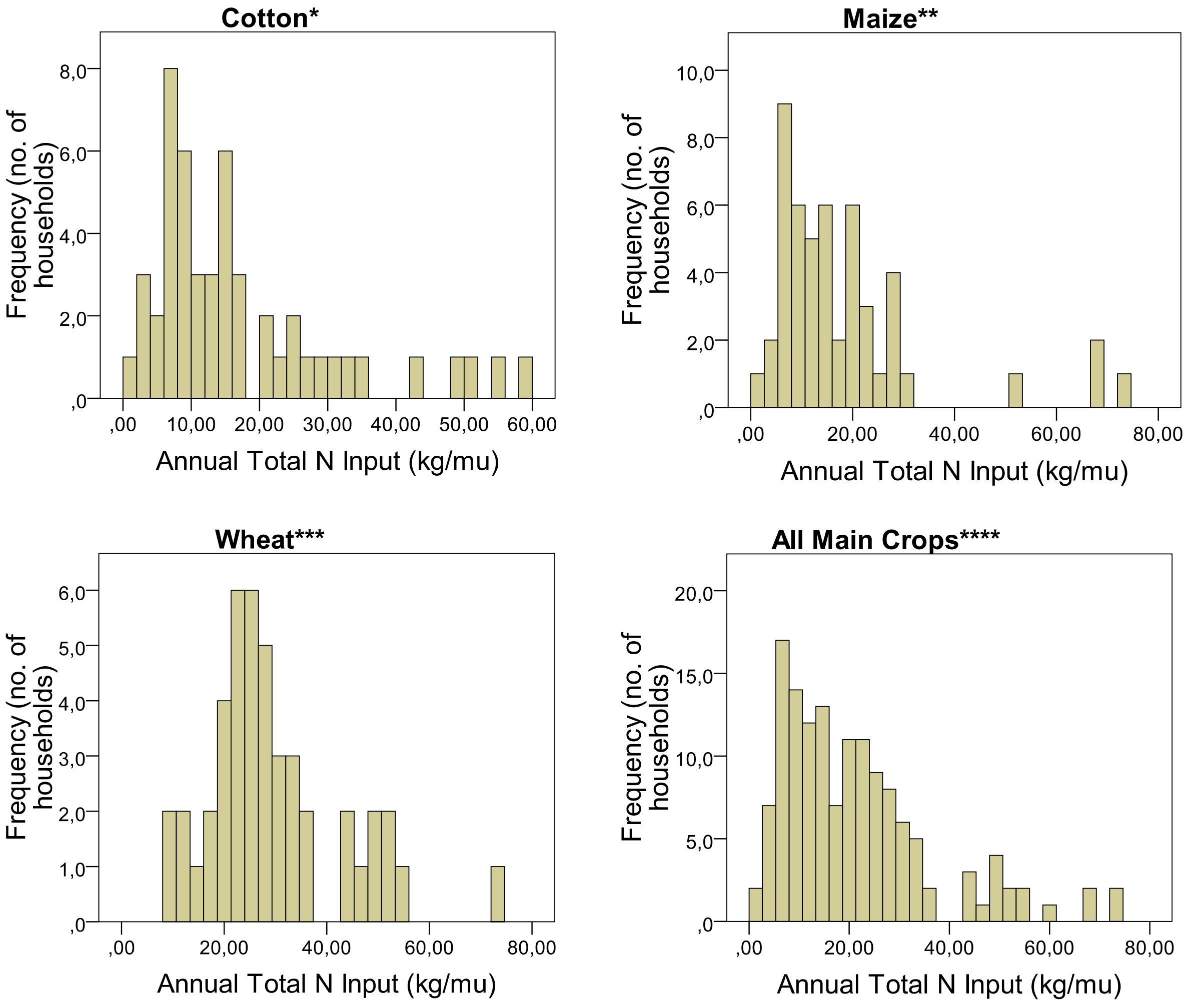


The scatter plots for the main crops of the surveyed households demonstrate that there are some households which apply manure even though they already apply high amounts of fertilization. This might represent a lack of methodological agricultural knowledge, indicate an excess application of nutrients and is one of the reasons for the high total N input levels for the main crops (see Figure 22). The total nutrient input (for N, P and K) is defined as:

Total Nutrient Input (kg/mu) = Nutrient Input Fertilization (kg/mu) + Nutrient Input Straw (kg/mu) + Nutrient Input Manure (kg/mu).

The histograms in Figure 22 illustrate total nutrient input of the main crops of the surveyed households.

Figure 22. Histograms of Total N Input for Main Crops of Surveyed Households



NOTE: *Standard Deviation: 14.15, Mean: 17.47, n=50

** Standard Deviation: 16.02, Mean: 18.41, n=50

*** Standard Deviation: 13.25, Mean: 29.25, n=45

**** Standard Deviation: 15.38, Mean: 21.19, n=141

Similar to the distribution of N input from fertilization, the total N input is strongly varying for all main crops. The mean total N input is the highest for wheat and the lowest for cotton. The combined mean N input for the SM-WW crop rotation is 47.70 kg N/mu. A study by JU *et al.* (2006) calculated the mean N input in the NCP for the SM-WW rotation with 40.12 kg N/mu, but this calculation did not include straw. Therefore, considering that straw makes up 26.77% of total N for maize and 32.23% for wheat (see Table 61), the mean total N input of the surveyed households might be comparable or even slightly below the findings from JU *et al.* (2006). The composition of total nutrient input is surveyed in Table 61. It should be noted that the calculations are based on a 100.00% return of straw; this might not always be realistic – consequently actual values might also be slightly lower.

Table 61. Mean Total Nutrient Input and Composition of Main Crops of Surveyed Households

	Cotton	Maize	Wheat
Mean Total Nutrient Input *(kg/mu)*:			
-N	17.47	18.41	29.25
-P	15.55	10.82	19.70
-K	12.43	15.03	26.58
Mean NUE *(kg/kg N)*	25.84	42.50	18.17
Mean Composition of N Sources *(% of Total N Input)*:			
-Fertilization	77.00%	60.01%	61.16%
-Manure	23.00%	13.22%	6.60%
-Straw	0.00%	26.77%	32.23%
Mean Composition of P Sources *(% of Total P Input)*:			
-Fertilization	74.50%	48.90%	74.47%
-Manure	25.50%	20.00%	11.28%
-Straw	0.00%	31.10%	13.99%
Mean Composition of K Sources *(% of Total K Input)*:			
-Fertilization	75.09%	24.69%	21.16%
-Manure	24.91%	10.44%	9.61%
-Straw	0.00%	64.87%	69.23%

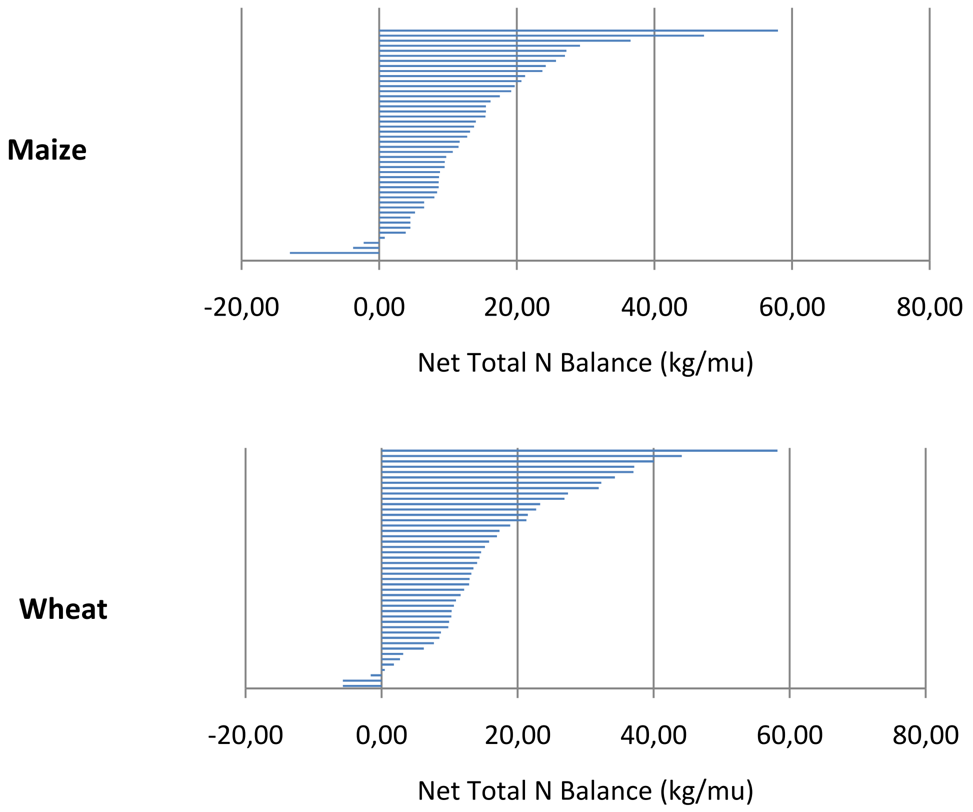
The composition of the mean nutrient input of maize and wheat is similar. For N and P fertilization represents the major source of nutrition. It is noteworthy that, for maize and wheat, straw is the main nutrient source of K. Straw is not applied in cotton production – therefore the nutrient composition is varying from other main crops. The mean total N input is higher than the over-fertilization baseline for cotton and for wheat – indicating an over-supply of N. The mean total N input for maize is below the baseline for over-fertilization. The NUE values of total N input for all main crops are lower compared to NUE of fertilization only; since straw return is common for maize and wheat production the difference between NUE values of total N input and N input from fertilization is larger. Considering that the mean price for 1 kg of N in manure is lower compared to fertilizers, the share of manure as a nutrient source is remarkably low.

Based on the specific nutrient uptakes for certain maize and wheat yields which were determined in a study by ZHANG *et al.* (2009) (see Table 74 and Table 76), total nutrient balances are analyzed. The total nutrient balance (for N, P and K) is calculated as:

Total Nutrient Balance (kg/mu) = Total Nutrient Input (kg/mu) – Nutrient Uptake (kg/mu).

The results of the N balance calculations are displayed in the nutrient management of maize and wheat are illustrated in Figure 23.

Figure 23. Net Total N Balances of Maize and Wheat of Surveyed Households



As illustrated in Figure 23 and as could be expected from the previous findings in this chapter, the net total N balance for wheat indicates a strong tendency for supplying more nutrients than the crops can absorb. Maize shows a similar tendency.

In addition, similar to the proceedings for the total N balances, the nutrient balances of maize and wheat are calculated for P and K – the results are displayed in Figure 24 (for P) and Figure 25 (for K).

Figure 24. **Net Total P Balances of Maize and Wheat of Surveyed Households**

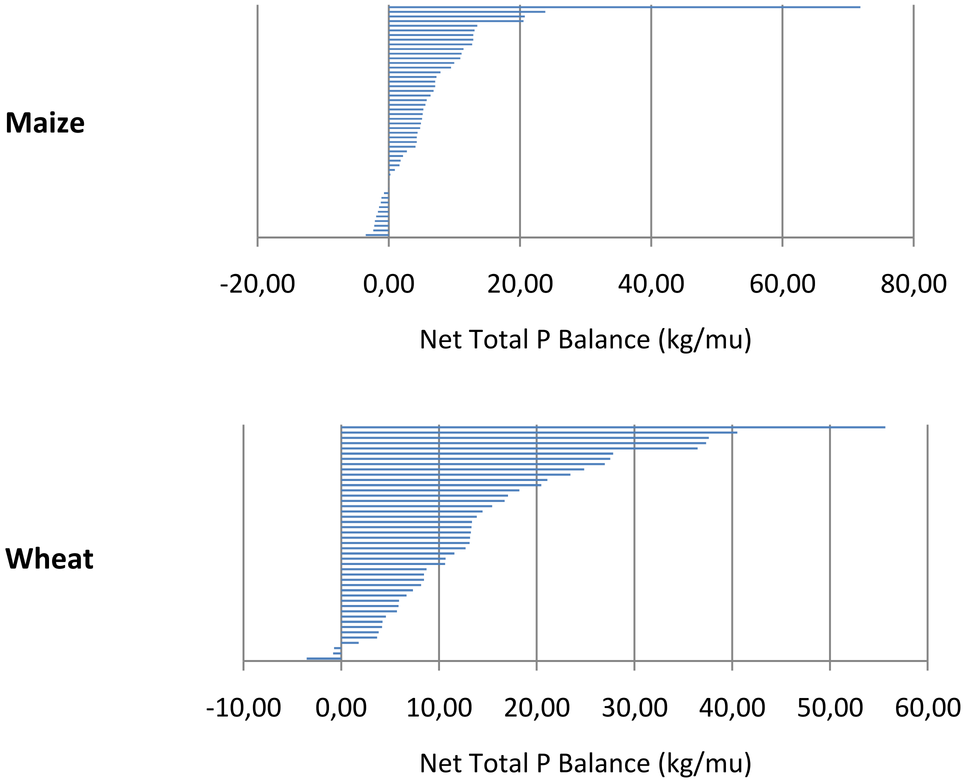
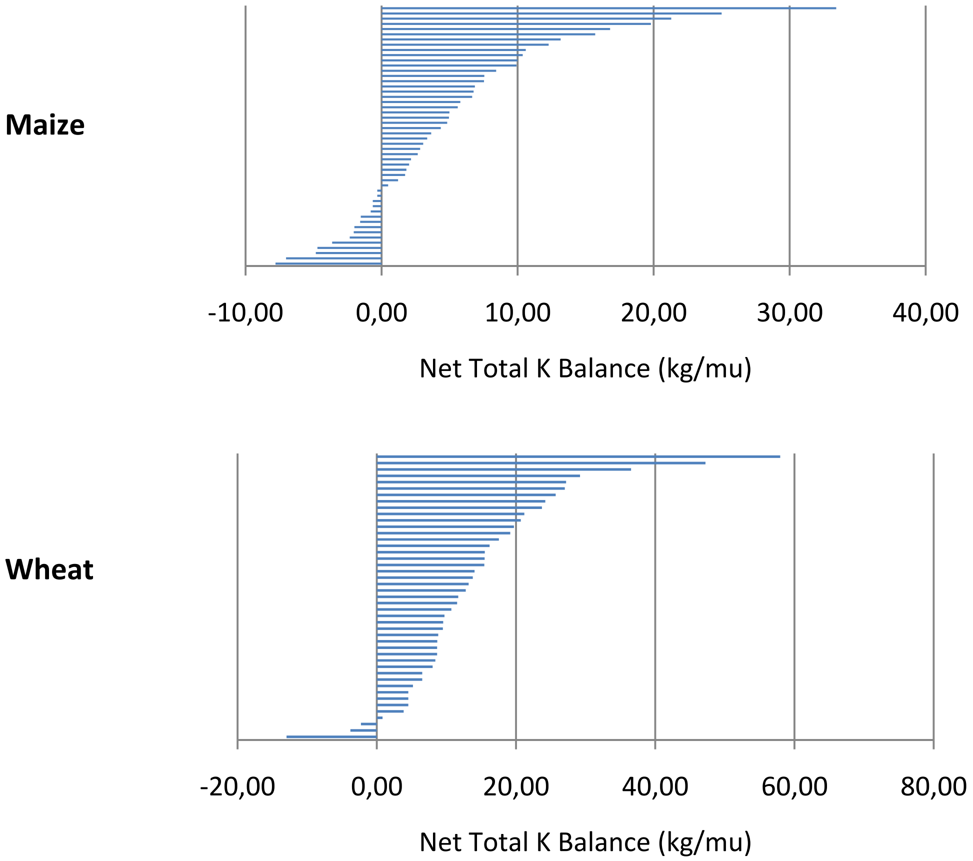


Figure 25. **Net Total K Balances of Maize and Wheat of Surveyed Households**



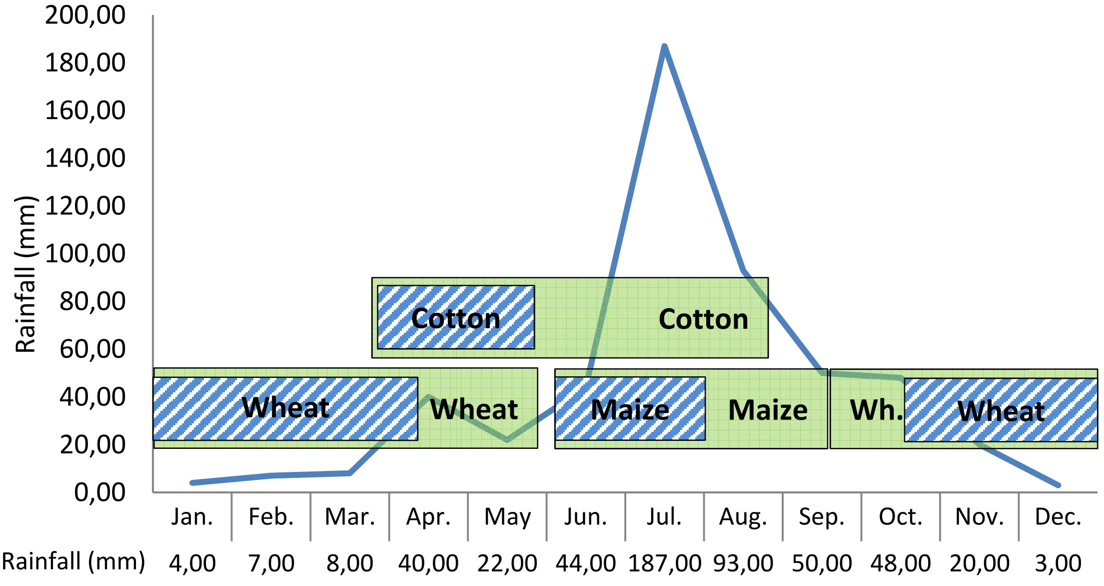
Similar to the net total N balance of wheat and maize, the net total balances for P and K show a strong tendency for over-supply. The net total K balance for maize shows some occurrences of under-supply. Even though the occurrences of undersupply of K are stronger compared to those of P, these findings are not fully supporting the conclusions of ZHEN *et al.* (2006) who state that organic manure and K are insufficiently applied, whereas N and P are over-supplied.

4.4.3. Water Management

As shown in Table 50 the mean machinery cost for irrigation – which represents an indirect volumetric water price – is ¥0.54 per m^3. This price is considerable lower than the marginal price of water estimated by the WORLDBANK (2007) for the NCP: ¥5.20 per m^3. Nevertheless, even the low indirect volumetric water price represents an important share of the mean expenses for the production of the main crops of the surveyed households (see Figure 33 to Figure 35). These findings should be kept in mind when discussing the possible effects of water pricing policies.

As described previously, predominant flood irrigation and concentrated rainfalls in summer combined with relatively dry winter months put pressure on the water resources in the NCP. Thus, Figure 26 illustrates the relations between rainfall and current cropping practices for the surveyed households.

Figure 26. Rainfall per month in Quzhou County and Mean Irrigation and Growing Periods of Main Crops of Surveyed Households*' **



NOTE: *calculated as mean value of answers

**Mean growing periods are colored green and mean irrigation periods are colored in blue diagonal lines

Source: FAO, 2006, modified

Figure 26 shows that the mean irrigation periods of wheat (October-April) and (partly) of cotton (March/April-May/June) of the surveyed households fall in the season with little rainfall – which puts additional pressure on the water resources in the NCP during the water scarce season. Maize is often irrigated by flood irrigation before planting; therefore the beginning of the mean irrigation period (June-July) is nearly congruent with the beginning of the maize growing season. Especially the mean growing season of wheat falls nearly completely into the water scarce season. The mean growing seasons of maize and cotton (partly) cover the summer months with strong rainfall.

By means of the computer program CROPWAT 8.0 (developed by the FAO 2000-2006[19]) the crop water requirements for the main crops, based on soil, climate and crop data, were calculated. The soil data were derived from the results of the respective soil samples in 4.4.1; climate data were provided by the CLIMWAT 2.0 computer program from a station in the survey area: Quzhou, Hebei Province (FAO, 2006) and crop data were derived from CROPWAT. The specific growing periods are based on the survey data for each household. That way for each household a specific analysis of the irrigation management could be performed, which resulted in individual results for potential water use for each main crop and effective rainfall during the growing season. Due to the lack of data, the default settings of the software[20] were used for the calculations, so actual crop requirements might slightly differ[21]. Table 62 presents a summary of the analysis of the water used of the main crops of the surveyed households, also based on the results of the CROPWAT 8.0 model.

Table 62. Analysis of Water Use for Main Crops of Surveyed Households

	Cotton	Maize	Wheat
Mean Growing Period	Mar./Apr.- Aug./Sep.	Jun.-Sep.	Sep./Oct.- May/Jun.
Share of Rainfall in Mean Growing Period *(% of total annual rainfall)**	78.90%	62.17%	37.83%
Mean Potential Water Use *(m^3/mu/year)***	428.37	240.79	321.85
Mean Effective Rainfall *(m^3/mu/year)***	246.79	178.48	84.40
Mean Required Irrigation *(Potential Crop Water Use – Effective Rainfall in m^3/mu/year)*	181.59	62.31	237.45
Mean Irrigation *(m^3/mu/year)*	153.56	192.52	243.13
Mean Water Input *(Eff. Rainfall + Irrigation in m^3/mu/year)*	400.34	371.00	327.53
Mean Net Water Balance *(Water Input – Potential Water Use in m^3/mu/year)*	-28.03	130.21	5.63
Mean Share of Rainfall in Total Water Uptake *(% of total water uptake)***	63.29%	53.35%	30.77%
Mean WUE *(kg product/m^3 water)*	0.69	1.47	1.53

NOTE: *based on data in Figure 26
** calculated with CROPWAT 8.0

WUE is calculated by dividing the respective yield (in kg/mu) with the total water input from irrigation and rain (in m^3/mu). Mean WUE of all main crops is 1.22 kg product per m^3 of

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[19] See FAO, 2010 for more information concerning the methodology of the CROPWAT 8.0 computer program.

[20] Settings: Rainfall according to USDA soil conservation service, irrigation at 100.00% critical depletion, refill soil moisture to 100.00% field capacity and irrigation efficiency: 70.00%

[21] Soil moisture content at field capacity at planting is assumed for all cases, thus actual crop requirements might be higher as the soil moisture content might be partially depleted.

applied water, which is lower than the average in developed countries (2.00 kg/m^3) – indicating inefficient water use. Table 63 demonstrates that the WUE values for maize and wheat of the surveyed households are comparable with other studies in the survey area.

Table 63. Summary of WUE Calculations for the NCP in other Studies in the NCP

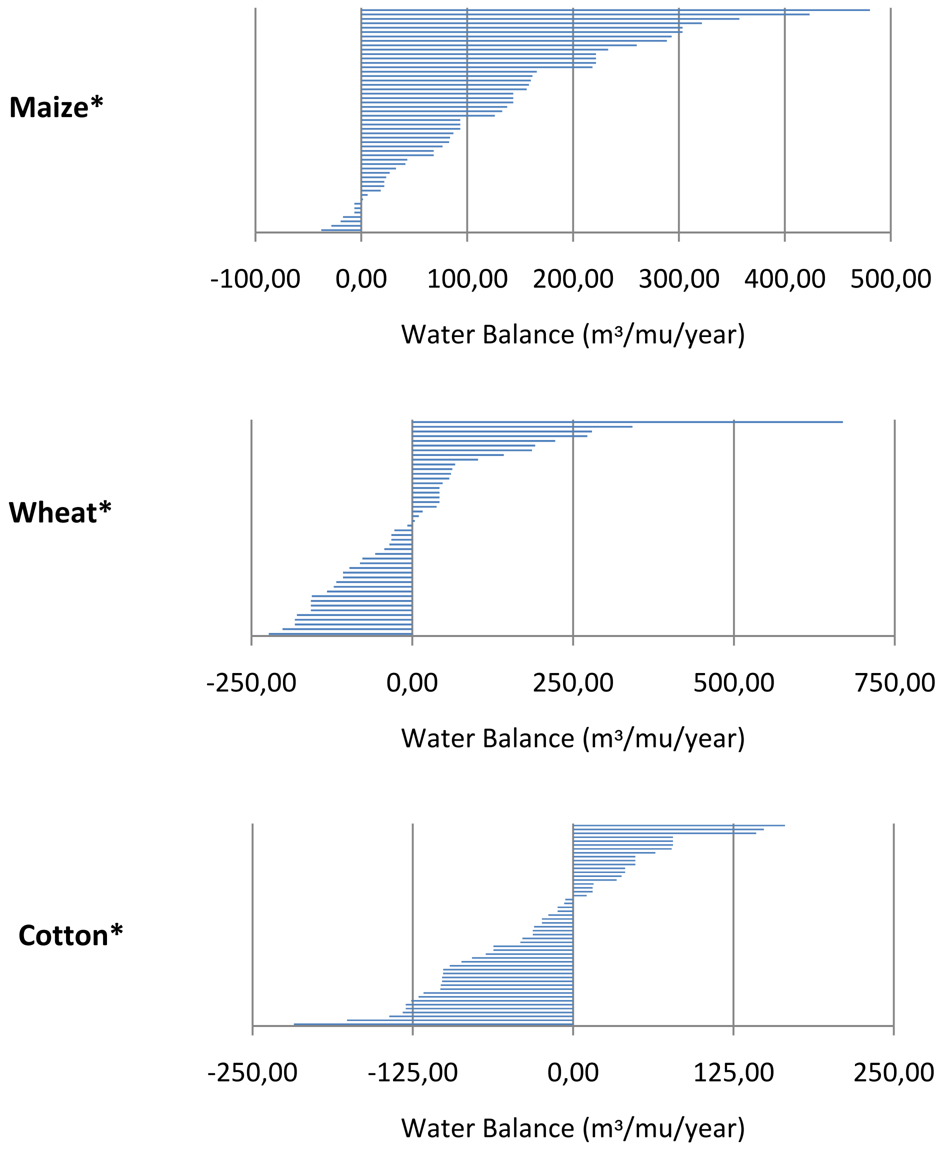
Study	Maize	Wheat
ZHU *et al.* (1994)	1.94	1.48
JIN *et al.* (1999)	2.06-2.34 (mulching and irrigation treatments)	1.49-2.30 (mulching and irrigation treatments)
McVICAR *et al.* (2002b)	0.17-3.90	0.12-2.15
LI *et al.* (2000)	1.26-2.31	0.65-1.21
ZHEN and ZOEBISCH (2006)	1.45	1.26
MO *et al.* (2005)	1.11-1.93 (irrigated) 0.5-1.10 (rain fed)	1.23-1.58 (irrigated) 0.05-0.83 (rain fed)

Source: MO *et al.* (2005), modified

Consequently the WUEs of the survey are in the same range with other studies in the research area, even though wheat has a tendency for lower WUEs than maize in other studies and the WUE of wheat in this study is slightly bigger than that of maize. Table 63 also demonstrated that the mulching can result in higher WUE for maize and wheat. Also for cotton ZHEN and ZOEBISCH (2006) estimated a comparable WUE: 0.69 kg/m^3. Another study in Hebei (YANG *et al.*, 2003) estimated total water use in Hebei for wheat with 180-250 m^3/mu and for maize with 140-200 m^3/mu – the results from this study are in the same range. Wheat has the lowest availability of water during its growing season and is consequently irrigated with the largest amounts of the main crops.

The mean net water balance for maize indicates water use which significantly exceeds the potential water use of the crop; the mean net water balances for cotton and wheat reveal frequent over- and undersupply; however it is noteworthy that the mean net water balance for cotton indicates a slight undersupply of water. Figure 27 illustrates the net water balances of the main crops of all surveyed households.

Figure 27. Net Water Balances of Main Crops of all Surveyed Households

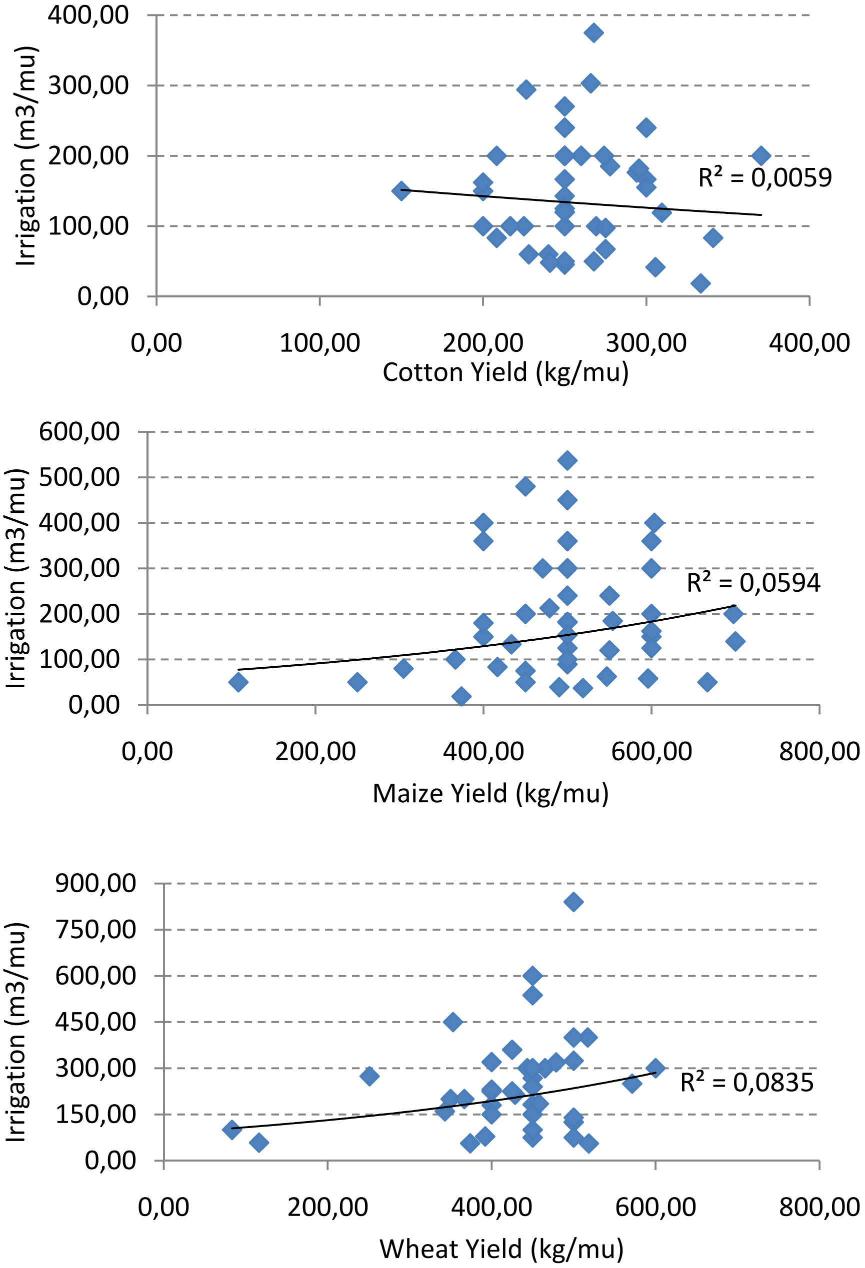


NOTE: *based on calculations with CROPWAT 8.0

The tendency towards overuse of water for the production of maize, the almost equal occurrence of overuse and undersupply of water for the production of wheat and the tendency towards under use of water for the production of cotton are displayed in Figure 27. This indicates, similar to fertilization, a strong variation and inadequate water use practices.

In order to survey the effects of water management on yields of the main crops, the scatter plots in Figure 28 survey the relations between irrigation and respective yields of the main crops.

Figure 28. **Scatter Plots of Yields of Main Crops of Surveyed Households and Irrigation**



The fitted exponential trend lines in Figure 28 show positive relations for maize and wheat yields and negative relations for cotton yields to total N input. However, all exponential trend lines have very low coefficient of determination (R^2) values, so the relation between the yields of the main crops and irrigation cannot be explained by these trend lines. These findings indicate that the yields of the surveyed households are not closely correlated with irrigation. For cotton and maize one explanation could be that 63.29% for cotton (and respectively 53.35% for maize) of mean total water uptake are stemming from rainfall (see Table 62); wheat has a considerable smaller share of rainfall in mean total water uptake (30.77%) and a slightly higher R^2 value.

4.4.4. Other

To reliably evaluate the practices regarding pest and weed control of the surveyed households is problematic and complex, as it depends on many specific factors like pest infestation, detailed information about growing stages or external influences which should be recorded during the complete growing season. These factors were not recorded during the survey, so according to expert's device a simple approximation method has been selected: the divergence from the mean pesticide expenses (per mu) per crop. The mean expenses for pesticides (liquid and solid) for the main crops are:

- Cotton: ¥240.34/mu;
- Maize: ¥43.61/mu;
- Wheat: ¥18.14/mu.

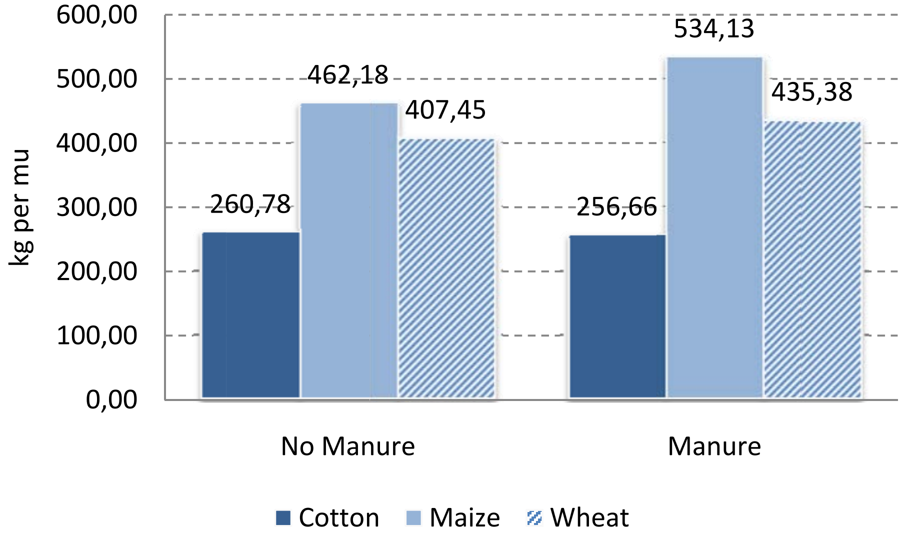
In this case the overuse of pesticides is defined as usage which exceeds the mean expenses by more than 50.00%, i.e. which is larger than ¥360.51/mu for cotton, ¥65.42/mu for maize and ¥27.21/mu for wheat. Based on this definition 18.00% of the cotton-, 14.00% of the maize- and 17.78% of the wheat-producing households are over-using pesticides. It should be noted that these numbers are only approximations and should be interpreted carefully.

In order to survey the environmental effects of pesticide use more thorough further research in the study area is needed. Besides pest infestation, weather conditions (i.e. wind or rain) can have considerable impacts on pollution when pesticides are applied – and data on these practices and whether they are considered by the farmers are lacking for NCP. Another sub-project of the IRTG research project is working on related topics.

Burning of crop residues after harvest represents a common practice which encompasses losses of nutrients (which are available free of costs) and organic matter in addition it represents a source of air pollution. Even though in the survey questions regarding burning of residues were – to a large extent – not answered, informal data confirms that the burning of residues is still wide-spread, although it is officially forbidden (LI *et al.*, 2005). However the quantification of these practices is not possible based on the data at hand.

In order to survey the effects of manure applications of the main crops of the surveyed households, their mean yields with or without manure application are compared in Figure 29.

Figure 29. **Comparison of Mean Yields of Main Crops with or without Manure Application of Surveyed Households**



As can be seen in Figure 29, the surveyed households which apply manure to maize and wheat tend to receive higher yields. The surveyed yield increase for maize lies at 17.52% and for wheat at 6.86%. No significant effect of manure application on cotton can be detected for cotton. It should be noted that other factors which are not controlled for in this comparison and might also have effects of on crop yields of maize and wheat of the surveyed households; therefore a quantification of these effects is would not be reliable, but the positive impact of manure on yields of maize and wheat remains noteworthy. Furthermore, as was shown in 4.4.1, the humus contents in the soils of the surveyed households are low and might limit soil fertility. So, the use of manure could also have positive effects on soil fertility.

4.4.5. Environmental Awareness

Besides education, methodological agricultural knowledge and information transfer, environmental awareness can play an important role for the implementation of agro-environmental policies. Table 64 displays the perception of the surveyed households towards changes in water quality.

Table 64. **Farmers' Perception towards Changes in Water Quality**

	Households
Changes in water quality *(no. of hhs and % of answers)*:	
-"Yes"	3 (4.69%)
-"No"	61 (95.31%)
If Change *(no. of hhs and % of answers)*:	
-"Improvement of quality"	3 (100.00%)
-"Deterioration of quality"	0 (0.00%)

As Table 64 displays, 95.31% of the farmers stated that there have been no changes in water quality. From those farmers that observed a change, unexpectedly all stated that the water quality improved. These answers clearly contradict other studies which described a deterioration of environmental conditions in the research area (see 2.4). Without the possibility to analyze water methodological it is difficult to assess the chemical quality of water reliably, therefore the improvement in water quality – seen in Table 64 – might rather relate to less debris and garbage in surface waters. The interviewed households have low levels of education. In addition, the interviewed farmers hardly had any contact with extension services or agricultural training. Consequently, these answers indicate a lack of environmental awareness of the surveyed households. This argumentation is similar to the reasoning in 4.1.5. However, it should be also noted that in total only 3 households stated that the water quality improved.

4.5. Economic Characteristics

This part focuses on the description of the economic characteristics of the surveyed households. It is divided into sections related to labor market and off-farm income, own consumption, marketing channels of main crops, economic characteristics of main crops and total household income.

4.5.1. Labor Market and Off-farm Income

None of the surveyed households employs permanent hired labor. Most of the work is carried out by household members. In some cases family members who are normally not living in the household might come for support during work peaks. In rare cases, some households employ laborers for a short period for specific tasks. However, as explained previously for the respective crop production processes, contractors who offer their labor in combination with machinery are commonly employed for certain production steps.

According to 4.1.2, a full-time worker is defined as a person who spends 6 days per week, 52 weeks a year, 8 hours per day working on farm (2496 hrs/year); a person who is "mostly working on the farm" spends ¾ of that time with farm-work (1872 hrs/year) and a "seasonal worker" spends ¼ of this time on the farm (624 hrs/year). This definition is also applied in the analysis in chapter 6. Based on this definition, the highest degree of farm work per household is displayed in Figure 30.

Figure 30. Highest Degree of Farm Work per Household (in % of Surveyed Households)

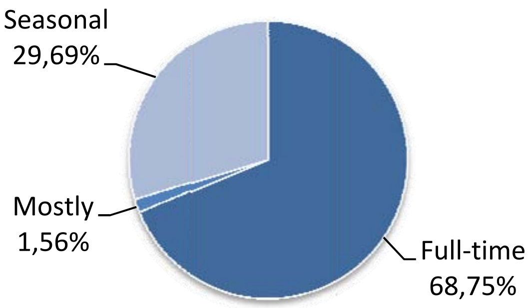


Figure 30 can be interpreted that in 31.25% of the surveyed households do not anymore have a member who is working full-time on the farm – this is a further indicator for the increasing importance of off-farm work. The mean available farm labor time of surveyed households is 4,962.75 hours per year (ranging from 1,248.00 to 12,480.00 hours per year). It should be noted that the mean available farm time is calculated based on the survey data and considers other activities like off-farm work or other businesses. The mean required farm work time (from all farming activities) for the surveyed households is 1,604.76 hours per year. This results in a theoretical mean labor excess of 3,357.99 hours per year for the surveyed households. This figure indicates that farm labor is evidently abundant in the research area. The share of the working steps of the mean available farm labor time is not displayed, as the individual farms vary strongly in this regard.

As outlined in 4.1.2, off-farm work is increasingly important for the surveyed households. Therefore the relations between the share off-farm work (in % of total household labor) and total net household income (in ¥ per year) of the surveyed households are analyzed in Figure 31.

Figure 31. Correlations between Share of Off-farm Labor and Total Net Household Income of Surveyed Households

		OffFarm	HHIncome
Off-Farm	Pearson Correlation	1	.319*
	Sig (2-tailed)		.010
	N	64	64
HHIncome	Pearson Correlation	.319*	1
	Sig (2-tailed)	.010	
	N	64	64

* Correlation is significant at the 0.05 level (2-tailed).

As can be seen in Figure 31, there seems to be a low positive significant correlation between the share of off-farm income and total net household income; i.e. the total net household income appears to rise with increasing shares of off-farm work of the surveyed household. These results are in accordance with the described tendency (2.1) that large parts of the agricultural population are moving into the industrial or service sector, in which the potential earnings are higher, as the surveyed households seem to have higher incomes the more off-farm income they generate.

In order to test whether off-farm labor has an effect on the crop productivity of the surveyed households, the correlations between the yields of the main crops and the share of off-farm labor (in % of total household labor) are calculated (see Figure 32).

Figure 32. Correlations between Share of Off-farm Labor and Yields of Main Crops of Surveyed Households

		Off-	Maize
Off-Farm	Pearson	1	.124
	Sig (2-tailed)		.391
	N	64	50
Maize	Pearson	.124	1
	Sig (2-tailed)	.391	
	N	50	50

		OffFarm	Wheat
Off-Farm	Pearson Correlation	1	-.010
	Sig (2-tailed)		.946
	N	64	45
Wheat	Pearson Correlation	-.010	1
	Sig (2-tailed)	.946	
	N	45	45

		OffFarm	Cotton
Off-Farm	Pearson Correlation	1	.147
	Sig (2-tailed)		.309
	N	64	50
Cotton	Pearson Correlation	.147	1
	Sig (2-tailed)	.309	
	N	50	50

* Correlation is significant at the 0.05 level (2-tailed).

Figure 32 shows that for the surveyed households there seems to be no relationship between the yields of the main crops and the share of off-farm income, as the correlation values are quite low. Furthermore the 2-tailed significance values of all main crops are rather high – especially for wheat – which also indicates that there is no relation between the respective yields and the share of off-farm income of the surveyed households.

4.5.2. Own Consumption

A lot of the surveyed households are (partially) consuming their agricultural products as food or feed. Many households perform basic or primitive forms of intercropping of vegetables and fruits within the production of main crops. A quantification of these practices is difficult, as the households produce these vegetables solely for own consumption purposes and, thus, often stated in the survey that they do not pay much attention to these crops and also do not pursue specific production strategies in order to improve their performance. Therefore (Table 65) is focusing on the own consumption and use of the main crops of the surveyed households.

Table 65. Characteristics of Own Consumption and Use of Main Crops of Surveyed Households

	Cotton	Maize	Wheat
Mean Own Consumption *(kg per hh)*	4.70	122.75	736.93
Mean Fodder Use *(kg per hh)*	0.00	315.90	30.68
Share of Total Harvest used for Own Consumption *(%)**	0.38%	9.72%	59.72
Share of Total Harvest used for Fodder *(%)**	0.00%	13.89%	1.43%
Share of Total Harvest used for Own Consumption and Fodder *(%)**	0.38%	23.60%	61.15%

NOTE: *of households producing respective crop

As can be seen in Table 65, on average 61.15% of the wheat harvested by the surveyed households is used in the households for food or feed; most of which is consumed as food. Also, nearly one quarter of the maize produced by the surveyed households is consumed within the household and its operations; where it is mostly used as feed. Cotton, as a typical cash crop, is naturally not consumed within the households on a large scale. In addition to the main crops, also major amounts of sweet potatoes (on average 71.43% of total harvest), peanuts (on average 60.67% of total harvest) and vegetables (on average 56.11% of total harvest) are directly consumed within the surveyed households; sweet potatoes, peanuts and vegetables are not used as fodder in the surveyed households. As stated above, the real amount of own consumption of these crops will be higher than indicated by these numbers, as the quantification of the production solely for own consumption is difficult. However, already these numbers emphasize the importance of own production as a nutritional source for the surveyed households. This should be kept in mind when considering issues regarding food security in China.

4.5.3. Marketing Channels of Main Crops

None of the surveyed households has a fixed marketing contract for selling their products. This indicates that after harvest the surveyed households have to find buyers for their produce – which decreases the households' planning reliability and represents transaction costs. The mean sale prices (mostly at farm gate) of the main crops of the surveyed households are: ¥5.34/kg cotton, ¥1.46/kg maize and ¥1.55/kg wheat. Table 66 presents the typical marketing channels of the main crops of the surveyed households.

Table 66. Marketing Channels and Mean Transport Costs of Main Crops of Surveyed Households

	Cotton	Maize	Wheat
Marketing Channel *(no. and % of answers)**			
-Hh transports to Village	1 (2.08%)	0 (0.00%)	0 (0.00)
-Hh transports to Buyer	2 (4.16%)	1 (2.63%)	2 (7.69%)
-Buyer picks up at Hh	45 (93.75%)	33 (86.84%)	24 (92.31%)
-Hh sells to Livestock Farm/Processor	0 (0.00%)	4 (10.53%)	0 (0.00%)
Mean Transport Costs *(¥/mu)***	¥0.01	¥0.01	¥0.06

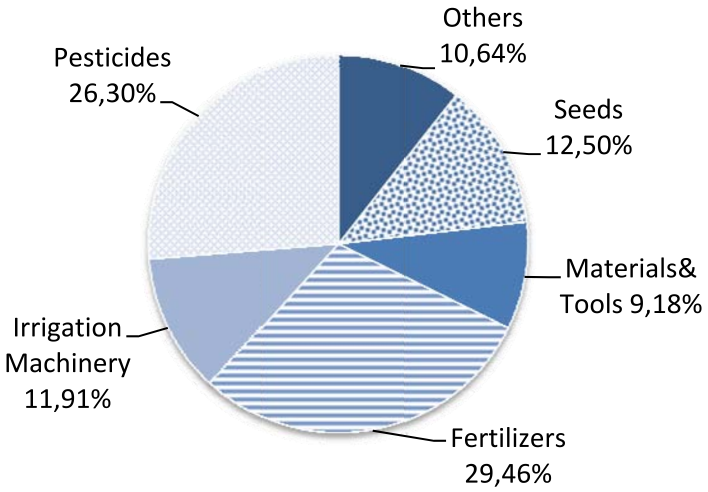
NOTE: *not all households answered
**of all households producing respective crop

The transport costs for the main crops of the surveyed households are relatively low, because most the households sell at the farm gate (i.e. the buyer picks up the produce at the farm gate) and consequently have no transport costs.

4.5.4. Economic Characteristics of Main Crops

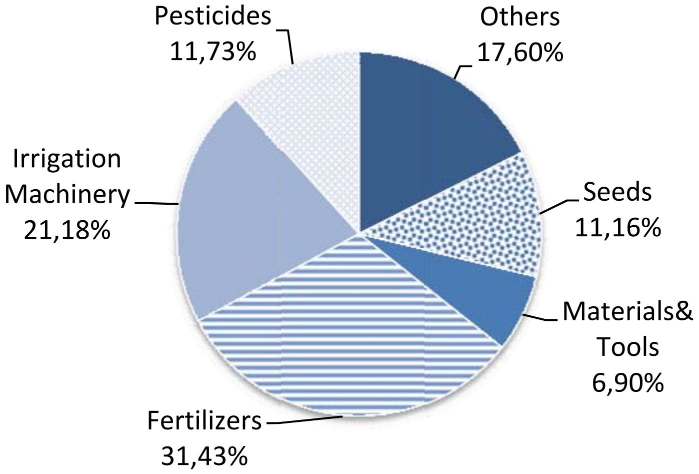
In order to survey the economic characteristics of the main crops of the surveyed households, the following Figures display the mean distribution of expenses for the production of the respective crops.

Figure 33. Mean Distribution of Expenses for the Production of Cotton of Surveyed Households (% of total mean expenses/area)



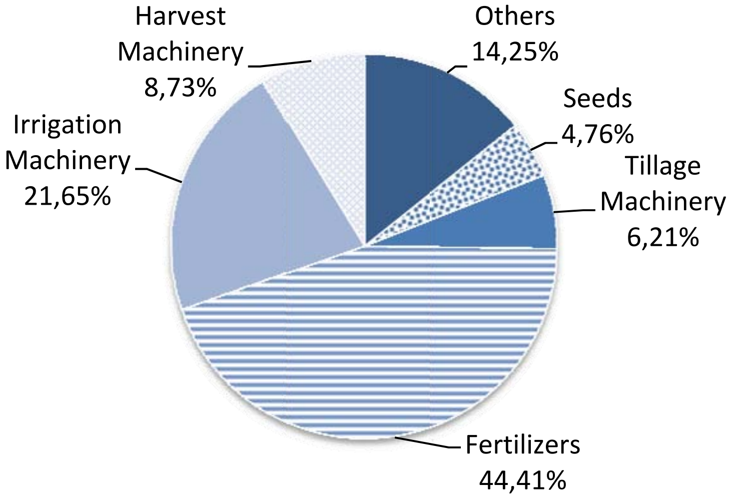
As can be seen in Figure 33, chemical inputs (fertilizers and pesticides) are the biggest expense factors for the production of cotton. Furthermore running/machinery costs for irrigation, seeds and materials&tools (i.e. plastic covers for mulching) make up the main production expenses for cotton.

Figure 34. Mean Distribution of Expenses for the Production of Maize of Surveyed Households (% of total mean expenses/area)



When reviewing Figure 33 and Figure 34 it can be concluded that the 5 main expense factors for production of cotton and maize are the same, however their extent varies strongly. Maize and cotton have very low shares of seeds which are collected from the fields (compare Table 29), which is why their expense share for seeds is higher compared to wheat (see Figure 35).

Figure 35. Mean Distribution of Expenses for the Production of Wheat of Surveyed Households (% of total mean expenses/area)



As described in the previous parts, contractors are commonly hired for tilling and harvest of wheat in the research area, which is why – for the only one of the main crops – tillage and harvest machinery costs are among the main cost factors for wheat production. Therefore wheat has the highest share of (combined) machinery costs. It is noteworthy that nearly half of the mean expenses for the production of wheat arise from fertilizers. It is notable that indirect water prices (i.e. through costs related to pumping water, see: 4.3.7) are within the main production cost factors for all main crops.

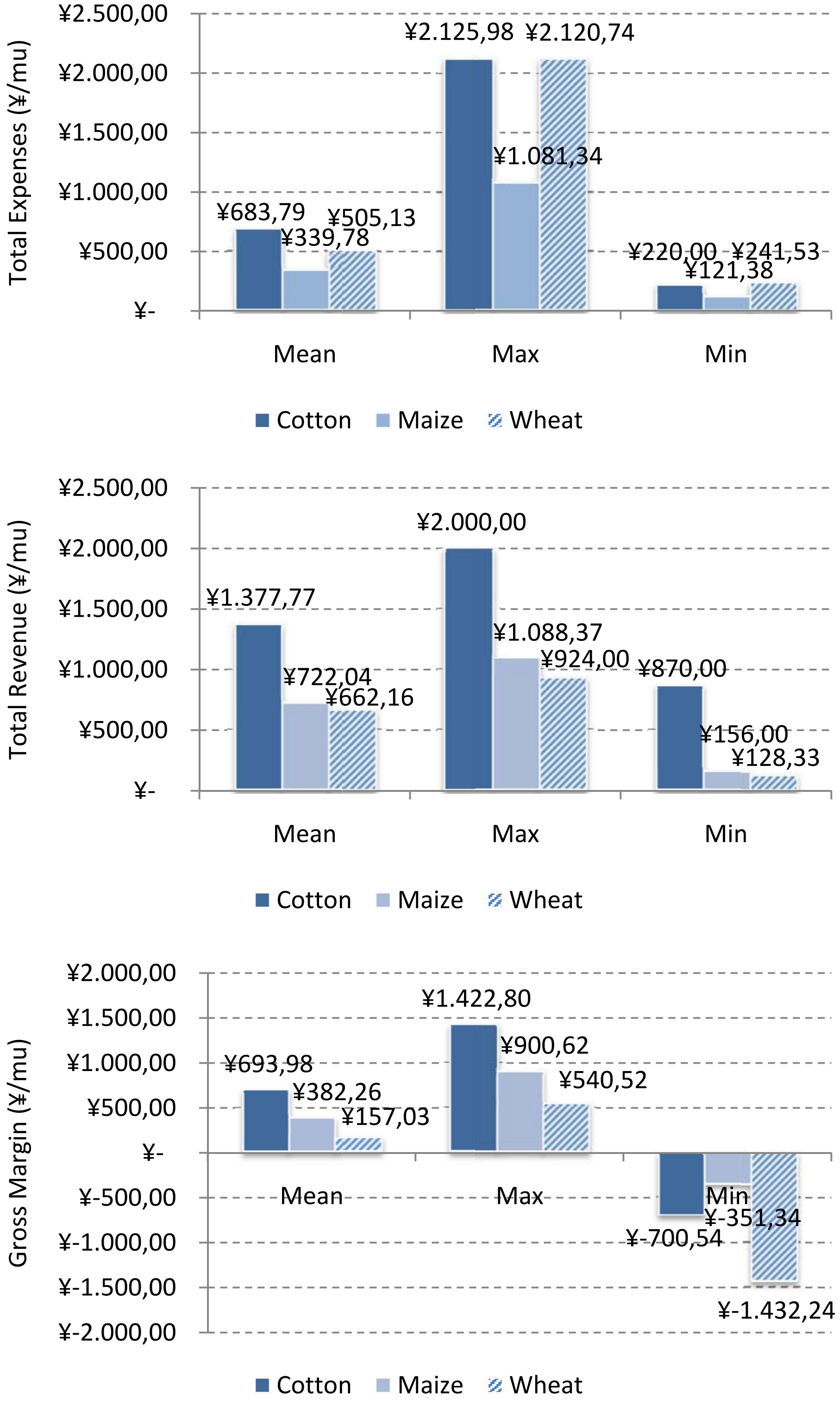
Previously the production steps were regarded separately; therefore – in order to characterize each production step – mean costs were calculated considering only those households which are carrying out the respective production step. Now, in order to represent and compare the mean expenses of all surveyed households, also those households which are not applying the respective production step are included in the calculation, thus the mean expenses of certain production steps in Table 67 can be lower than indicated in the previous chapters. It also should be noted that own consumption of farm products is economically not considered in these calculations, it is assumed that the complete harvest is sold at market prices. This is reasonable, as the farmers are aware of the opportunity costs of own consumption (amounting to foregone earnings from sales) and decide to consume instead of selling. This choice incorporates the potential to sell the whole harvest and acquire foodstuff through other channels (which would also create costs). Table 67 presents the mean gross margins of the main crops.

Table 67. Mean Gross Margins of Main Crops of the Surveyed Households

	Cotton	Maize	Wheat
Mean Expenses of Production Steps *(¥/mu/year and % of mean expenses per crop of all hhs)*:			
-Land Rent	¥14.89(1.66%)	¥4.00(1.06%)	¥4.44(0.63%)
-Materials&Tools	¥50.04(9.18%)	¥19.30(6.90%)	¥16.60(4.26%)
-Tillage (Machinery)	¥20.20(3.86%)	¥3.40(0.92%)	¥24.55(6.21%)
-Planting (Machinery)	¥7.35(1.43%)	¥9.09(3.25%)	¥9.89(2.37%)
-Seeds	¥74.98(12.50%)	¥32.03(11.16%)	¥21.19(4.76%)
-Manure	¥21.09(3.32%)	¥12.56(4.03%)	¥13.29(2.95%)
-Fertilizers	¥183.60(29.46%)	¥121.17(31.43%)	¥260.45(44.41%)
-Fertilization (Machinery)	¥0.60(0.09%)	¥3.38(1.29%)	¥1.12(0.33%)
-Pesticides	¥240.34(26.30%)	¥43.61(11.73%)	¥18.14(3.70%)
-Pesticide Appl. (Machinery)	¥1.40(0.26%)	¥0.00(0.00%)	¥0.00(0.00%)
-Irrigation (Machinery)	¥69.10(11.19%)	¥70.98(21.18%)	¥99.00(21.65%)
-Harvest (Labor)	¥0.18(0.01%)	¥0.00(0.00%)	¥0.00(0.00%)
-Harvest (Machinery)	¥0.00(0.00%)	¥0.40(0.12%)	¥36.39(8.73%)
-Postharvest (Labor)	¥0.00(0.00%)	¥0.71(0.22%)	¥0.00(0.00%)
-Postharvest (Machinery)	¥0.00(0.00%)	¥19.14(6.71%)	¥0.00(0.00%)
-Transport	¥0.01(0.01%)	¥0.06(0.01%)	¥0.01(0.01%)
TOTAL	**¥683.79**	**¥339.78**	**¥505.13**
Mean Income *(¥/mu/year and % of mean revenues per crop of all hhs)*:			
-Direct Crop Subsidies	¥0.71(0.05%)	¥0.50(0.07%)	¥2.78(0.42%)
-Crop Sales	¥1,377.05(99.95%)	¥721.54(99.93%)	¥655.38(99.58%)
TOTAL	**¥1,377.77**	**¥722.04**	**¥662.16**
Mean Gross Margin *(¥/mu/year)*	**¥693.98**	**¥382.25**	**¥157.03**

“Machinery” refers to running costs of own machinery or rental costs for machines which are provided by contractors. As can be seen in Table 67, the surveyed households do not pay direct water prices – they only pay indirectly through the machinery usage for irrigation. As shown before, cotton has the highest share of pesticide costs of all main crops. It is also notable that subsidies only make up a small share of the mean income of the main crops – such a low share makes the existence and effectiveness of direct crop subsidies questionable. For illustration, the mean, maximum and minimum expenses, revenues and gross margins are graphically displayed in Figure 36.

Figure 36. Expenses, Revenues and Gross Margins of Main Crops of Surveyed Households, 2007



The mean gross margin of wheat is the lowest of the main crops of the surveyed households. This indicates the importance of wheat as a subsistence crop (see Table 65), it is mostly grown for own consumption, not considering its economic efficiency.

The mean expenses for cotton are the highest. However, also the mean revenues are the highest for cotton. These high investment needs might indicate a risk for farmers, as they could be reluctant to invest large amounts into one crop – but this characteristic is typical for cash crops like cotton. With the lowest mean expenses, maize generates high revenues and consequently high mean gross margins, thus the financial risk for maize seems to be low compared to the other main crops.

When comparing the gross margins of cotton with wheat and maize it should be kept in mind that commonly maize and wheat are grown within the SM-WW double crop rotation, i.e. cotton should normally be compared to the sum of maize and wheat. Consequently, the combined mean gross margin of maize and wheat (as grown in the double crop rotation) is ¥539.29 per mu. However, the mean gross margin for cotton (¥693.98 per mu) is still higher than that of the double crop rotation.

4.5.5. Total Household Income

The total net household income of the surveyed households is generated by many factors. The net incomes of the individual households vary strongly; in 2007 the household with the highest net income generated ¥152,388.48 and the household with the lowest net income had a deficit of ¥-51,763.80. The negative net income can be explained with large investments in the respective year. Table 68 presents the mean total annual net household income of the surveyed households for 2007.

Table 68. Mean Total Annual Net Household Income of Surveyed Households, 2007

	Mean *(¥/hh/year)*	**Mean Share** *(% of total mean revenue and costs)*
Net Revenues:		
-Main Crops	¥4,657.99	24.60%
-Other Crops	¥432.62	2.28%
-Livestock	¥3,794.36	20.04%
-Support from hh Members	¥1,165.63	6.15%
-Land Rent	¥124.22	0.66%
-Other Enterprise	¥2,324.22	12.27%
-Subsidies	¥345.91	1.83%
-Off-farm	¥5,441.41	28.73%
-Pensions	¥651.56	3.44%
TOTAL	**¥18,937.92**	**-**
Expenses:		
-Running of Machinery	¥961.70	12.67%
-Tools	¥115.47	1.52%
-Support to hh Members	¥897.34	11.83%
-Education	¥1,338.28	17.64%
-Medical	¥691.48	9.11%
-Marriages and Funerals	¥1,087.50	14.33%
-Transport and Communication	¥560.47	7.39%
-Food	¥1,935.31	25.52%
TOTAL	**¥7,587.56**	**-**
TOTAL Net Income	**¥11,350.36**	**-**

In this calculation machinery running costs (of own machinery) and costs for tools are considered general variable costs which are not assigned to a specific step of production or crop. It is noteworthy that, for the surveyed households, the mean net revenue from off-farm income is larger than the combined income from crop production (main crops and other crops). As indicated in 4.2.3, livestock production generally does not play an important role for the surveyed households; the high mean net revenue is stemming from a few households with large numbers of poultry. The largest factor of expenses for the surveyed households is food. Similar to the direct crops subsidies (see Table 67), the area subsidies do not have a strong influence on the mean revenues of the surveyed households (1.83%). This indicates that the agricultural policy reforms (see 2.1) did not yet have a strong impact, except that all surveyed households did not pay agricultural taxes anymore. It should be noted that off-farm income represents the largest item in the composition of mean net household revenue. However, the combined revenue from farming activities (main crops, other crops and livestock) makes up 46.92% of mean net household revenue and is, thus, only slightly bigger than the combined revenue from off-farm income, support from family members and other enterprises which makes up 46.15%. It should be noted that education represents the second biggest expense factor for the surveyed households (17.64%). Considering that the item “support to household members” also often constitutes of education-related expenses (i.e. for family members who study away from home), it can be assumed that education – along with food – make up the major factors of expenses of the surveyed households. Considering the current low level of education of the surveyed households this trend might improve the educational situation of the surveyed households. The mean net per capita income of the surveyed households[22] is ¥2,741.63; which is considerably lower than the net per capita income of the Hebei Province in 2007: ¥4,293.43 (NBS, 2008). This difference can be explained by different definitions of “household members” in the official data and in this study (see 4.1.1).

20 of the surveyed households have no off-farm income and no revenue from another own enterprises – so agriculture represents their main income source. Table 69 compares the income of this group with the households which have off-farm and/or income from other enterprises.

Table 69. Comparison of Mean Household Income of Different Types of Surveyed Households

	Households with No Off-farm Income and No Revenue from Other Enterprises	**Households with Off-farm and/or Revenue from Other Enterprises**
Mean Net hh Income *(¥/year)*	¥7,484.94	¥13,119.61

Table 69 shows that the mean net income of the surveyed households with no off-farm income and no revenue from other enterprises is notably lower than that of the households with a more diversified income composition. This finding represents another indicator for the importance of non-agricultural income sources for the surveyed households and is in accordance with the result of Figure 31.

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[22] Mean net hh income/mean hh size

5. Methodology of Farm Modeling

This chapter describes the methodologies which will be applied for the analysis in this work. The first part describes the methodology and its selection process. First the reasons for selecting linear programming as analysis method are outlined. The second part explains the selection process for the integrated households. The last part describes the processes of environmental assessment by means of selected indicators.

5.1.Selection of Methodology

The problem at hand will be analyzed by a planning tool. DABBERT and BRAUN (2009) define planning as “formative thinking for the future. It is the attempt to create a simplified picture of the reality and of the consequences of different procedures in order to make decisions[23]”. The main elements of planning are: goals, strategic options and resources. Figure 37 illustrates the steps of planning and the corresponding parts of this work.

Figure 37. Steps of Planning and Related Parts of this Work

Steps of Planning	Task	Related Parts of this Work
Real Problem		Part 2
↓	←Abstraction	
Mathematical Model		Part 5.2
↓	←Algorithm (Calculation)	
Model Solution		Part 6
↓	←Interpretation of Solution	
Proposal of Solution		Part 8

Source: LIPPERT *et al.* (2009), modified

This work will follow the structure of Figure 37 for the analysis. Table 70 presents an overview of common planning methods; divided into simple planning methods and planning models.

Table 70. Planning Methods

Basic Planning Methods	-Estimate of cost calculation -Bar planning technique -Net planning technique
Planning Models	-Comparison of operations -Linear programming -Program planning -Heuristic planning models -Simulation

Source: DOLUSCHITZ (1997), translated

From the available planning methods linear programming (LP) has been selected for this work – as it is a common planning tool. LP determines the most efficient outcome of a given model by means of optimization. For agricultural operations “Linear programming (LP) is a mathematical procedure that uses a systematic technique to find the “best” (e.g. most

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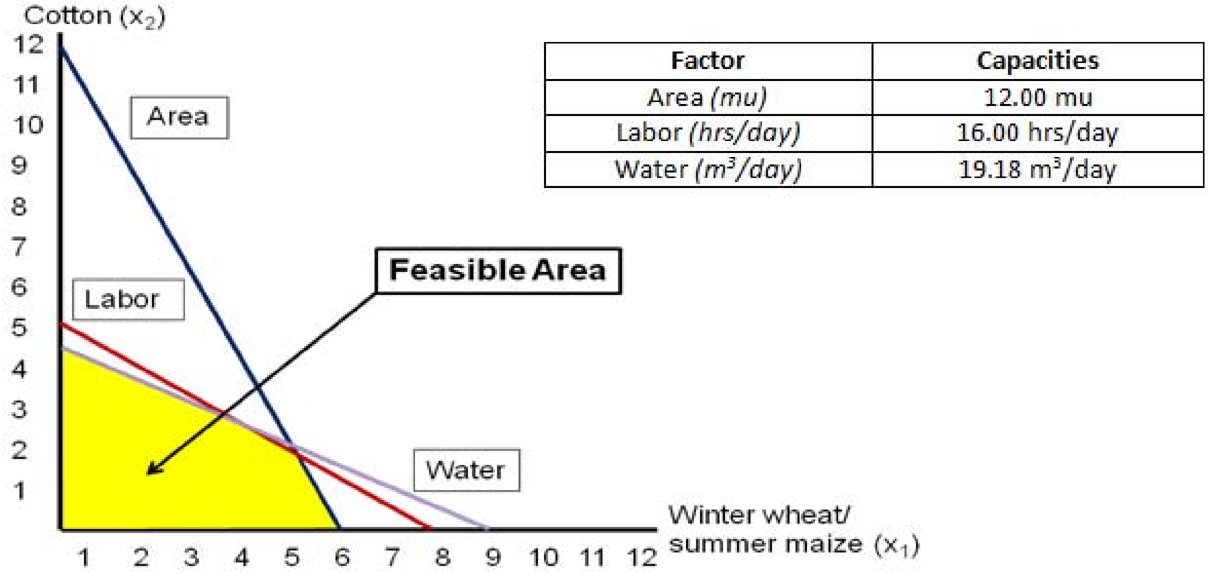
[23] Translated from the original German text: Planen ist gestaltendes Denken für die Zukunft. Es ist der Versuch, sich ein vereinfachtes Bild von der Realität und den Konsequenzen unterschiedlicher Handlungsweisen zu verschaffen, um auf dieser Grundlage Entscheidungen zu treffen.

profitable) possible combination" (KAY *et al.*, 2008); in agriculture these combinations typically can represent input mixes or production options. The combinations form the model, i.e. the linear objective function. "The concept of optimization is now well rooted as a principle underlying the analysis of many complex decision or allocation problems" (LUENBERGER and YE, 2008). Therefore LP fits best to the requirements of this analysis. An essential characteristic of economic models is the ceteris-paribus-condition, which states that only one factor is varied, while all factors others remain constant (DABBERT and BRAUN, 2009). The linear objective function can be defined by economic parameters (e.g. income, cost or gross margin) or other parameters (e.g. N-excess, labor input or distance). The linear objective function is optimized (i.e. maximized or minimized) to achieve the most efficient outcome. The optimization process is subject to linear equality and linear constraints. These constraints shape the borders of the model – they are defined by the capacities of the respective enterprise and the requirements of the optimization options; they are expressed in inequations (e.g. according to the example in Figure 38: area = $2x_1+1x_2\leq12$). The constraints, capacities and requirements form the feasible area for the combinations of given optimization options. Figure 38 demonstrates the determination of the feasible area (i.e. all realizable solutions considering the given constraints) for an exemplary farm for the optimization options x_1 summer maize-winter wheat (with the following requirements: area= 2.00 mu, labor= 2.00 hrs/day and water= 2.00 m^3/day) and x_2 cotton (with the following requirements: area: 1.00 mu, labor: 3.00 hrs/day and water: 4.00 m^3/day).

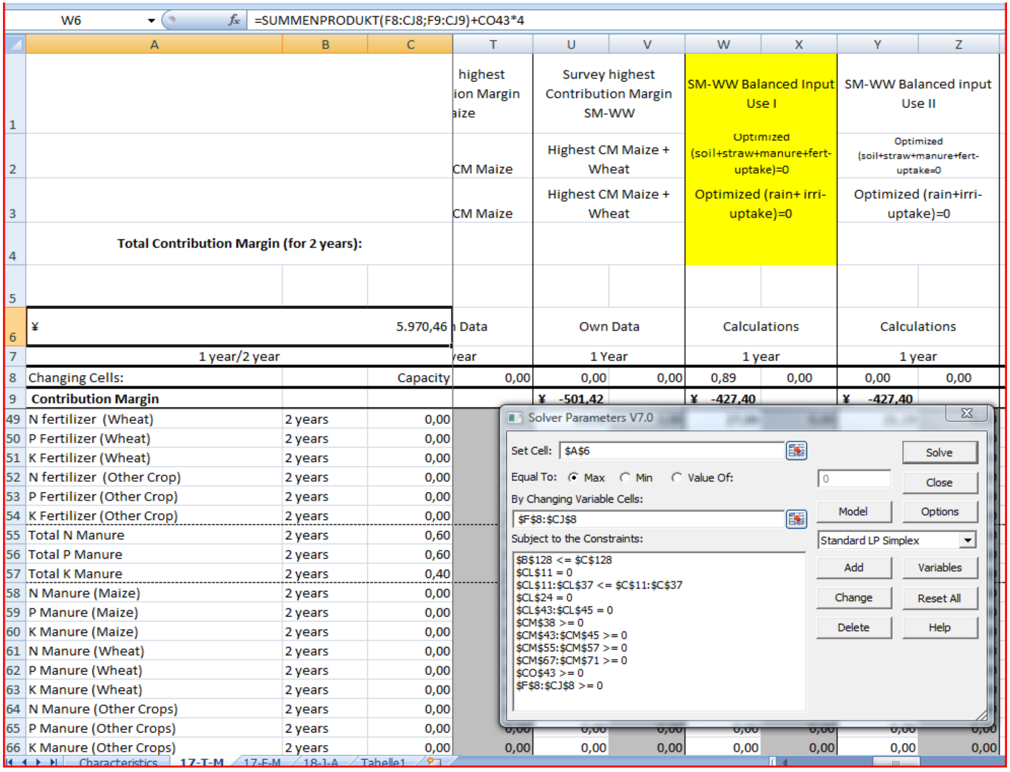
Figure 38. Graphical Demonstration of Determination of the Feasible Area of an Exemplary Farm



Factor	Capacities
Area *(mu)*	12.00 mu
Labor *(hrs/day)*	16.00 hrs/day
Water *(m^3/day)*	19.18 m^3/day

The feasible area in Figure 38 represents all possible combinations of optimization options under given constraints. Consequently the most efficient option has to be selected from these possible combinations. In order to determine the most efficient option, the simplex method has been selected for this work; it is based in the idea that the optimal solution always lies on the vertex of the feasible area. "The simplex method operates by first identifying any basic feasible solution (or extreme point) for an LP problem, and then moving to an adjacent extreme point, if such a move improves the value of the objective function. When no adjacent extreme point has a better objective function value, the current extreme point is optimal and the simplex method terminates" (RAGSDALE, 2008). Computerized it operates with an algorithm which introduces slack variables (which represent not-used capacities) to transform the inequations into equations (e.g. according to the example in Figure 38: area = $2x_1+1x_2 \leq 12$ will transformed into $2x_1 + 1x_2 + 1x_3 = 12$; x_3 = slack variable). The operational cycle of the algorithm will test for optimality until the optimal solution has been determined; for this work a MS EXCEL-based macro called Premium Solver for Education, Version 7.0[24] has been applied. Figure 39 displays a screenshot of the Solver application during the simulation processes of this work.

Figure 39. Screenshot from Solver for Education (Version 7.0) Application



W6 =SUMMENPRODUKT(F8:CJ8;F9:CJ9)+CO43*4

	A	B	C	T	U	V	W	X	Y	Z
1				highest ion Margin aize	Survey highest Contribution Margin SM-WW		SM-WW Balanced Input Use I		SM-WW Balanced input Use II	
2				CM Maize	Highest CM Maize + Wheat		Optimized (soil+straw+manure+fert-uptake)=0		Optimized (soil+straw+manure+fert-uptake=0	
3				CM Maize	Highest CM Maize + Wheat		Optimized (rain+ irri-uptake)=0		Optimized (rain+irri-uptake)=0	
4	**Total Contribution Margin (for 2 years):**									
5										
6	¥		5.970,46	Data	Own Data		Calculations		Calculations	
7	1 year/2 year			ear	1 Year		1 year		1 year	
8	Changing Cells:		Capacity	0,00	0,00	0,00	0,89	0,00	0,00	0,00
9	**Contribution Margin**				¥ -501,42		¥ -427,40		¥ -427,40	
49	N fertilizer (Wheat)	2 years	0,00							
50	P Fertilizer (Wheat)	2 years	0,00							
51	K Fertilizer (Wheat)	2 years	0,00							
52	N fertilizer (Other Crop)	2 years	0,00							
53	P Fertilizer (Other Crop)	2 years	0,00							
54	K Fertilizer (Other Crop)	2 years	0,00							
55	Total N Manure	2 years	0,60							
56	Total P Manure	2 years	0,60							
57	Total K Manure	2 years	0,40							
58	N Manure (Maize)	2 years	0,00							
59	P Manure (Maize)	2 years	0,00							
60	K Manure (Maize)	2 years	0,00							
61	N Manure (Wheat)	2 years	0,00							
62	P Manure (Wheat)	2 years	0,00							
63	K Manure (Wheat)	2 years	0,00							
64	N Manure (Other Crops)	2 years	0,00							
65	P Manure (Other Crops)	2 years	0,00							
66	K Manure (Other Crops)	2 years	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00

Solver Parameters V7.0

Set Cell: $A$6

Equal To: ● Max ○ Min ○ Value Of: 0

By Changing Variable Cells: $F$8:$CJ$8

Standard LP Simplex

Subject to the Constraints:

```
$B$128 <= $C$128
$CL$11 = 0
$CL$11:$CL$37 <= $C$11:$C$37
$CL$24 = 0
$CL$43:$CL$45 = 0
$CM$38 >= 0
$CM$43:$CM$45 >= 0
$CM$55:$CM$57 >= 0
$CM$67:$CM$71 >= 0
$CO$43 >= 0
$F$8:$CJ$8 >= 0
```

For the purpose of this study, which is to define agro-environmental policy and management measures aiming at reducing environmental impacts of farming and at keeping grain production levels high, LP represents an excellent and long-trusted methodology, as "it can handle large, complex planning problems quickly and accurately and also provides information" (KAY *et al.*, 2008). That is one reason why LP has been chosen as the method of analysis. In this work the LP model surveys the effects of changing management measures, policy scenarios and possible impacts of innovation. The details of the LP model of this work are explained in the following part.

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[24] Frontline Systems Inc.

In order to survey the uncertainty or variation of the model, a sensitivity analysis is conducted after the optimization. The sensitivity analysis assesses “the sensitivity of the solution to uncertainty or estimation errors in the model coefficients, and also the solution’s sensitivity to changes in model coefficients (…)” (RAGSDALE, 2008). The calculations for sensitivity analysis assume ceteris paribus conditions and are included in the Premium Solver for Education, Version 7.0. The shadow prices of the constraints are calculated; they indicate the amount by which the objective function would increase if the respective constraint were relaxed by one unit. The shadow price of a constraint equals 0.00 if not all respective resources (i.e. capacities) are used. Also it is surveyed which of the constraints is binding and which are not binding. A binding constraint indicates that all respective resources are used in the optimal result and that no remaining capacities exist. In addition the reduced costs for the variables are calculated, they indicate the amount by which the value of the respective variable would have to increase to be included in the optimal solution, as it “is equal to the per-unit amount that the product contributes to profits, minus the per-unit value of the resources it consumes” (RAGSDALE, 2008). Reduced costs are displayed in negative values.

5.2.Description of the LP Model

This part describes the specification of the LP model of this work. Firstly the selection process for the surveyed households is described in 5.2.1. Then the aim and the specific characteristics of the model are introduced. Finally all integrated optimization options will be outlined in 5.3.

5.2.1. Selection of Households

The following methodology has been applied In order to select representative farms. As described in 5.2.2, only crop rotations including maize and/or wheat are considered in the model. Therefore only 45 surveyed households which grow the SM-WW crop rotation are included in the selection process. However, 4 of these households are lacking data for the 5 selected key variables (see below), so they were excluded from the selection process. Consequently 41 of the surveyed households are included in the further selection process. Based on the context of this research, 5 key variables were selected. Due to the described environmental problems of agricultural production in the research area, N fertilization for maize and wheat as well as irrigation of both crops were selected. In addition total annual household income was selected, as it includes also income from other crops, off-farm activities or other enterprises. In a cluster analysis variables with higher (or lower) values have respectively a higher (or lower) influence on the result. Therefore, in order not to weigh one of the variables preferably, it was attempted to put each selected variable in a general range of 3 decimal places – therefore the selected variables were included in these scales:

- Annual N fertilization Maize *(kg/ha)*;
- Annual N fertilization Wheat *(kg/ha)*;
- Annual irrigation Maize *(m^3/ha)*;
- Annual irrigation Wheat *(m^3/ha)*;

- Total annual household income *(in ¥$^{-100}$)*.

A cluster analysis with the 5 selected key variables determined two farm clusters with respective cluster centers (see Table 71).

Table 71. Cluster Centers of Selected Variables for Household Selection

Cluster Centers of the Final Result

	Cluster	
	1	2
NMAize	189.14	173.81
NWheat	282.88	281.88
IrriMaize	159.68	373.74
IrriWheat	252.95	467.10
HHIncome	137.96	-51.79

Cluster 1 includes 29 households and cluster 2 consists of 12 households. The 2 clusters have similar centers for N fertilization for maize and wheat, but they differ greatly in irrigation and total household income. Within each cluster the farm with the least combined distance of all 5 selected key variables to the respective cluster center was determined by the ordinary least square (OLS) method. This way 2 farms were selected: one for each cluster. A third farm was selected from the medians of the 5 selected key variables; again the combined least distance to the respective medians of the 5 key variables was determined by the OLS method. In total 3 of the surveyed households were selected to be included in the model – in the following parts these households are called "typical households". The relevant characteristics of the selected households are described in Table 72.

Table 72. Characteristics of the Selected Households

	Household 1	Household 2	Household 3
Farm Size:			
-Total *(mu)*	2.00	7.50	9.85
-Cotton *(mu)*	0.00	1.30	5.40
-Other Crops *(mu)*	0.00	1.40	0.45
Livestock *(yes/no)*	Yes	No	No
Household Members *(no.)*	1	5	3
Share of Off-farm Income from Total Hh-income *(%)*	0.00%	6.48%	52.51%
Total Annual Net Household Income *(¥)*	**¥306.60**	**¥10,096.47**	**¥7,221.88**

Table 73 presents the characteristics of the current SM-WW crop rotation systems which the selected households are currently operating[25].

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[25] The data in Table 73 also represents the optimization option *Farmer's Practice* for the respective household.

Table 73. Characteristics of the SM-WW Crop Production Systems of the Selected Households in the Initial Situation (for a 2-year period)

	Household 1 (HH1)	**Household 2 (HH2)**	**Household 3 (HH3)**
Labor Requirement *(hours and available hours)**			
-Jan	1.50 (196.00)	0.00 (364.00)	3.00 (312.00)
-Feb	0.00 (196.00)	2.09 (364.00)	0.00 (312.00)
-Mar	5.50 (196.00)	0.83 (364.00)	3.00 (310.00)
-Apr	1.50 (196.00)	0.00 (261.20)	0.00 (15.48)
-May	0.50 (196.00)	2.09 (317.00)	1.50 (215.00)
-Jun	3.25 (196.00)	13.75 (309.00)	29.88 (159.00)
-Jul	37.50 (196.00)	5.00 (303.00)	15.50 (280.00)
-Aug	1.50 (196.00)	2.09 (204.00)	6.50 (312.00)
-Sep	13.00 (196.00)	0.00 (300.00)	29.00 (111.00)
-Oct	2.00 (196.00)	23.36 (364.00)	7.00 (307.50)
-Nov	0.00 (196.00)	0.00 (364.00)	0.00 (308.00)
-Dec	0.00 (196.00)	0.00 (364.00)	0.00 (312.00)
SM-WW Area *(mu)**	2.00	4.80	4.00
Maize:			
-Irrigation *(m^3/mu)*	720.00	240.00	300.00
-N/P/K Fertilizer *(kg/mu)*	6.40/6.40/6.40	34.00/34.00/34.00	25.50/0.00/0.00
-N/P/K Manure *(kg/mu)*	0.00/0.00/0.00	0.00/0.00/0.00	0.00/0.00/0.00
-N/P/K Straw *(kg/mu)*	15.30/3.40/34.00	14.40/3.20/32.00	14.40/3.20/32.00
-Yield *(kg/mu)*	800.00	1100.00	800.00
-Own Consumption *(kg)*	200.00	100.00	100.00
Wheat:			
-Irrigation *(m^3/mu)*	720.00	360.00	450.00
-N/P/K Fertilizer *(kg/mu)*	42.20/20.00/0.00	31.60/30.90/31.60	32.00/32.00/32.00
-N/P/K Manure *(kg/mu)*	0.00/0.00/0.00	0.00/0.00/0.00	0.00/0.00/0.00
-N/P/K Straw *(kg/mu)*	5.34/3.21/14.96	7.35/4.41/20.57	5.34/3.21/14.96
-Yield *(kg/mu)*	850.00	800.00	800.00
-Own Consumption *(kg)*	300.00	1000.00	1000.00
Balances			
Maize:			
-WUE *(kg/ m^3)*	0.66	1.84	1.27
-NUE *(kg/kg N)***	125.00	32.35	31.37
-Water Balance *(m^3/mu)*	586.26	83.34	186.94
-N-P-K Balance *(kg/mu)*	0.78/3.66/18.00	20.46/30.30/35.20	22.18/-2.90/10.00
Wheat:			
-WUE *(kg/ m^3)*	0.96	1.51	1.29
-NUE *(kg/kg N)***	20.14	25.32	25.00
-Water Balance *(m^3/mu)*	206.06	-153.94	-63.94
-N-P-K Balance *(kg/mu)*	24.34/14.04/-9.63	15.34/25.89/26.46	14.14/26.03/22.37
TOTAL Water Balance *(m^3)*	792.86	-70.60	123.00
TOTAL WUE *(kg/m^3)*	0.79	1.69	1.28
TOTAL N-P-K Balance *(kg)**	25.12/17.70/8.37	35.80/56.19/61.66	33.30/23.13/32.37
TOTAL NUE *(kg/kg N)***	33.95	28.96	27.83
TOTAL Grain *(kg)*	3,300.00	9,120.00	6,400.00
Gross Margin *(¥/mu)*	**¥517.60**	**¥1,554.76**	**¥1,078.60**
Total Gross Margin *(¥)*	**¥1,035.20**	**¥7,462.85**	**¥4,314.40**

NOTE: *area and labor are displayed as one-year values
**of fertilization

The households differ strongly in their characteristics and also in their current cropping practices. Consequently the selected households should be able to simulate and represent many different types of household. However, they also have some common features: all selected household have a water balance indicating excess irrigation for maize, all households return straw to the fields and the NUE for wheat of all selected households is smaller than the average from the survey (29.91). None of the selected households is applying manure and only one household holds livestock. Below, the characteristics of each selected household will be separately analyzed and explained.

Household 1 (HH1):
HH1 is the smallest of the selected households in terms of household members and farm size. It is the only selected household with no off-farm income. *HH1* has abundant labor availability for the SM-WW crop rotation in every month. Also due to the smallest area *HH1* has the significantly lowest total gross margin (per area unit and total); but it also has the lowest net household income. Since it is the smallest household, the own consumption requirements are lower than those of the other 2 selected households.

Moreover, it is the only selected household which is exclusively growing the SM-WW crop rotation and which holds livestock. However, livestock only refers to chicken for own consumption. It is remarkable that this is the only household which has higher yields of wheat compared to maize; it also has the highest yields of wheat of the selected households. *HH1* is applying the largest amounts of irrigation for maize and wheat of the selected households. Furthermore irrigation is exceeding the mean irrigation amounts from the survey (for a 2-year period: 385.04 m^3/mu for maize and 486.26 m^3/mu for wheat). It also has the lowest WUE values of the selected households – the WUE is clearly below the averages from the survey (1.47 kg/m^3 for maize and 1.53 kg/m^3 for wheat). This indicates that the factor input of water of *HH1* is inefficient.

The nutrient balance of wheat shows an undersupply of K, one reason might be that no K fertilization was applied (only N and P). *HH1* has the lowest excess of nutrients in the total nutrient balance of all selected households. In this context it should be noted that the fertilization amounts of *HH1* are below the mean fertilization values of the survey (for a 2-year period: maize=25.42 kg N/mu, 12.76kgP/mu and 8.62kgP/mu and wheat=38.22 kg N/mu, 30.30 kg P/mu and 14.04 kg K/mu), except N for wheat. It is noticeable that *HH1* has the highest NUE for maize of the selected households, which is also higher than the average for maize of the survey (69.26 kg/kg N), but it also has the lowest NUE for wheat.

Household 2 (HH2):
HH2 is the largest of the selected households in terms of household members. With 4.8 mu it uses the biggest area of the selected households for the SM-WW crop rotation; on 1.3 mu cotton is grown and other crops on 1.4 mu. It has a small share of off-farm income and the highest total annual net income. *HH2* has abundant labor availability for the SM-WW crop

rotation in every month. The own consumption requirements of *HH2* and *HH3* are the same, even though *HH2* has more members.

HH2 has a negative water balance for wheat and consequently a negative total water balance of the cropping system – indicating insufficient water supply. Regardless, *HH2* has the highest WUE of all selected households. The WUEs are above the averages from the survey (1.47 kg/m^3 for maize and 1.53 kg/m^3 for wheat). The irrigation of *HH2* is below the mean values of the survey (for a 2-year period: 385.04 m^3/mu for maize and 486.26 m^3/mu). Of the selected households, *HH2* has the largest excess nutrient balance. In addition fertilization exceeds all mean fertilization values of the survey (for a 2-year period: maize = 25.42 kg N/mu, 12.76 kg P/mu and 8.62 kg P/mu and wheat=38.22 kg N/mu, 30.30 kg P/mu and 14.04 kg K/mu), except N fertilization of wheat. Nevertheless, *HH2* has the highest NUE values for maize and wheat – however they are still below the survey average for wheat.

HH2 produces the most total grain per mu in the SM-WW rotation of the selected households. In addition it has the highest gross margin (per mu and in total – also due to the largest area) of the selected households – an explanation might be the highest yields of the selected households, on the other hand this household also applies the highest fertilization levels.

Household 3 (HH3):
HH3 is the largest of the selected households in terms of total area. The SM-WW rotation is grown on 4.0 mu; for this household cotton production takes most of the available area (5.4 mu) and other crops are grown on 0.45 mu. The household has the highest share of off-farm income; the share of off-farm income is also considerably higher than that of the survey average (28.73%). Therefore labor availability in April is scarce and low in June and September; in other months labor availability is high – labor availability might be a constraint for some optimization options (see 5.3). The own consumption requirements of *HH2* and *HH3* are the same, even though *HH2* has more members.

Also, *HH3* has a negative water balance for wheat, but total water balance of the cropping system is positive – indicating excess applications for maize. It is remarkable that *HH3* only fertilizes N for maize (and no P or K); consequently a slight undersupply of K can be observed for maize. N fertilization of maize is very close to the survey mean of 25.42 kg/mu (for a 2-year period). Wheat fertilization differs from the average of the survey (for a 2-year period: wheat=38.22 kg N/mu, 30.30 kg P/mu and 14.04 kg K/mu). *HH3* is also irrigating below the average of the survey, but the gap to the survey means (for a 2-year period: 385.04 m^3/mu for maize and 486.26 m^3/mu) is smaller compared to *HH2*.

HH3 attains the lowest gross margin per mu of the SM-WW crop rotation of the selected households – indicating inefficient practices. However, its gross margin (per mu) is nearly congruent with mean of the SM-WW crop rotation of the survey (¥1,078.58/mu for a 2-year period).

5.2.2. Characteristics and Aim of the LP Model

The aim of the optimization process of this work is to determine the most efficient production option for the SM-WW crop rotation for the selected households under changing scenarios, considering environmental impacts, sustainability and grain self-sufficiency. Based on the findings from the optimization processes, agro-environmental policy and management measures for the achievements of the objectives (reduced environmental impacts and continuously high grain production) will be developed and analyzed in chapter 8. Consequently the optimized production options have to, at least, maintain current production levels but create less environmental impacts. Under various scenarios the integrated optimization options test the central hypothesis that "a change of the management system is able to meet the production goals, to achieve a higher input-output efficiency and to reduce negative environmental impacts". Those optimization options (see 5.3) are either determined through the survey, the IRTG database or other studies – they represent innovations or management measures. In addition selected relevant policy and management scenarios (see chapter 6) are introduced to be able to analyze and determine efficient options under changing environments or conditions.

The optimization process of this work maximizes the objective function, total gross margin, of the SM-WW crop rotation of the selected households (selection process is described in 5.2.1). For each selected combination, total gross margin *TCM*, is calculated by:

TCM = crop sales – (specific costs + costs for fertilizers + costs for manure + costs for irrigation);

All factors are expressed in ¥ per mu for 2 years. The optimization is only covering maize, wheat and crops which are grown together with at least one of them, as data for optimization options for cotton and other crops are lacking. Furthermore cotton does not fulfill the Chinese goals of grain-self-sufficiency and does not help food security – thus it is not in accordance with the goals of this work; other crops are not grown on a considerable large scale. Thus only the current SM-WW areas of the selected households are used and optimized in the model (unless mentioned otherwise in the respective scenario). All optimization options have to include at least maize or wheat. It is assumed that the selected households continue growing cotton and other crops in the same scale, which means that time and resource requirements of these crops remain unchanged. So the model only optimizes the area which the respective household used for the production of maize and/or wheat in the survey and can only use the labor resources which are not allocated to the production of cotton or other crops. Some of the optimization options are covering 2 years, so the model is regarding 2-year periods, in which 1-year crop rotations are repeated in the second year. Consequently total gross margin of SM-WW is maximized for a 2-year period. The included constraints of the model are:

- Labor, Total and per Month *(hrs)*;
- Area *(mu)*;

- Irrigation Water *(m^3)*;
- N, P, K Fertilization *(kg)*;
- N, P, K Manure *(kg)*;
- Own Consumption;
- Total Grain Yield *(kg)*.

Labor per month is calculated as available time for farming reduced by the time requirements of other farming activities (e.g. livestock, cotton or other crops) – i.e. labor represents the net time available for the SM-WW crop rotation. The corresponding requirements of the optimization options (see Table 78 and Table 79) are expressed per mu over the period for 2 years.

Since one of the central goals of this work is to develop strategies which ensure grain production in this important agricultural region, therefore – unless mentioned differently in the respective scenario – the model is restricted to solutions which generate total grain yields (from wheat and maize) which are equal to or larger than current production levels (see Table 72). However, wheat and maize can be substituted for each other, i.e. only wheat or only maize could make up total grain yield. These are the minimum required total grain yields of the selected households[26]:

- HH1: 3,300.00 kg;
- HH2: 9,120.00 kg;
- HH3: 6,400.00 kg.

It should be noted that also own consumption (incl. consumption of own animals) of maize and wheat of the selected households remains the same as in the surveyed year, as own consumption plays an important role for food security of the surveyed households. So, if – for example – an optimization option does not provide wheat, the household has to buy the amount which is equal to the own consumption and the required amount for animal feed in the survey; these costs are integrated in the respective optimization option. These are the integrated total amounts for own consumption of the selected households[27]:

- HH1: 200.00 kg maize and 300.00 kg wheat;
- HH2: 1,000.00 kg maize and 100.00 kg wheat;
- HH3: 100.00 kg maize and 1,000.00 kg wheat.

Another constraint is that the optimization options cannot use more labor or area than the respective selected household has available. Unless not mentioned specifically, water, fertilization and manure are used only according to the demand of the optimization options. If a selected household did not have any livestock or not sufficient manure in the survey, it has to buy manure to fulfill the requirements of optimization options which require manure.

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[26] For the 2-year period of the model

[27] For the 2-year period of the model

As described in the previous parts, the following mean prices from the survey for fertilizer, manure and water (indirect price), are used (unless mentioned differently in the scenarios):

- Fertilizer prices *(¥/kg nutrient)*: ¥3.95/kg N, ¥4.35/kg P and ¥2.97/kg K;
- Manure prices *(¥/kg nutrient)*: ¥2.30/kg N, ¥2.33/kg P and ¥3.50/kg K;
- Water price *(¥/m^3)*: ¥0.54/m^3.

All specific other costs are displayed for each optimization option. These specific other costs refer to expenses related to seeds, tillage (machinery), planting (machinery), other materials, harvest (machinery), postharvest (machinery) and pesticides. These specific other costs are only included as a total sum which remains the same for every scenario. Costs for manure, fertilizer, water and labor are part of the optimization process and relate to the requirements of the respective optimization option. Unless mentioned in a specific scenario, the labor price is ¥0.00 per hour, as labor is abundant in the surveyed households (see 4.5.1).

The main source of earning in the model is the sale of crops, which are produced in a crop rotation containing at least maize or wheat. All other income sources (other crops, subsidies, off-farm income etc.) are not included in the model and are assumed to remain constant. The prices for crop sales are:

- Maize: ¥1.46/kg;
- Wheat: ¥1.55/kg;
- Peanut: ¥7.70/kg;
- Cabbage: ¥0.75/kg;
- Soybeans: ¥2.96/kg.

Commonly the prices for maize and wheat (products) in shops are higher than the price the farmer receives for selling these products; so the prices of buying maize and wheat are calculated by multiplying prices for crop sales with a factor of 2 (consequently ¥2.92 per kg maize and ¥3.10 per kg wheat).

For the discussion of the results of the optimization in each scenario, the results from the sensitivity analysis (i.e. reduced costs and shadow prices) will be consulted.

5.3.Integrated Optimization Options

The following parts describe the details of the optimization options which are integrated into the model. Some of the integrated optimizations cover 2 years, thus, the optimization options which cover only one year will be repeated in the second year. Data for the optimization options are derived from literature, the survey, studies, experiments and the IRTG database (IRTG, 2010) – whenever datasets were not complete estimations were applied. These estimations were discussed with experts in the respective fields in order to ensure reliability of the estimations.

Some integrated optimization options are theoretical and based on nutrient absorption baselines from other studies for the research area. Table 74 presents the nutrient absorption levels for winter wheat and summer maize in the double cropping system in the research area for specific yield levels for these optimization options.

Table 74. Nutrient Absorption of Winter Wheat and Summer Maize in the Double-Cropping System in North China at Different Yield Levels (kg/mu)

Yield Level *(kg/mu)*	**Summer Maize** *(kg/mu)* **N**	**P_2O_5**	**K_2O**	**Winter Wheat** *(kg/mu)* **N**	**P_2O_5**	**K_2O**
300.00	-	-	-	8.33	3.20	8.13
400.00	8.93	2.73	7.80	11.07	4.27	10.80
500.00	10.73	3.93	10.00	13.80	5.33	13.47
600.00	12.53	5.13	12.20	17.67	6.33	17.00
700.00	14.67	5.67	14.33	-	-	-

Source: ZHANG *et al.* (2009), modified

Another approach for theoretical optimization options are fertilization recommendations for the research area. Table 75 presents fertilization recommendations for winter wheat and summer maize in the double cropping systems for the research area.

Table 75. Fertilization Recommendations for Winter Wheat and Summer Maize in the SM-WW Double Cropping System in North China for Different Target Levels

Target Yield *(kg/mu)*	**Winter Wheat** *(kg/mu)* **N**	**P_2O_5**	**K_2O**
<300.00	8.00-10.00	3.00-4.00	0.00-3.00
300.01-500.00	10.00-12.00	4.00-6.00	0.00-3.00
500.01-600.00	12.00-14.00	6.00-8.00	4.00-5.00
>600.01	14.00-16.00	8.00-10.00	5.00-6.00
Target Yield *(kg/mu)*	**Summer Maize** *(kg/mu)* **N**	**P_2O_5**	**K_2O**
<450.00	9.00-11.00	2.00-3.00	0.00-3.00
450.01-600.00	10.00-12.00	3.00-4.00	2.00-4.00
600.01-700.00	12.00-15.00	4.00-5.00	4.00-5.00
>700.01	14.00-16.00	5.00-6.00	6.00-7.00

Source: ZHANG *et al.* (2009), modified

The selected study also provides further recommendations regarding the fertilization practices for the SM-WW crop rotation (ZHANG *et al.*, 2009):

- For winter wheat and summer maize: 1/3 of N fertilizer amount should be applied as base fertilizer and the rest as top dressing;
- The amount of fertilization can be decreased if manure is used;
- For yield levels above 600.00 kg/mu of summer maize: fertilizer top dressing should be applied after flowering.

The recommendation that the amount fertilization can be decreased if manure is used, is in accordance with the findings from the survey which indicate that some households apply manure even though they already high levels of fertilization (4.4.2).

The model also integrates optimization options which include only spring maize (in a single crop system) – consequently, in these options, wheat has to be bought to fulfill requirements of own consumption and animal feed. Table 76 presents the nutrient absorption levels for spring maize in the research area for specific yield levels.

Table 76. Nutrient Absorption of Spring Maize in Northeast China at Different Yield Levels (kg/mu)

Yield Level *(kg/mu)*	**Spring Maize** *(kg/mu)* **N**	**P_2O_5**	**K_2O**
<500.00	11.00	3.53	9.53
500.01-650.00	13.00	4.00	12.53
>650.01	15.00	4.53	14.53

Source: ZHANG *et al.* (2009), modified

Simultaneously to the SM-WW rotation, Table 77 presents fertilization recommendations for spring maize for the research area.

Table 77. Fertilization Recommendations for Spring Maize in Northeast China for Different Target Levels

Yield Level *(kg/mu)*	**Spring Maize** *(kg/mu)* **N**	**P_2O_5**	**K_2O**
<500.00	11.00	4.50	3.00
500.01-650.00	13.00	5.00	4.00
>650.01	15.00	4.50	4.50

Source: ZHANG *et al.* (2009), modified

Also for spring maize the selected study provided further recommendations for the fertilization practices (ZHANG *et al.*, 2009):

- Decrease amount of base N-fertilizer;
- Soil with high PH, high yield or low zinc: should apply zinc fertilizer;
- Soil with high K, low yield or applied organic manure: amount of K fertilizer can be reduced;
- For yield above 600.00 kg/mu: fertilizer top dressing after flowering.

In order to facilitate the interpretation the results of the optimization processes, Table 78 and Table 79 present the characteristics of the integrated optimization options. The balances in this part represent simple input-output calculations for nutrients and water. The data set did not provide enough information to include all relevant processes and factors – as for example only soil samples were taken at only one point during the year. The nutrient balances are calculated following the procedure in part 4.4.2. The water balances are calculated according to the procedure which is described in part 4.4.3. The grain-Straw ratio is calculated according to ZHENG *et al.* (2007): in China maize has a grain/straw-ration of 2.00 and wheat has a grain/straw-ration of 1.336. The nutrient content of the straw is estimated according to Table 36. However it is assumed that due to losses only 80.00% of the total available straw is returned to the fields.

The optimization options are divided into innovations (which represent either a change of the standard SM-WW crop rotation or a technical innovation) and management measures (which include all alterations of the cultivation practices of the SM-WW crop rotation). However the division is not clear in all cases. On the following pages the integrated optimization options are introduced, their characterizations can be found in Table 78 and Table 79. Optimization options which exclude the production of wheat have been selected as – based on the survey – the production of wheat is the largest consumer of fertilizers and irrigation water. Consequently wheat production is closely related to the central environmental problems of the research area; however, wheat plays an important role for grain self sufficiency. It should be noted that the mean gross margin of the integrated optimization options (excluding *Farmer's Practice*) is ¥1,769.20 per mu – this is considerably higher than the combined mean gross margin of maize and wheat in the survey: ¥539.29 per mu (see 4.5.4).

5.3.1. Optimization Options: Management Measures

This part presents the optimization options which are categorized as management measures. For detailed comparison Table 78 and Annex 9 to Annex 17 present overviews, including the characteristics, input figures as well as water and nutrient balances of these optimization options.

Farmer's Practice:
The optimization option *Farmer's Practice* is derived from the survey. It represents the actual practices of the respective selected household in 2007 (see Table 73). This optimization option is included to test whether the respective household is already applying an efficient production option. Naturally *Farmer's Practice* is the only optimization option which is varying for all selected households – as it is based on the respective practices of the household. This is a SM-WW optimization option.

Survey Mean:
The optimization option *Survey Mean* represents a mathematically calculated household – the "mean household" of those which were included in the selection process. It does not exist in reality and it is characterized by the means of the relevant factors of the survey (see Table 78). It is included to test whether the mean of all households already represents an efficient option for the selected households. This is a SM-WW optimization option. *Survey Mean* is the optimization option with the lowest WUE for summer maize and the total cropping system – indicating the comparably low resource use efficiency of the surveyed households.

Survey Highest Maize Yield:
The optimization option *Survey Highest Maize Yield* represents the household which had the highest maize yield of all households which were included in the selection process for the model. It is included to test under which condition this high yielding input-mix (see Table 78) might be the most efficient option for the selected households. This is a SM-WW

optimization option. . It is remarkable that this optimization option has the highest P excess of the total cropping system of all included optimization options.

Survey Highest Wheat Yield:
The optimization option *Survey Highest Wheat Yield* represents the household which had the highest wheat yield of all households which were included in the selection process for the model. Simultaneously it is the household which has the highest total yield of maize and wheat during a complete growing season. In addition it is also the household which has the highest gross margin for wheat production. It is included to test under which condition this high yielding and economically profitable input-mix (see Table 78) might be the most efficient option for the selected households. This is a SM-WW optimization option. *Survey Highest Wheat Yield* is the optimization option with the largest excess of irrigation for wheat.

Survey Lowest N Fertilization – Maize:
The optimization option *Survey Lowest N Fertilization – Maize* represents the household which had the lowest amount of applied N fertilization for maize production of all households which were included in the selection process for the model. It is included to test under which condition this low fertilization use input-mix (see Annex 9) might be the most efficient option for the selected households. This is a SM-WW optimization option.

Survey Lowest N Fertilization – Wheat:
The optimization option *Survey Lowest N Fertilization – Wheat* represents the household which had the lowest amount of applied N fertilization for wheat production of all households which were included in the selection process for the model. Simultaneously it is the household which has the lowest total N fertilization of maize and wheat during a complete growing season. It is included to test under which condition this low fertilization use input-mix (see Annex 9) might be the most efficient option for the selected households. This is a SM-WW optimization option *Survey Lowest N Fertilization – Wheat* has the lowest NUE for wheat of all optimization options, as it is not fertilized with N.

Survey Lowest Irrigation – Maize:
The optimization option *Survey Lowest Irrigation – Maize* represents the household which had the lowest amount of irrigation for maize and simultaneously for wheat production of all households which were included in the selection process for the model. Consequently it is the household which has the lowest irrigation of maize and wheat during a complete growing season. It is included to test under which condition this low water-use input-mix (see Annex 9) might be the most efficient option for the selected households. This is a SM-WW optimization option. Interestingly this optimization option has the highest WUE for wheat and for the total cropping systems of all optimization options. Furthermore, *Survey Lowest Irrigation – Maize* is the optimization option with the highest NUE for maize.

Survey Highest Gross Margin – Maize:
The optimization option *Survey Highest Gross Margin – Maize* represents the household which had the highest gross margin for maize production of all households which were

included in the selection process for the model. It is included to test under which condition this economically profitable input-mix (see Annex 10) might be the most efficient option for the selected households. This is a SM-WW optimization option. It is remarkable that this optimization option has the highest N excess of the total cropping system of all included optimization options. Furthermore it is the optimization option with the largest excess of irrigation for summer maize. It is also is the optimization option with the highest NUE for wheat.

Survey Highest Gross Margin – SM-WW:
The optimization option *Survey Highest Gross Margin – SM-WW* represents the household which had the highest gross margin for the complete SM-WW crop rotation of all households which were included in the selection process for the model. It is included to test under which condition this economically profitable input-mix (see Annex 10) might be the most efficient option for the selected households. This is a SM-WW optimization option.

SM-WW Balanced Input Used I-IV:
The theoretical optimization options SM-WW Balanced Input Used I-IV represent fertilization and irrigation according to the respective demands of the plants (i.e. demand-driven input use). They are included to test whether these optimized options represent efficient solutions for the selected households (see Annex 11 and Annex 12). For SM-WW Balance Input Use I a cropping system with high annual yields of 700.00 kg/mu for maize and 600.00 kg/mu for wheat is assumed (SM-WW Balanced Input Use II: 600.00 kg/mu for maize and 500.00 kg/mu for wheat; SM-WW Balanced Input Use III: 500.00 kg/mu for maize and 400.00 kg/mu for wheat; SM-WW Balanced Input Use IV: 400.00 kg/mu for maize and 300.00 kg/mu for wheat – see Table 74). The nutrient absorption levels (according to Table 74) for the respective yields have to equal the sum of nutrients from the input from straw residues and from fertilization. It is assumed that no manure is used in this system. Consequently, the nutrient balances are evened and fertilization is adjusted according to the expected absorption of the expected yields in the respective SM-WW cropping system. In case the expected inputs from straw exceed the expected absorbed amounts no fertilization is added. Also the irrigation amounts are balanced according to the expected potential water use. It is assumed that the crops are only irrigated if the effective rainfall is less than the potential water use of the respective crop. The potential water use, effective rainfall and resulting required irrigation are calculated with the CROPWAT 8.0 software (as explained in part 4.4.3). These are SM-WW optimization options.

SM-WW Recommended Fertilization and Optimized Irrigation I-IV:
The theoretical optimization options *SM-WW Recommended Fertilization and Optimized Irrigation I-IV* represent fertilization according to the respective recommendations and irrigation according to the respective demands of the plants (i.e. demand-driven irrigation). They are included to test whether these optimized options represent efficient solutions for the selected households (see Annex 12 and Annex 13). For *SM-WW Recommended Fertilization and Optimized Irrigation I* a cropping system with high annual yields of 700.01

kg/mu for maize and 600.01 kg/mu for wheat is assumed (*SM-WW Recommended Fertilization and Optimized Irrigation II*: 650.00 kg/mu for maize and 550.00 kg/mu for wheat; *SM-WW Recommended Fertilization and Optimized Irrigation III*: 525.00 kg/mu for maize and 400.00 kg/mu for wheat; *SM-WW Recommended Fertilization and Optimized Irrigation IV*: 449.99 kg/mu for maize and 299.99 kg/mu for wheat – see Table 75). The crops are fertilized with the respective recommended amounts according to the expected yields (see Table 75). The irrigation amounts are balanced according to the expected potential water use. It is assumed that the crops are only irrigated if the effective rainfall is less than the potential water use of the respective crop. The potential water use, effective rainfall and resulting required irrigation are calculated with the CROPWAT 8.0 software (as explained in part 4.4.3). These are SM-WW optimization options. It is remarkable that *SM-WW Recommended Fertilization and Optimized Irrigation IV* has the lowest WUE for wheat of all optimization options – as wheat yields are comparably low. *SM-WW Recommended Fertilization and Optimized Irrigation I* has the highest total grain yield of all optimization options.

SprM Balanced Input Use I-III:
The theoretical optimization options *SprM Balanced Input Use I-III* represent fertilization and irrigation according to the respective demands of spring maize (demand-driven input use). They are included to test whether these optimized options represent efficient solutions for the selected households (see Annex 13 and Annex 14). For *SprM Balanced Input Use I* a cropping system with high annual yields of 650.01 kg/mu for spring maize is assumed (*SprM Balanced Input Use II*: 575.00 kg/mu for spring maize; *SprM Balanced Input Use III*: 499.99 kg/mu for spring maize – see Table 76). The nutrient absorption levels (according to Table 76) for the respective yields have to equal the sum of nutrients from the input from straw residues (from maize) and from fertilization. It is assumed that no manure is used in this system. Consequently, the nutrient balances are evened and fertilization is adjusted according to the expected absorption of the expected yields. In case the expected inputs exceed the expected absorbed amounts no fertilization is added. Also the irrigation amounts are balanced according to the expected potential water use. It is assumed that the crops are only irrigated if the effective rainfall is less than the potential water use of the respective crop. The potential water use, effective rainfall and resulting required irrigation are calculated with the CROPWAT 8.0 software (as explained in 4.4.3). These optimization options include only the production of spring maize – it is assumed that possible requirements of wheat for own consumption have to be bought. *SprM Balanced Input Used III* is the optimization option with the highest NUE for the total cropping system. This might be explained by the lack of wheat – which has a lower NUE compared to maize – in this optimization option. On the other hand it has the lowest WUE for spring maize – as spring maize yields are comparably low.

SprM Recommended Fertilization and Optimized Irrigation I-III:
The theoretical optimization options *SprM Recommended Fertilization and Optimized Irrigation I-III* represent fertilization according to the respective recommendations and irrigation according to the respective demands of spring maize. They are included to test

whether these optimized options represent efficient solutions for the selected households (see Annex 14 and Annex 15). For *SprM Recommended Fertilization and Optimized Irrigation I* a cropping system with high annual yields of 650.01 kg/mu for spring maize is assumed (*SprM Recommended Fertilization and Optimized Irrigation II*: 575.00 kg/mu for spring maize; *SprM Recommended Fertilization and Optimized Irrigation III*: 499.99 kg/mu for spring maize – see Table 77). The crops are fertilized with the respective recommended amounts according to the expected yields (see Table 77). The irrigation amounts are balanced according to the expected potential water use (i.e. demand-driven irrigation). It is assumed that the crops are only irrigated if the effective rainfall is less than the potential water use of the respective crop. The potential water use, effective rainfall and resulting required irrigation are calculated with the CROPWAT 8.0 software (as explained in 4.4.3). These optimization options include only the production of spring maize – it is assumed that possible requirements of wheat for own consumption have to be bought.

Conventional SM-WW I-II:
The optimization options Conventional SM-WW I-II represent farming according to defined “farmers’ practice” of field-experiments of the IRTG research project. The applied amounts for inputs in the experiment (i.e. “farmers’ practice”) and all other data were defined by the individual sub-projects and are based on interviews and experiments (IRTG DATABASE, 2010). The yields of maize and wheat were determined by field experiments in the research area. The corresponding data are displayed in Table 78. Conventional SM-WW I and II are included to test whether the assumed “farmers’ practices” represent efficient options for the selected households (see Annex 15 and Annex 16). These are SM-WW optimization options. Conventional SM-WW II has the lowest NUE for maize and the total cropping system of all optimization options.

Optimized SM-WW:
The optimization option Optimized SM-WW represents farming according to defined optimized irrigation and fertilization levels of field experiments of the IRTG research project. The applied amounts for inputs in the experiments and all other data were based on interviews and experiments (IRTG DATABASE, 2010). The yields of maize and wheat are determined by field experiments in the research area. The corresponding data are displayed in Annex 16. *Optimized SM-WW* is included to test whether the assumed optimized input levels represent efficient options for the selected households. This is a SM-WW optimization option.

Optimized Continued SprM I-II:
The optimization options Optimized Continued SprM I-II represent farming according to defined optimized irrigation and fertilization levels of field experiments of the IRTG research project. The applied amounts for inputs in the experiment and all other data were based on interviews and experiments (IRTG DATABASE, 2010). The yields of maize were determined by field experiments in the research area. The corresponding data are displayed in Table 78. *Optimized Continued SprM I and II* are included to test whether the assumed optimized input

levels (see Annex 16 and Annex 17) represent efficient options for the selected households. These optimization options include only the production of spring maize – it is assumed that possible requirements of wheat for own consumption have to be bought. *Optimized Continued SprM I* has the highest K excess of the total cropping system of all included optimization options; *Optimized Continued SprM II* represents the optimization option with the smallest specific costs per mu.

Reduced Inputs SM-WW:

The optimization option *Reduced Inputs SM-WW* represents farming according to defined reduced irrigation and fertilization levels of field experiments of the IRTG research project. The applied amounts for inputs in the experiments and all other data were based on interviews and experiments (IRTG DATABASE, 2010). The yields of maize and wheat were determined by field experiments in the research area. The corresponding data are displayed in Annex 17. *Reduced Inputs SM-WW* is included to test whether the reduced input levels represent an efficient option for the selected households. This is a SM-WW optimization option. *Reduced Inputs SM-WW* represents the optimization option with the largest lack of P and K in the total nutrient balance of the cropping system.

Table 78. Characteristics of Integrated Optimization Options - Management Measures (per mu per 2 years)

	Survey Mean	*Survey Highest Maize Yield*	*Survey Highest Wheat Yield*
SPECIFIC COSTS *(¥)*	**-¥517.26**	**-¥465.60**	**-¥411.96**
REQUIREMENTS:			
- Total Labor *(hours)*	74.25	75.27	119.65
- Area *(mu)*	1.00	1.00	1.00
Maize:			
- Irrigation *(m^3)*	444.66	468.00	468.00
- N-P-K Fertilizer *(kg)*	24.62/12.38/8.88	30.00/30.00/30.00	35.40/17.00/17.00
- N-P-K Manure *(kg)*	6.72/6.64/4.42	3.00/3.00/2.00	0.00/0.00/0.00
- Yield *(kg)*	946.82	1,395.35	1,200.00
Wheat:			
- Irrigation *(m^3)*	631.26	617.40	736.40
- N-P-K Fertilizer *(kg)*	37.69/30.21/15.29	20.00/56.00/0.00	35.00/17.00/17.00
- N-P-K Manure *(kg)*	6.49/6.44/4.64	3.00/3.00/2.00	0.00/0.00/0.00
- Yield *(kg)*	854.19	930.23	1,200.00
Other Crops:			
- Irrigation *(m^3)*	0.00	0.00	0.00
- N-P-K Fertilizer *(kg)*	0.00/0.00/0.00	0.00/0.00/0.00	0.00/0.00/0.00
- N-P-K Manure *(kg)*	0.00/0.00/0.00	0.00/0.00/0.00	0.00/0.00/0.00
- Yield *(kg)*	0.00	0.00	0.00
BALANCES:			
Maize:			
-N-P-K Straw *(kg)*	12.30/2.73/27.33	13.40/2.98/29.77	17.28/3.84/38.40
-N-P-K Uptake *(kg)*	21.46/7.86/20.00	29.34/11.34/28.66	25.06/6.26/24.40
-N-P-K Balance *(kg)*	22.18/13.89/20.63	17.06/24.64/33.11	27.62/14.58/31.00
-NUE *(kg/kg N)*	38.46	46.51	33.90
-Potential Water Use *(m^3)* **	617.74	443.60	443.60
-Effective Rainfall *(m^3)* **	484.00	330.54	330.54
-Water Balance *(m^3)*	310.92	354.94	354.94
-WUE *(kg/m^3)*	1.02	1.75	1.50
Wheat:			
-N-P-K Straw *(kg)*	5.06/3.04/14.17	7.46/4.47/20.88	6.41/3.85/17.96
-N-P-K Uptake *(kg)*	22.14/8.54/21.60	27.60/10.66/26.94	35.34/12.66/34.00
-N-P-K Balance *(kg)*	27.10/31.15/12.50	2.86/52.81/-4.06	6.07/8.19/0.96
-NUE *(kg/kg N)*	22.66	46.51	34.29
-Potential Water Use *(m^3)***	683.34	370.80	683.34
-Effective Rainfall *(m^3)***	169.40	143.34	169.40
-Water Balance *(m^3)*	117.32	389.94	222.46
-WUE *(kg/m^3)*	1.07	1.22	1.32
TOTAL WATER BALANCE(m^3)*, **	428.28	744.88	577.40
TOTAL WUE (kg/m^3)*	1.04	1.49	1.41
TOTAL N-P-K BALANCE (kg)*	49.28/45.04/33.13	19.91/77.45/29.05	33.69/22.77/31.96
TOTAL NUE (kg/kg N)*	28.90	46.51	34.09
TOTAL GRAIN (kg)*	1,801.01	2,325.58	2,400.00

NOTE: *of maize and wheat

**calculated with CROPWAT 8.0

5.3.2. Optimization Options: Innovations

This part presents the optimization options which are categorized as innovations. These innovative optimization options are derived from experiments and studies in the IRTG research project. The aims of the optimization options are within the overall objectives of the research project; which are: “developing cropping systems and management practices for the North China Plain that will ensure high intensities and will at the same time be environmentally, economically, and socially sustainable” (IRTG, 2009). Also ZHEN *et al.* (2005) emphasized the potential benefits from innovative cropping systems which include legumes and changed rotation patterns in the NCP. For detailed comparison Table 79 presents an overview, incl. the characteristics, input figures as well as water and nutrient balances of these optimization options.

SprM Cabbage Intercropping:

The optimization option *SprM Cabbage Intercropping* represents an innovation: instead of the typical SM-WW rotation 2 rows of Chinese cabbage are grown within 2 rows of spring maize. This innovative production system was surveyed in field experiments of the IRTG research project. The applied amounts for inputs in the experiments and all other data were based on interviews and experiments (IRTG DATABASE, 2010). The yields of maize and Chinese cabbage were determined by field experiments in the research area. The corresponding data are displayed in Table 79. *SprM Cabbage Intercropping* is included to test whether differing cropping systems with other input/output combinations can represent efficient options for the selected households. The aims of this system are higher yields (compared to mono-cropping), increased resource use efficiency and increased land use. This optimization option includes only the production of spring maize – it is assumed that possible requirements of wheat for own consumption have to be bought. *SprM Cabbage Intercropping* is the optimization option with the largest excess of irrigation for spring maize. It is also the optimization with the highest gross margin (per mu).

SprM Peanut Intercropping:

The optimization option *SprM Peanut Intercropping* represents an innovation: instead of the typical SM-WW rotation strips of peanut are grown within rows of spring maize. This innovative production system was surveyed in field experiments of the IRTG research project. The applied amounts for the inputs in the experiments and all other data were based on interviews and experiments (IRTG DATABASE, 2010). The yields of maize and peanut were determined by field experiments in the research area. The corresponding data are displayed in Table 79. *SprM Peanut Intercropping* is included to test whether differing cropping systems with other input/output combinations can represent efficient options for the selected farms. In addition, peanut is a leguminous plant with beneficial traits like the ability to fixate N and resulting positive impacts on soil structures. This optimization option includes only the production of spring maize – it is assumed that possible requirements of wheat for own consumption have to be bought.

SM-WW-SprM 3-harvests-in-2-years I-II:

The optimization options *SM-WW-SprM 3-harvests-in-2-years I-II* represent innovations: instead of the typical SM-WW rotation with 2 harvests in 1 year, 3 crops are harvested with 2 years: winter wheat, summer maize and in the following year spring maize. These innovative production systems were surveyed in field experiments of the IRTG research project. The applied amounts for inputs in the experiments and all other data were based on interviews and experiments (IRTG DATABASE, 2010). The yields of maize and wheat were determined by field experiments in the research area. The corresponding data are displayed in Table 79. *SM-WW-SprM 3-harvests-in-2-years I-II* are included to test whether cropping systems with lower pressure on land (i.e. less harvests) but similar crops can be efficient options for the selected households. The aim of this system is to determine new cropping systems with continuing high yield levels, less use of resources and reduced pressure on land. This is a SM-WW optimization option. *SM-WW-SprM 3-harvests-in-2-years II* represents the optimization option with the largest lack of N in the total nutrient balance of the cropping system. It is also the optimization option with the highest WUE for spring maize. In addition *SM-WW-SprM 3-harvests-in-2-years II* is the optimization options with the lowest gross margin (per mu).

Wheat-Soy-Maize 3-harvests-in-2-years:

The optimization option *Wheat-Soy-Maize 3-harvests-in-2-years* represents an innovation: instead of the typical SM-WW rotation with 2 harvests in 1 year, 3 crops are harvested with 2 years: winter wheat, summer soybean and in the following year spring maize. This innovative production system was surveyed in field experiments of the IRTG research project. The applied amounts for the inputs in the experiments and all other date were based on interviews and experiments (IRTG DATABASE, 2010). The yields of maize, wheat and soybean were determined by field experiments in the research area. The corresponding data are displayed in Table 79. *Wheat-Soy-Maize 3-harvests-in-2-years* is included to test whether cropping systems with lower pressure on land (i.e. less harvests) and differing outputs can be efficient options for the selected households. Furthermore it should be kept in mind that soybean represents an important protein source for animal nutrition and meat consumption in China is expected to rise continuously. In addition, soybeans are leguminous plants with beneficial traits like the ability to fixate N and resulting positive impacts on soil structures. The aim of this system is to determine new cropping systems with continuing high yield levels and less use of resources. This is not a SM-WW optimization option, but it includes the production of both: maize and wheat.

SM-WW Improved Maize Seeds:

The optimization option *SM-WW Improved Maize Seeds* represents an innovation: improved maize seeds – according to breeding experiments regarding the specific conditions in the research area – are introduced into a SM-WW crop rotation. This innovative production system was surveyed in field experiments of the IRTG research project. The applied amounts for inputs in the experiments and all other data were based on estimations and experiments (IRTG DATABASE, 2010). The yields of maize were determined by field experiments in the research area. The corresponding data are displayed in Table 79. *SM-WW Improved Maize Seeds* is included to test whether cropping systems with the newly developed maize seeds (with improved characteristics for the conditions in the research area) can be efficient options for the selected households. The aim of this system is to increase yields while decreasing input use in the specific conditions of the research area. This optimization option includes only the production of spring maize – it is assumed that possible requirements of wheat for own consumption have to be bought. This optimization option has the highest WUE for summer maize.

Table 79. Characteristics of Integrated Optimization Options - Innovations (per mu per 2 years)

	SprM Cabbage Intercropping	*SprM Peanut Intercropping*	*SM-WW-SprM 3-harvests-in-2-years I*
SPECIFIC COSTS *(¥)*	**-¥223.32**	**-¥506.66**	**-¥317.57**
REQUIREMENTS:			
- Total Labor *(hours)*	139.00	138.00	66.25
- Area *(mu)*	1.05	1.00	1.00
Maize:			
- Irrigation *(m^3)*	200.00	150.00	n.a.
- N-P-K Fertilizer *(kg)*	18.66/5.34/5.34	37.33/12.00/12.00	19.33/6.00/6.00
- N-P-K Manure *(kg)*	6.00/6.00/4.00	0.00/0.00/0.00	0.00/0.00/0.00
- Yield *(kg)*	933.33	1,213.32	1,266.67
Wheat:			
- Irrigation *(m^3)*	0.00	0.00	n.a.
- N-P-K Fertilizer *(kg)*	0.00/0.00/0.00	0.00/0.00/0.00	14.93/5.00/5.00
- N-P-K Manure *(kg)*	0.00/0.00/0.00	0.00/0.00/0.00	0.00/0.00/0.00
- Yield *(kg)*	0.00	0.00	483.34
Other Crops:			
- Irrigation *(m^3)*	200.00	0.00	n.a.
- N-P-K Fertilizer *(kg)*	19.66/6.66/13.34	13.33/12.00/12.00	0.00/0.00/0.00
- N-P-K Manure *(kg)*	0.00/0.00/0.00	0.00/0.00/0.00	0.00/0.00/0.00
- Yield *(kg)*	4333.34	286.67	0.00
BALANCES:			
Maize:			
-N-P-K Straw *(kg)*	0.00/0.00/0.00	0.00/0.00/0.00	6.96/1.55/15.47
-N-P-K Uptake *(kg)*	22.00/7.06/19.06	26.00/8.00/25.06	27.67/9.67.26.86
-N-P-K Balance (kg)	2.66/4.28/-9.72	11.33/4.00/-13.06	24.91/5.42/16.07
-NUE *(kg/kg N)*	50.02	32.50	65.53
-Potential Water Use *(m^3)* **	617.74	787.60	702.67
-Effective Rainfall *(m^3)* **	484.00	508.00	496.00
-Water Balance *(m^3)*	66.26	-129.60	n.a.
-WUE *(kg/ m^3)*	1.36	1.84	n.a.
Wheat:			
-N-P-K Straw *(kg)*	-	-	6.77/4.06/18.95
-N-P-K Uptake *(kg)*	-	-	13.80/5.33/13.47
-N-P-K Balance *(kg)*	-	-	7.90/3.73/10.48
-NUE *(kg/kg N)*	-	-	32.37
-Potential Water Use (m^3)**	-	-	185.40
-Effective Rainfall (m^3)**	-	-	71.67
-Water Balance (m^3)	-	-	n.a.
-WUE (kg/ m^3)	-	-	n.a.
TOTAL WATER BALANCE *(m^3)****, **	66.26	-129.60	n.a.
TOTAL WUE *(kg/ m^3)******	1.36	1.84	2.02
TOTAL N-P-K BALANCE *(kg)******	2.66/4.28/-9.72	11.33/4.00/-13.06	32.81/9.15/26.56
TOTAL NUE *(kg/kg N)******	50.02	32.50	51.08
TOTAL GRAIN *(kg)******	933.33	1,213.32	1,750.01

NOTE: *of maize and wheat

**calculated with CROPWAT 8.0

Table 79. – Continued – Characteristics of Integrated Optimization Options - Innovations (per mu per 2 years)

	SM-WW-SprM 3-harvests-in-2-years II	***Wheat-Soy-Maize 3-harvests-in-2-years***	***SM-WW Improved Maize Seeds***
SPECIFIC COSTS *(¥)*	**-¥522.58**	**-¥342.81**	**-¥320.40**
REQUIREMENTS:			
- Total Labor *(hours)*	181.67	73.25	31.25
- Area *(mu)*	1.00	1.00	1.00
Maize:			
- Irrigation *(m^3)*	162.00	n.a.	0.00
- N-P-K Fertilizer *(kg)*	13.00/7.53/12.47	12.00/5.00/5.00	15.52/20.80/13.34
- N-P-K Manure *(kg)*	0.00/0.00/0.00	0.00/0.00/0.00	0.00/0.00/0.00
- Yield *(kg)*	800.00	533.33	1,200.00
Wheat:			
- Irrigation *(m^3)*	120.00	n.a.	720.00
- N-P-K Fertilizer *(kg)*	10.27/4.00/0.00	14.93/5.00/5.00	42.20/20.00/0.00
- N-P-K Manure *(kg)*	0.00/0.00/0.00	0.00/0.00/0.00	0.00/0.00/0.00
- Yield *(kg)*	340.00	466.67	850.00
Other Crops:			
- Irrigation *(m^3)*	0.00	n.a.	0.00
- N-P-K Fertilizer *(kg)*	0.00/0.00/0.00	3.00/2.00/2.00	0.00/0.00/0.00
- N-P-K Manure *(kg)*	0.00/0.00/0.00	0.00/0.00/0.00	0.00/0.00/0.00
- Yield *(kg)*	0.00	266.67	0.00
BALANCES:			
Maize:			
-N-P-K Straw *(kg)*	0.00/0.00/0.00	6.72/1.49/14.93	0.00/0.00/0.00
-N-P-K Uptake *(kg)*	19.93/6.26/17.33	13.00/4.00/12.53	25.06/10.26/24.40
-N-P-K Balance *(kg)*	-23.06/-6.26/-21.46	18.72/6.49/19.93	-9.54/10.54/-11.06
-NUE *(kg/kg N)*	61.54	44.44	77.32
-Potential Water Use *(m^3)* **	650.43	393.80	513.86
-Effective Rainfall *(m^3)* **	357.20	254.00	357.20
-Water Balance *(m^3)*	-181.40	n.a.	-156.66
-WUE *(kg/m^3)*	1.54	n.a.	3.36
Wheat:			
-N-P-K Straw *(kg)*	0.00/0.00/0.00	2.85/1.71/7.98	0.00/0.00/0.00
-N-P-K Uptake *(kg)*	8.33/3.20/8.13	13.80/5.33/13.47	22.14/8.54/21.60
-N-P-K Balance *(kg)*	1.94/0.80/-8.13	3.98/1.38/-0.49	20.06/11.46/-21.60
-NUE *(kg/kg N)*	33.11	31.26	20.14
-Potential Water Use *(m^3)***	341.67	185.40	683.34
-Effective Rainfall *(m^3)***	84.70	71.67	169.40
-Water Balance *(m^3)*	-136.97	n.a.	206.06
-WUE *(kg/m^3)*	2.83	n.a.	0.96
TOTAL WATER BALANCE*(m^3)**, **	-318.37	n.a.	49.40
TOTAL WUE *(kg/m^3)**	4.04	n.a.	1.64
TOTAL N-P-K BALANCE *(kg)**	-21.12/-5.46/-29.59	22.70/7.87/19.44	10.52/22.00/-32.66
TOTAL NUE *(kg/kg N)**	48.99	37.13	35.52
TOTAL GRAIN *(kg)**	1,140.00	1,000.00	2,050.00

NOTE: *of maize and wheat

**calculated with CROPWAT 8.0

5.4.Environmental Indicators

Indicators are an evaluation method, in this case for the environmental assessment of the optimization processes. Indicators describe single quantities to reflect a more complex attribute; typically expressed in physical, economic, biological or chemical data. An indicator is applied because it represents a variable which supplies information on other variables which are difficult to access and which can be used as a benchmark to take a decision (VAN DER WERF and PETIT, 2002). MITCHELL *et al*. (1995) define indicators as "alternative measures that are used to identify the status of a concern when for technical or financial reasons the concern cannot be measured directly". In other words, indicators can facilitate and enable information transfer to a wide audience and can support evaluations.

Two approaches for indicator development can be distinguished: data-driven and theory-driven (NIEMEIJER, 2002). In the data-driven approach, the availability of data is the central criterion for indicator development. A theory-driven approach concentrates on selecting the best possible indicators from a theoretical point of view. This work follows the data-driven approach, as the indicators are selected from an already existing data set.

The list of possible indicators for environmental evaluation is long. Hence the selection of indicators is necessary, because "a long list runs the risk of information overload (…), while a short list runs the risk that something important is left out" (PERMAN *et al.*, 2003). However, to select the appropriate indicator is problematic, as subjectivity and arbitrariness can influence the selection process. In order to increase the degree of objectivity in the selection process, the OECD (2002) developed the following criteria:

- Policy relevance and utility for users (referring to i.e. representativeness, interpretability, comparability or responsiveness);
- Analytical soundness (referring to i.e. technical and scientific terminology, international standards and validity or ability to link with models and forecasting systems);
- Measurability (referring to i.e. availability, documentation or regular updating).

Even if these OECD criteria are followed, the indicator selection process still represents a trade-off between simplicity and complexity and might still include a certain degree of subjectivity and arbitrariness. In order to measure the sustainability of farming in the NCP comprehensively, local, regional and global environmental impacts should be considered. The focus lies on the most urgent environmental impacts to evaluate the environmental impacts and sustainability of optimized results. For this purpose the following indicators have been selected:

- WUE *(m^3/mu)* – as in Table 62;
- Total Water Use *(m^3)* – as in Table 62 as "mean irrigation";
- Total Water Balance *(m^3)* – as in Table 62;
- NUE *(kg/kg N)* – as in part 4.4.2;

- Total N/P/K Nutrient Balance *(kg/mu)* – as in part 4.4.2;
- Total N/P/K Fertilizer Use *(kg)* – as in Table 41.

The indicators WUE and NUE relate to resource use efficiency, so increased WUE and NUE values are desirable. Whereas the other indicators refer to resource use and pollution, for total water use and total fertilizer use decreased values are indicating reduced negative environmental impacts; the water and nutrient balances should be evened out so that the resources are used only to fulfill the needs of the plants. Here it should be noted that excess supply (of water and fertilizers) has negative environmental effects and undersupply is not sustainable.

6. Results of Simulations of Scenarios

In this part the model – which was described in part 5.2 – is applied to simulate and analyze the selected households in changing scenarios. Each Scenario is first described individually and then the simulation results are presented and discussed. It should be kept in mind that these simulations assume ceteris paribus conditions. For most scenarios the model has to be adjusted in order to include the respective restrictions. It should be noted that all presented data refers to 2-year cycles.

ZILKENS (2004) analyzed several optimized irrigation and fertilization strategies for the NCP. Optimization strategies can be related to negative side effects. However he concluded that the positive environmental effects outweigh these negative side effects when both factors are optimized simultaneously. Nevertheless it should be considered that optimization strategies might also reduce the productivity or increase the operating expenses. Therefore the optimized results are only useful if the production costs are not rising and the yields are not declining. The evaluation of the optimization processes considers sustainability criteria (environmental and economic performance) and the impacts on food security and grain self-sufficiency – as the households should, at least, maintain current grain production levels. Therefore one restriction in the model is that optimized maize and wheat production has to be equal to or larger than the initial yields. Increased gross margins can potentially lead to higher household income which can support local rural development. The results of the scenario are also evaluated based on the performance of the selected environmental indicators.

In the following parts 24 relevant scenarios will be outlined and analyzed. Their results will then be discussed concerning the objectives of this work. In the end of this chapter the regional transferability of the simulation results are discussed. The chapter concludes with a summary of the simulation results. Table 80 summarizes the main characteristics and main analytical objectives of the respective simulated scenarios.

Table 80. Main Characteristics and Analytical Objectives of Simulated Scenarios

Scenario	Main Characteristics	Main Analytical Objectives
Optimization under Current Conditions	Baseline scenario without policy intervention	Determining optimum solution under current conditions
Optimization under Current Conditions – no Grain Production Requirements	No policy intervention, but grain production requirements are omitted	Determining optimum solution under current conditions (without grain production requirements) and competitiveness of grain production
Input Price Increase: Fertilization	Price for fertilizers are raised*	Determining optimum solution with increased prices for fertilization and effectivity of related policies
Input Price Change: Fertilization Subsidy	Prices for fertilizers are decreased*	Determining optimum solution with decreased prices for fertilization and effectivity of related policies
Input Price Change: Introduction of Marginal Water Price	Price for water is raised*	Determining optimum solution with increased prices for water and effectivity of related policies
Input Price Change: Pesticides	Prices for pesticides are raised*	Determining optimum solution with increased prices for pesticides and effectivity of related policies
Output Price Increase: Maize	Market price for maize is raised*	Determining optimum solution with increased market price for maize and effectivity of related policies
Output Price Increase: Wheat	Market price for wheat is raised*	Determining optimum solution with increased market price for wheat and effectivity of related policies
Output Price Increase: SM-WW	Market prices for maize and wheat are raised*	Determining optimum solution with increased market prices for maize and wheat and effectivity of related policies
Output Price Increase: Soy	Market price for soybeans is raised*	Determining optimum solution with increased market price for soy and effectivity of related policies
Output Price Increase: Peanut	Market price for peanuts is raised*	Determining optimum solution with increased market price for peanuts and effectivity of related policies
Output Price Increase: Cabbage	Market price for cabbage is raised*	Determining optimum solution with increased market price for cabbage and effectivity of related policies
Output Price Decrease: Maize	Market price for maize is lowered*	Determining optimum solution with decreased market price for maize and effectivity of related policies
Output Price Decrease: Wheat	Market price for wheat is lowered*	Determining optimum solution with increased market price for wheat and effectivity of related policies
N Fertilization Cap	Maximum fertilization threshold is introduced	Determining optimum solution with fertilization threshold and effectivity of related policies
Irrigation Cap	Maximum irrigation threshold is introduced	Determining optimum solution with irrigation threshold and effectivity of related policies
Total Area: Substitutability with Cotton	SM-WW production can be substituted for cotton	Determining competitiveness of SM-WW rotation (compared to cotton)

NOTE: *compared to initial situation

Table 80 – Continued – Main Characteristics and Analytical Objectives of Simulated Scenarios

Scenario	Main Characteristics	Main Analytical Objectives
Less Available Labor	Available labor is decreased*	Determining impact of labor on optimum solution
Introduction of Price for Labor	Opportunity costs for labor are introduced	Determining impact of labor prices on optimum solution
Area Subsidy: Wheat	Area subsidy for wheat is introduced	Determining optimum solution with subsidy for wheat (i.e. to increase competitiveness of wheat) and effectivity of related policies
Yield Premium	Premium for increased grain yields*	Determining optimum solution with grain premium (i.e. to increase competitiveness of grains) and effectivity of related policies
Premium for Reduced Water Use	Premium for decreased water usage*	Determining optimum solution with premium for smaller water use and effectivity of related policies
Premium for Reduced Fertilizer Use	Premium for decreased fertilizer usage*	Determining optimum solution with premium for smaller fertilizer use and effectivity of related policies
Environmental Fee	Premium for decreased water and fertilizer usage*	Determining optimum solution with premium for smaller water and fertilizer use and effectivity of related policies

NOTE: *compared to initial situation

6.1. Optimization under Current Conditions

The results from this optimization are used as a baseline for comparison for the following scenarios. If a scenario does not result in cultivation practices (i.e. combinations of optimization options) which differ from *Optimization under Current Conditions*, it can be assumed that respective scenario does not represent a further improvement. If scenarios do not create changes from the results in the scenario *Optimization under Current Conditions*, the respective policies or measures are considered not effective as they represent extra investments or efforts which do not generate results which differ from the optimization in the scenario without intervention. This *Optimization under Current Conditions* represents an optimization of current practices without any additional policy interventions. Table 81 displays the results of the simulation for the scenario *Optimization under Current Conditions*.

Table 81. Simulation Results for the Scenario *Optimization under Current Conditions*

	SprM Cabbage Intercropping *(mu and % of Total Available Area)*	**SM-WW Balanced Input Use I** *(mu and % of Total Available Area)*	**Total Used Area** *(mu and % of Total Available Area)*
HH 1	1.11 (55.50%)	0.89 (44.50%)	2.00 (100.00%)
HH 2	1.96 (40.91%)	2.84 (59.09%)	4.80 (100.00%)
HH 3	2.34 (58.44%)	1.66 (51.56%)	4.00 (100.00%)

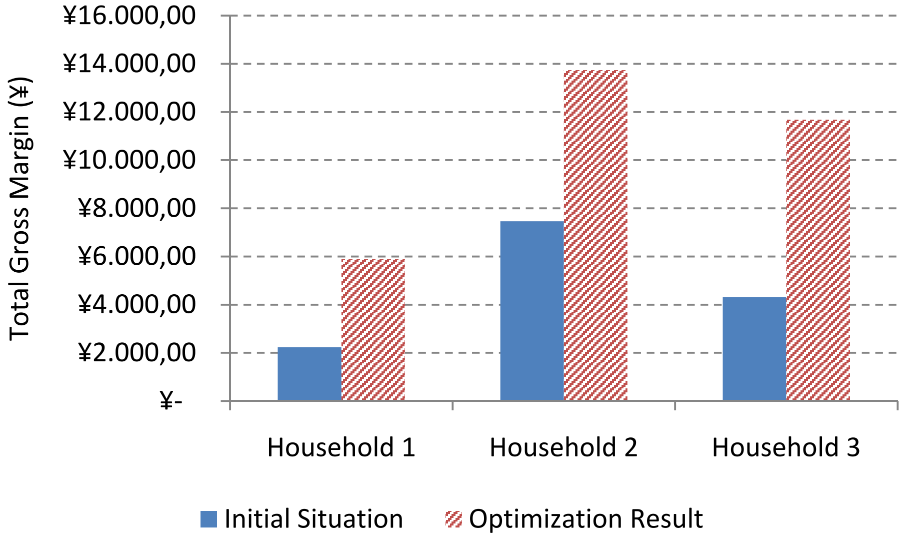
The optimization in the scenario *Optimization under Current Conditions* results in 100.00% land use of all selected households. *SprM Cabbage Intercropping* is the optimization option with the highest gross margin per mu. Table 82 presents the production characteristics of the simulation in the scenario *Optimization under Current Conditions*.

Table 82. Production Characteristics of the Simulation in the Scenario *Optimization under Current Conditions*

	Total Maize *(kg and initial Total Maize)*	**Total Wheat** *(kg and initial Total Wheat)*	**Total Other Crop** *(kg and initial Total Other Crops)*	**Bought Crops** *(kg)*	**Total Gross Margin** *(¥ and initial Total Gross Margin)*
HH 1	2,232.47 (1,600.00)	1,067.53 (1,700.00)	Cabbage: 4,582.56 (0.00)	0.00	¥5,885.77 (¥2,235.20)
HH 2	5,716.36 (5,280.00)	3,403.64 (3,840.00)	Cabbage: 8,103.89 (0.00)	0.00	¥13,739.85 (¥7,462.85)
HH 3	4,405.19 (3,200.00)	1,994.81 (3,200.00)	Cabbage: 9,647.49 (0.00)	0.00	¥11,676.74 (¥4,314.40)

One of the restrictions of the model forces the households to produce – at least – the same amount of grains as in the initial situation. It is, thus, noteworthy that all households produce only exactly the amount of grains which they are required to produce in the model. In addition all selected households produce cabbage – which none of the households produced in the initial situation. The effects on the total gross margin of the selected households are displayed in Figure 40.

Figure 40. Total Gross Margins in the Scenario *Optimization under Current Conditions*



Optimization under Current Conditions has significant positive effects on the total gross margins of the selected households: the total gross margin of HH1 increases by +163.32%, HH2 by +84.11% and HH3 by +170.65%. Such a strong increase could play an important role in the composition of rural household income; especially when agriculture is competing with off-farm income or other non-agricultural income sources. Table 83 displays which constraints are binding and which are not binding in this scenario.

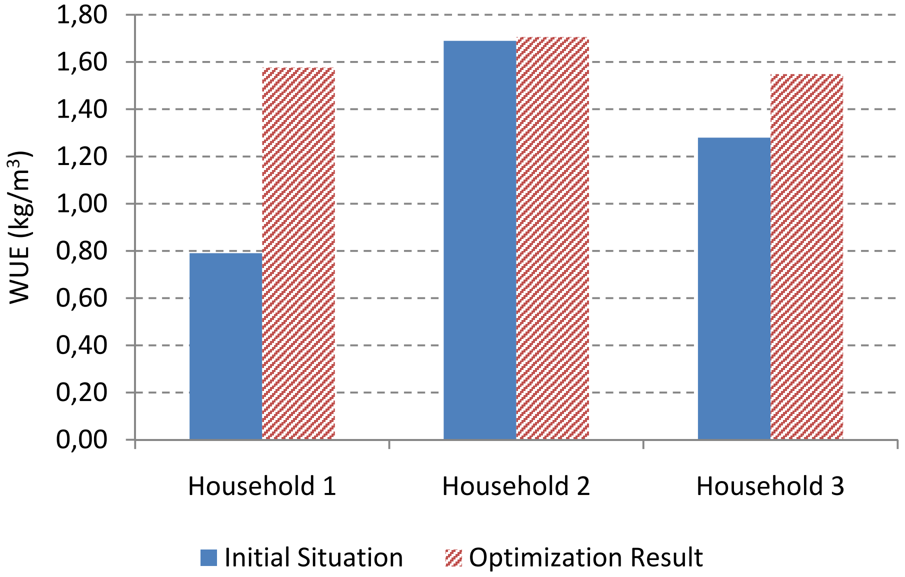
Table 83. Binding and not binding Constraints in the Scenario *Optimization under Current Conditions*

	HH1	HH2	HH3
Labor	Not Binding	Not Binding	Not Binding
Area	Binding	Binding	Binding
Total Irrigation	Binding	Binding	Binding
Total N/P/K Fertilization	Binding	Binding	Binding
Total N/P/K Manure	Binding	Binding	Binding
Total Grain Production	Binding	Binding	Binding
Own Consumption Maize	Binding	Binding	Binding
Own Consumption Wheat	Binding	Binding	Binding

The only not binding constraint in this scenario is *Labor*, as the households still have available labor resources. All other constraints are binding. The sensitivity analysis, by means of reduced cost values, surveys by which amount the value of the variable has to increase in order to change the current optimum solution. All variables which are included in the current optimum solution have reduced cost values of ¥0.00. Variables with low reduced cost values require only small changes to be included in a new optimal solution under unchanged conditions. The price increases of all variables (i.e. reduced cost values) which are necessary to change the optimal solution are displayed in Annex 19. The mean reduced cost value of the optimization options (excl. *Farmers' Practice*) is ¥1,463.66 – this indicates that the uncertainty of this scenario is low as most optimization options have high reduced cost values. In this scenario, the shadow price for area is ¥4,112.55 – this means that one more mu land would increase the optimum result by the respective amounts. The shadow price for total grain is ¥0.48 per kg, which means that if the minimum required amount for total grain production would increase by 1 kg, the optimal solution would decrease by that amount. In the optimum solution, considering that the current prices of renting land in the research area are very low compared to the shadow price (see part 4.2.2), it would be advisable to rent additional land for the surveyed households.

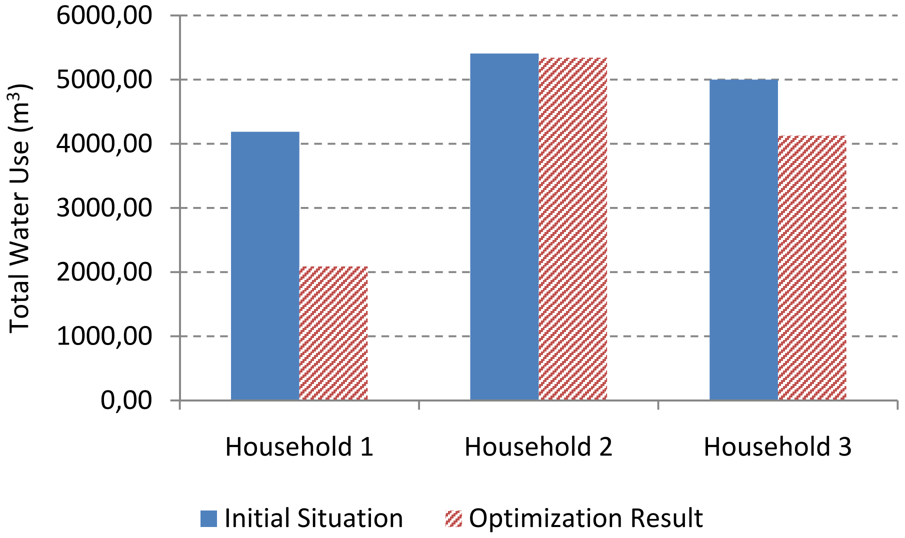
By means of the selected environmental indicators, the environmental impacts of the optimization in the scenario *Optimization under Current Conditions* are analyzed – Figure 41 displays the total WUEs.

Figure 41. **Total Water Use Efficiencies in the Scenario *Optimization under Current Conditions***



Optimization under Current Conditions leads to increased WUEs of all selected households. Only the magnitude of the increase is varying: the WUE of HH1 increases by 99.65% (due to very low WUE in the initial situation), of HH2 by only 0.99% (highest WUE in the initial situation) and of HH3 by 21.04%. Another effect is that the WUE values of the selected households are more equal after the optimization (ranging from 1.55-1.71). Figure 42 compares the total water use in the initial situation and after the optimization.

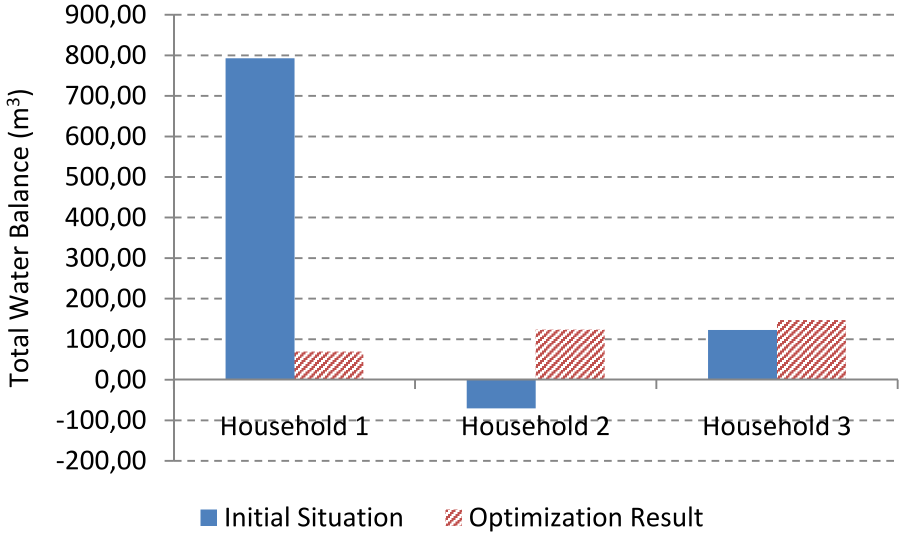
Figure 42. **Total Water Use in the Scenario *Optimization under Current Conditions***



Also total water use decreases in the scenario *Optimization under Current Conditions*. The decrease of HH1 is the strongest: 50.03%, HH2 decreases by 1.19% and HH3 by 17.38%. In

Table 73 it was already demonstrated that the water balance of HH1 in the initial situation indicates a strong over use – so the effects of the optimization (i.e. the decreased total water use) are the largest for HH1. Figure 43 displays the impacts of the *Optimization under Current Conditions* on the total water balance of the selected households.

Figure 43. Total Water Balance in the Scenario *Optimization under Current Conditions'****

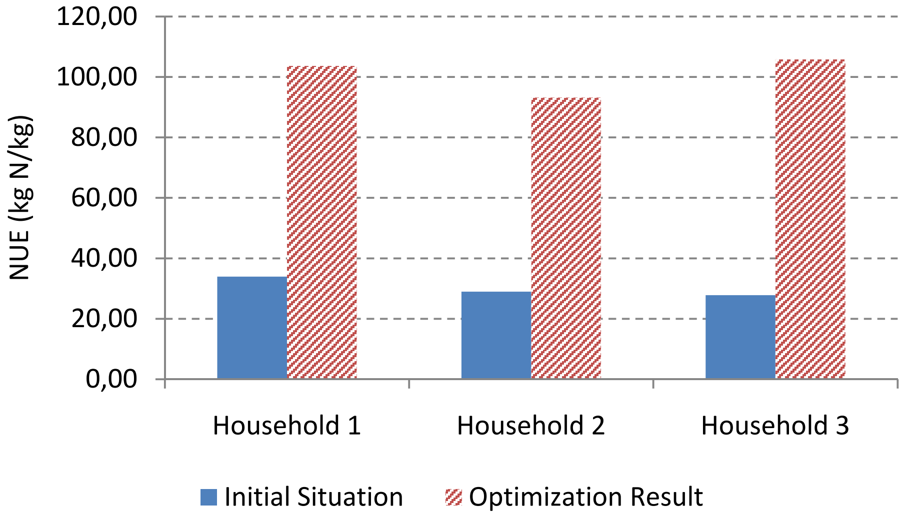


NOTE: *the calculation of the water balance is described in Table 62

**total water balance includes summer maize, spring maize and winter wheat

The impacts on the total water balance are not uniform: the excess of HH1 is decreasing, the undersupply of HH2 is turning into a small excess and the excess of HH3 is slightly increasing. Consequently the *Optimization under Current Conditions* does not seem to lead to uniformly balanced water use. However, the water use is more balanced in the sense that – after the optimization – no household undersupplies water to maize and wheat. Figure 44 displays the resulting NUEs for fertilization in the simulation of the scenario *Optimization under Current Conditions*.

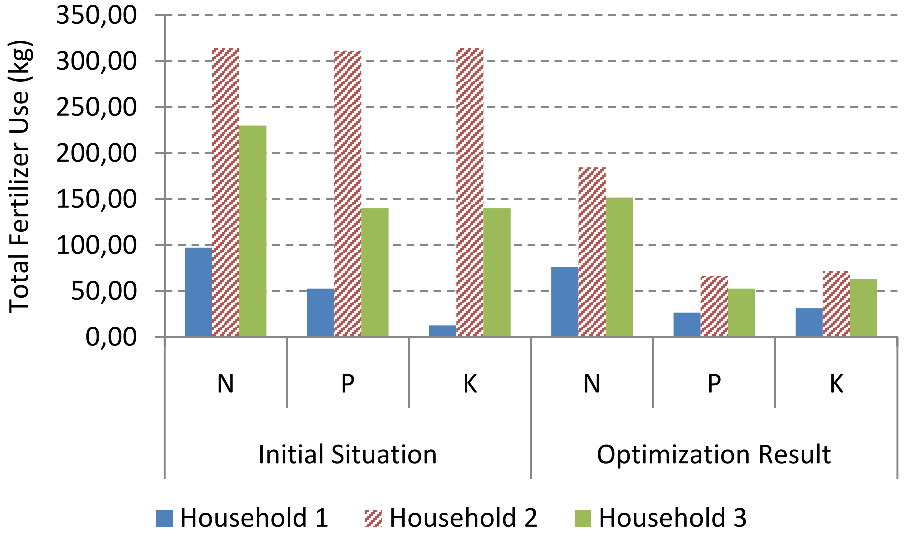
Figure 44. Total Nitrogen Use Efficiencies in the Scenario *Optimization under Current Conditions**



NOTE: *of fertilization

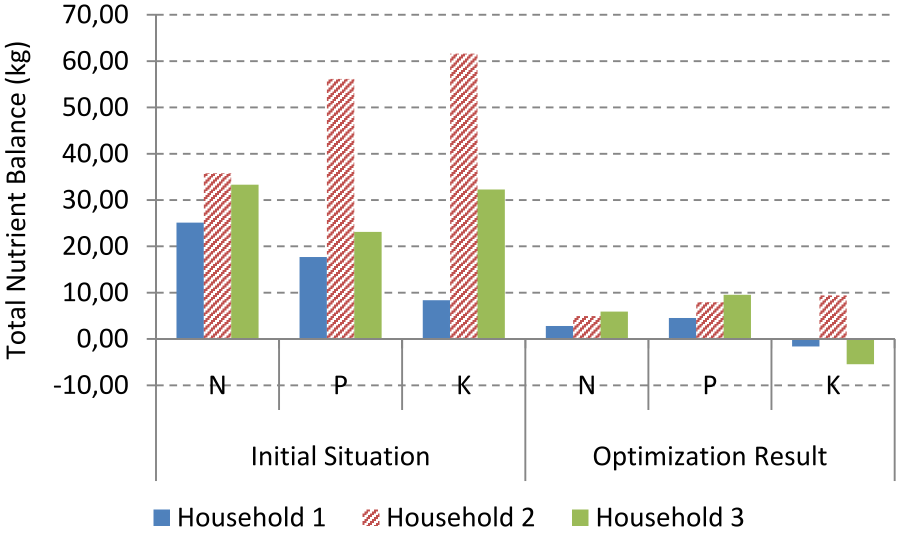
As demonstrated in Figure 44, the NUEs of the simulation in the scenario *Optimization under Current Conditions* indicate a clearly improved resource efficiency of N fertilization. The NUE of all households increases strongly: HH1 by +205.39%, HH2 by +221.72% and HH3 by +280.22%. Increased NUE values are in accordance with the goals of this work. Figure 45 compares the total fertilizer use in the initial situation and after the *Optimization under Current Conditions*.

Figure 45. Total Fertilizer Use in the Scenario *Optimization under Current Conditions*



The results of the simulation in the scenario *Optimization under Current Conditions* indicate that total fertilizer use of the optimized households decreases. Except K fertilization of HH1 (which increases by +145.03%) – as in the initial situation HH1 was fertilizing maize with only very small amounts and did not apply K fertilization for wheat (see Table 73) – all households apply less fertilizers: HH1 (N = -21.78% and P = -49.58%), HH2 (N = -41.20%, P = -78.54% and K = -77.12%) and HH3 (N = -34.06%, P = -62.32% and K = -54.80%). Decreasing total fertilizer use is in accordance with the goals of this work. It should also be pointed out that the households apply manure in this scenario, which is positive, because – as shown in the previous parts – manure use in China dramatically decreased over the past decades and it has positive impacts on soil characteristics. Figure 46 compares the total nutrient balances of the initial situation and of the results of the *Optimization under Current Conditions*.

Figure 46. Total Nutrient Balances in the Scenario *Optimization under Current Conditions**



NOTE: * total nutrient balance includes summer maize, spring maize and winter wheat

As Figure 46 demonstrates, the optimization leads to a reduced excess of all nutrients for HH1 (N = -88.80%, P = -74.43% and K = -119.30%), HH2 (N = -86.09%, P = -85.76% and K = -84.68%) and HH3 (N = -82.21%, P = -58.81% and K = -116.89%). Therefore the total nutrient balances are closer to the equilibrium, but HH1 and HH3 show an undersupply of K – such an undersupply can endanger the sustainability of the optimized cropping system.

The simulated effects of the introduction of the *Optimization under Current Conditions* can be summarized:

- Total fertilizer use decreases;
- WUE improves;
- NUE improves clearly;
- Nutrient excess decreases, but undersupply of K which endangers sustainability;
- Total water balance results are not uniform;
- Total water use decreases;
- Total food production increases (grain production remains unchanged);
- Strongly increased total gross margin.

6.2. Optimization under Current Conditions – no Grain Production Requirements

This scenario does not survey the introduction of a policy option, as – again – the selected households are optimized under current conditions, but this time the requirements for grain production levels are omitted; i.e. in this scenario the households are not required reach production levels from the initial situation (the households only have to fulfill own consumption needs through producing or buying of grains). This is done to survey the impacts of the grain production requirements on the optimized solution and aims at determining the competitiveness of grain production. Table 84 displays the results of the simulation for the scenario *Optimization under Current Conditions – no Grain Production Requirements*.

Table 84. Simulation Results for the Scenario *Optimization under Current Conditions – no Grain Production Requirements*

	SprM Cabbage Intercropping *(mu and % of Total Available Area)*	**SM-WW Balanced Input Use I** *(mu and % of Total Available Area)*	**SprM Peanut Intercropping** *(mu and % of Total Available Area)*	**Total Used Area** *(mu and % of Total Available Area)*
HH 1	1.75 (87.50%)	0.25 (12.50%)	0.00 (0.00%)	2.00 (100.00%)
HH 2	4.72 (98.33%)	0.08 (1.67%)	0.00 (0.00%)	4.80 (100.00%)
HH 3	2.49 (62.23%)	0.83 (20.83%)	0.68 (16.94%)	4.00 (100.00%)

The optimization in the scenario *Optimization under Current Conditions – no Grain Production Requirements* results in 100.00% land use of all selected households. *SprM Cabbage Intercropping* is the optimization option with the highest gross margin per area. Table 85 presents the production characteristics of the simulation in the scenario Optimization under Current Conditions – no Grain Production Requirements.

Table 85. Production Characteristics of the Simulation in the Scenario *Optimization under Current Conditions – no Grain Production Requirements*

	Total Maize *(kg and initial Total Maize)*	**Total Wheat** *(kg and initial Total Wheat)*	**Total Other Crop** *(kg and initial Total Other Crops)*	**Bought Crops** *(kg)*	**Total Gross Margin** *(¥ and initial Total Gross Margin)*
HH 1	1,905.55 (1,600.00)	300.00 (1,700.00)	Cabbage: 7,222.23 (0.00)	0.00	¥6,412.05 (¥2,235.20)
HH 2	4,309.24 (5,280.00)	100.00 (3,840.00)	Cabbage: 19,465.64 (0.00)	0.00	¥16,005.04 (¥7,462.85)
HH 3	4,201.28 (3,200.00)	1,000.00 (3,200.00)	Cabbage: 9,647.49 (0.00) Peanut: 194.22 (0.00)	0.00	¥11,905.06 (¥4,314.40)

Also the *Optimization under Current Conditions – no Grain Production Requirements* results in increased total gross margins. However, all selected households produce less total grain than in the initial situation, especially wheat is only produced in the minimum amounts which fulfill the requirements for own consumption. This scenario emphasized the need for incentives for wheat production in the research area, as other production options – which do not include wheat – offer attractive alternatives to the traditional SM-WW crop rotation. Consequently grains (especially wheat) do not represent the most efficient production option. Especially wheat seems to be not competitive with other crops. This results clearly indicate that grain self sufficiency is endangered in the research area. Consequently these results are not in accordance with the goals of this research. Therefore the environmental impacts of *Optimization under Current Conditions – no Grain Production Requirements* are not analyzed further. For the same reason also no sensitivity analysis will be conducted in this scenario.

The simulated effects of erasing the grain production requirements in the model can be summarized:

- Total gross margin increases – grains (especially wheat) are not the most efficient production option in the research area;
- Total grain production decreases strongly (especially wheat): not in accordance with the goals of this work.

6.3.Input Price Increase: Fertilization

The scenario *Input Price Increase: Fertilization* surveys the effects of raised prices for fertilization. Such a price increase could be the result of a policy of introducing taxes on fertilization or of cutting (indirect) subsidies on fertilization. This scenario aims at determining the effectivity of such a policy. The initial prices in the model for fertilizers (from the survey) are:

- N: ¥3.95 per kg;
- P: ¥4.35 per kg;
- K: ¥2.97 per kg.

The simulation shows that only a price increase by factor 11.9 (N: ¥47.01/kg, P: ¥51.77/kg and K: ¥35.34/kg) would create results which differ from the combination of optimization options in the scenario *Optimization under Current Conditions*. It should be noted that the characteristics of the model also have impacts on these results. The operational range of the model is limited as it is using fixed optimization options instead of continuous production functions and can, thus, occasionally only react stepwise. Therefore the model is sometimes limited to operating in optimum ranges rather than optimum points, as intermediate might be lacking. However, in order to be able to integrate the optimization options which are derived from other studies and experiments (management measures and innovations) it was necessary to formulate the model in this way. It can be assumed that in reality – when farmers are not limited to fixed optimization options – lower price increases would be necessary in order to make households react to the increasing fertilization prices. So the results in this scenario should be interpreted carefully. In addition, such a strong price increase is not realistic and would have strongly negative impacts on total gross margins, see Table 86.

Table 86. Total Gross Margins in the Scenario *Input Price Increase: Fertilization*

	Price Increase *(factor)*	**Total Gross Margin** (*¥ and initial Total Gross Margin)*
HH 1	11.90	¥340.32 (¥2,235.20)
HH 2	11.90	¥291.07 (¥7,462.85)
HH 3	11.90	¥606.17 (¥4,314.40)

These findings suggest that – within the limitations of the model – fertilization price increase is not an appropriate measure to reduce fertilization, as the resulting production combinations are congruent with the results in the scenario *Optimization under Current Conditions* – until unrealistically high prices of fertilization are reached. The optimized households carry a higher financial burden, but the environmental effects do not change compared to *Optimization under Current Conditions*. The effective price increase (by factor 11.9) would decrease total gross margins of the optimized households between 84.77% and 96.10%. Such a decreased total gross margin might represent a threat for the future of agriculture.

Consequently it can be summarized that, according to the results from the simulation and considering the limitations of the model, increasing input prices for fertilization does not represent an effective measure to comply with the goals of this work. Therefore no sensitivity analysis will be conducted for this scenario.

6.4.Input Price Change: Fertilization Subsidy

Unlike in the scenario *Input Price Increase: Fertilization*, in this scenario the prices for fertilization are decreased. The price decrease could be the result of (indirect) subsidies for fertilization. This scenario aims at determining the effectivity of such a policy. The initial prices in the model for fertilizers (from the survey) are:

- N: ¥3.95 per kg;
- P: ¥4.35 per kg;
- K: ¥2.97 per kg.

The simulation shows that only a subsidy to the extent that fertilizers are for free would create results which differ from the combination of optimization options in the scenario *Optimization under Current Conditions*. Again, it should be noted that the characteristics of the model also have impacts on these results. The operational range of the model is limited as it is using fixed optimization options instead of continuous production functions and can, thus, occasionally only react stepwise. Therefore the model is sometimes limited to operating in optimum ranges rather than optimum points, as intermediate might be lacking. However, in order to be able to integrate the optimization options which are derived from other studies and experiments (management measures and innovations) it was necessary to formulate the model in this way. It can be assumed that in reality – when farmers are not limited to fixed optimization options – lower price decreases would be necessary in order to make households react to the decreasing fertilization prices. So the results in this scenario should be interpreted carefully. Additionally such a strong subsidy is not realistic and might create negative environmental impacts (related to over use of fertilizers) which are not covered in this model. Therefore the findings suggest that – within the limitations of the model – also a fertilization subsidy does not have a significant effect on the optimized solution, as the resulting combinations of optimization options are congruent with *Optimization under Current Conditions* (see above). The environmental effects do not change compared to *Optimization under Current Conditions*. Only unrealistically high subsidies (fertilizers for free) would lead to small further changes of farming practices. Consequently it can be summarized that, according to the results from the simulation and considering the limitations of the model, subsidizing input prices for fertilization does not represent an effective measure to comply with the goals of this work. Therefore no sensitivity analysis will be conducted for this scenario.

6.5.Input Price Change: Introduction of Marginal Water Price

This scenario surveys the introduction of the marginal water price – which is ¥5.20 per m^3 – for the NCP (calculated by WORLDBANK (2007). So in the model the price for water is increased from ¥0.54 per m^3 (representing the current indirect water price) to ¥5.20 per m^3. It should be noted that such a strong price increase (by factor 9.63) is unrealistic and politically difficult to communicate, but as many studies agree: current price too low and the marginal water price represents a realistic measure to express all costs which are associated with water use in the NCP. In addition monitoring equipment is lacking in the NCP, which aggravates the introduction of such policies. However, this scenario aims at determining the effectivity of such a policy. Table 87 represents the results of the simulations in the scenario *Introduction of Marginal Water Price*.

Table 87. Simulation Results for the Scenario *Introduction of Marginal Water Price*

	SprM Peanut Intercropping *(mu and % of Total Available Area)*	**Optimized SM-WW** *(mu and % of Total Available Area)*	**Total Used Area** *(mu and % of Total Available Area)*
HH 1	1.24 (62.00%)	0.76 (38.00%)	2.00 (100.00%)
HH 2	1.94 (40.42%)	2.86 (59.58%)	4.80 (100.00%)
HH 3	2.66 (66.50%)	1.34 (33.50%)	4.00 (100.00%)

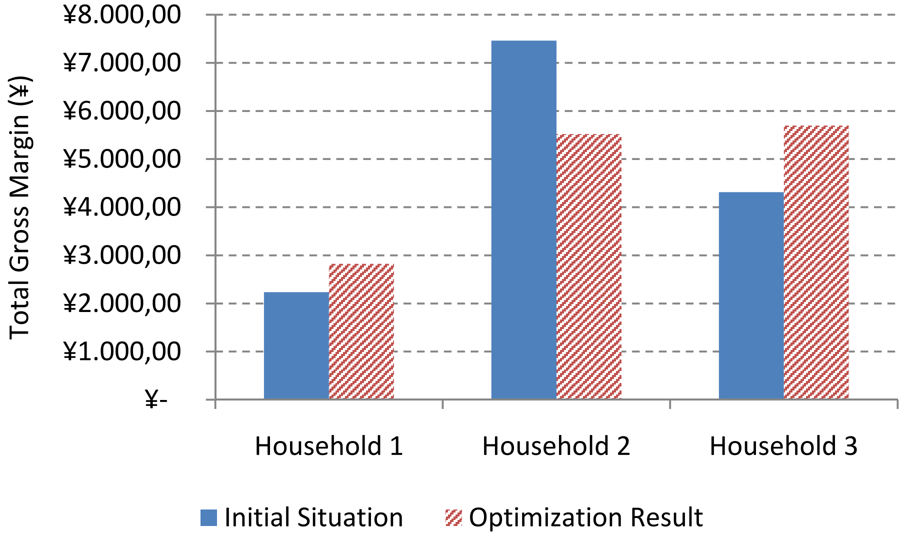
The optimization in the scenario *Introduction of Marginal Water Price* results in 100.00% land use of all selected households. The optimized cropping strategies of the selected households are comparable. Table 88 displays the production characteristics of the optimized solution in the scenario *Introduction of Marginal Water Price*.

Table 88. Production Characteristics of the Simulation in the Scenario *Introduction of Marginal Water Price*

	Total Maize *(kg and initial Total Maize)*	**Total Wheat** *(kg and initial Total Wheat)*	**Total Other Crop** *(kg and initial Total Other Crops)*	**Bought Crops** *(kg)*	**Total Gross Margin** *(¥ and initial Total Gross Margin)*
HH 1	2,568.00 (1,600.00)	732.00 (1,700.00)	Peanut: 356.26 (0.00)	0.00	¥2,825.27 (¥2,235.20)
HH 2	6,357.42 (5,280.00)	2,762.57 (3,840.00)	Peanut: 556.77 (0.00)	0.00	¥5,522.16 (¥7,462.85)
HH 3	5,103.63 (3,200.00)	1,296.37 (3,200.00)	Peanut: 762.24 (0.00)	0.00	¥5,701.13 (¥4,314.40)

It should be noted that in this scenario none of the selected households would produce more grain than required by the model. The results of the simulation in the scenario Introduction of Marginal Water Price lead to decreased production of wheat. The increased production amounts of maize can compensate for the decreased wheat production: total grain production of the optimization equals total grain production in the initial situation. The simulated result shows that all households would begin to produce peanuts. Figure 47 displays the total gross margins after the optimization in the scenario Introduction of *Marginal Water Price*.

Figure 47. Total Gross Margins in the Scenario *Introduction of Marginal Water Price*



The Optimization in this scenario leads to diverse effects on total gross margins; for HH1 it increases by +26.40%, for HH2 it decrease by -26.00% and for HH3 it increases by +32.14%. It is remarkable that the optimization of 2 of the 3 selected households can still increase gross margins, even though prices of water increased so strong. This can be explained by the fact that HH1 and HH3 had lower WUEs in the initial situation and the optimization significantly increased WUEs of the selected households (see Figure 48). In addition total water use decreased (see Figure 49). Table 89 displays which constraints are binding and which are not binding in this scenario.

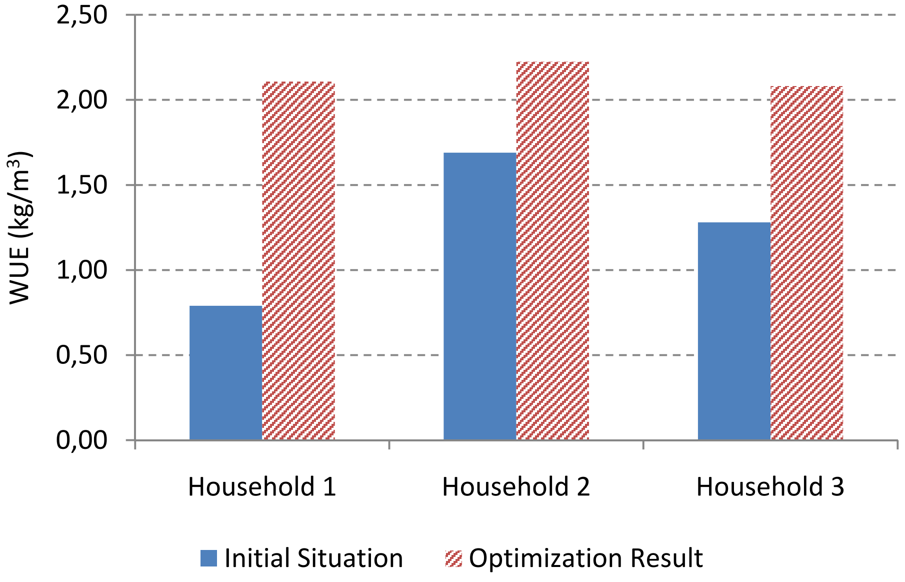
Table 89. Binding and not binding Constraints in the Scenario *Introduction of Marginal Water Price*

	HH1	**HH2**	**HH3**
Labor	Not Binding	Not Binding	Not Binding
Area	Binding	Binding	Binding
Total Irrigation	Binding	Binding	Binding
Total N/P/K Fertilization	Binding	Binding	Binding
Total N/P/K Manure	Binding	Binding	Binding
Total Grain Production	Binding	Binding	Binding
Own Consumption Maize	Binding	Binding	Binding
Own Consumption Wheat	Binding	Binding	Binding

The only not binding constraint in this scenario is *Labor*, as the households still have available labor resources. All other constraints are binding. The sensitivity analysis, by means of the reduced cost values, surveys by which amount the value of the variable has to increase in order to change the current optimal solution. All variables which are included in the current optimum solution have reduced cost values of ¥0.00. Variables with low reduced cost values require only small changes to be included in a new optimal solution under unchanged conditions. The price increases of all variables (i.e. reduced cost values) which are necessary to change the optimal solution are displayed in Annex 20. The mean reduced cost value of the optimization options (excl. *Farmers' Practice*) is ¥2,377.14 – this indicates that the uncertainty of this scenario is low as most optimization options have high reduced cost values; in addition it is the third largest mean reduced cost value from all optimized results. In this scenario, the shadow price for area is ¥3,781.95 which means that one more mu land would increase the optimum result by the respective amounts. The shadow price for total grain is ¥1.21 per kg, which means that if the minimum required amount for total grain production would increase by 1 kg, the optimal solution would decrease by that amount. In the optimum solution, considering that the current prices of renting land in the research area are very low compared to the shadow price (see part 4.2.2), it would be advisable to rent additional land for the surveyed households.

To assess the environmental impacts of the optimization in the scenario *Introduction of Marginal Water Price* the performances of the selected environmental indicators are analyzed. Figure 48 displays the Total WUEs of maize and wheat after the optimization in the scenario *Introduction of Marginal Water Price*.

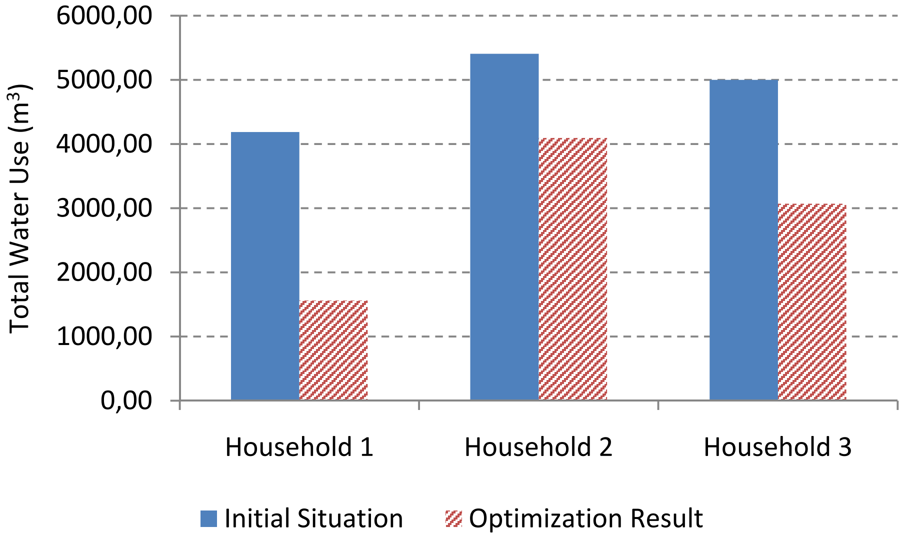
Figure 48. Total Water Use Efficiencies in the Scenario *Introduction of Marginal Water Price***



NOTE: *of maize and wheat

The scenario *Introduction of Marginal Water Price* has positive effects on the Total WUE of maize and wheat of all optimized households. The optimization increases WUE of HH1 by +166.93%, the WUE of HH2 – which was the highest in the initial situation – still increases by +31.69% and the WUE of HH3 increases by +62.72%. It should be noted the all WUEs are above 2.00 kg/m^3 – which represents a rough threshold for efficient water use (see part 2.4.2). Therefore the effect of an introduction of the marginal water price on WUEs can be estimated to be positive. Figure 49 compares the total water use per household in the initial situation and after the optimization in the scenario *Introduction of Marginal Water Price*.

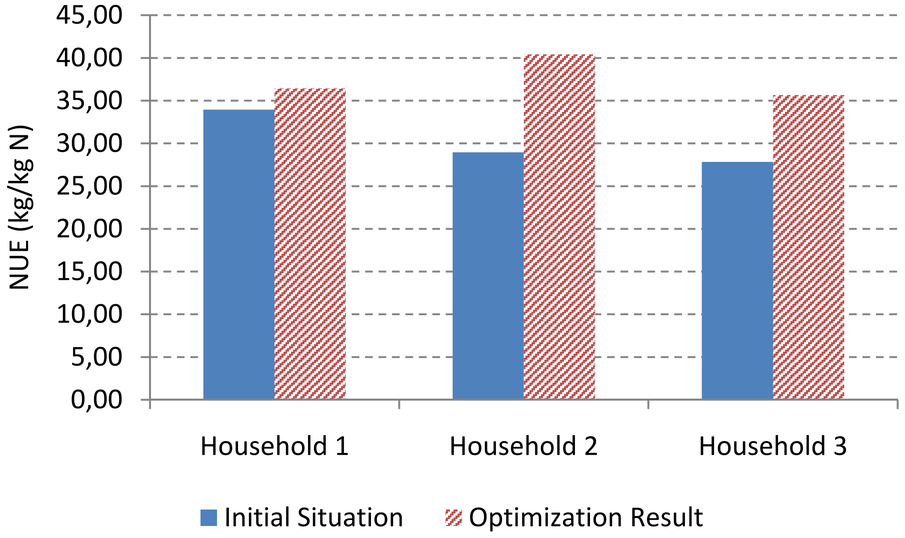
Figure 49. Total Water Use in the Scenario *Introduction of Marginal Water Price*



As can be expected, the total water use of all included households is decreasing in the scenario *Introduction of Marginal Water Price*. The total water use in HH1 decreases by -62.62%, by -24.22% in HH2 and by -38.54% in HH3. In Table 73 it was already demonstrated that the water balance of HH1 in the initial situation indicates a strong over use – so the effects of the optimization (i.e. the decreased total water use) are the largest for HH1.

It should be noted that the water balances of the optimization processes cannot be displayed, as necessary data for the calculations for *Optimized SM-WW* are lacking. Figure 50 presents the resulting NUEs of the scenario *Introduction of Marginal Water Price*.

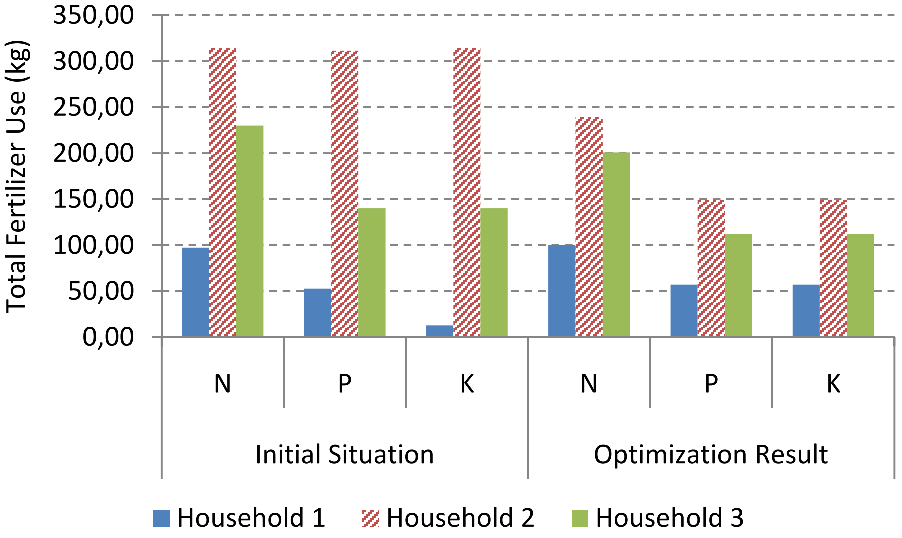
Figure 50. Total Nitrogen Use Efficiencies in the Scenario *Introduction of Marginal Water Price **



NOTE: *of fertilization

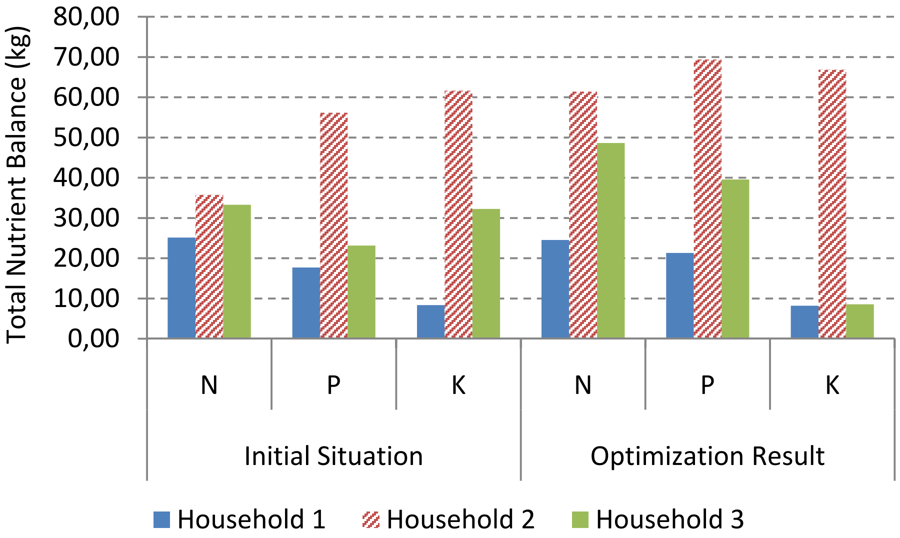
Compared to the NUEs in the initial situation, the optimization in the scenario *Introduction of Marginal Water Price* improves the NUEs: HH1 by +7.35%, HH2 by 39.58% and HH3 by 28.12%. HH1 has the highest NUE in the initial situation; therefore the resulting increase of the optimization is the smallest. However, a slightly positive effect of the introduction of the marginal water price on NUE can be assumed. Figure 51 compares the total fertilizer use in the initial situation and in the scenario *Introduction of Marginal Water Price*.

Figure 51. Total Fertilizer Use in the Scenario *Introduction of Marginal Water Price*



As can be seen in Figure 51, the total amounts of all nutrients applied by fertilization are not uniform in the results of the scenario *Introduction of Marginal Water Price*. The total fertilizer use of HH1 is increasing (N = +3.21%, P = +8.12% and K = +345.99%), whereas the total fertilizer use of HH2 (N = -23.86%, P = -52.01% and K = -52.45%) and HH3 are decreasing (N = -12.67%, P = -19.93% and K = -19.93%). One explanation for the increased use of fertilization of HH1 might be that in the initial situation (see Table 73) HH1 was fertilizing maize with only very small amounts and did not apply K fertilization for wheat. The resulting total nutrient balances are displayed in Figure 52.

Figure 52. **Total Nutrient Balances in the Scenario *Introduction of Marginal Water Price****



NOTE: * total nutrient balance includes summer maize, spring maize and winter wheat

Also the effects of the scenario *Introduction of Marginal Water Price* on the resulting total nutrient balances are not uniform for the optimized households:

- HH1: N = -2.34%, P = +20.42% and K = -1.86%;
- HH2: N = +71.64%, P = +23.59% and K = +8.48%;
- HH3: N = +46.65%, P = +71.12% and K = -73.45%.

Concluding it can be stated that an introduction of the marginal water price might lead to increased P fertilization.

The simulated effects of the *Introduction of Marginal Water Price* can be summarized:

- Not uniform/meaningful results considering fertilization use and nutrient balances;
- Decreased total water use;
- Strongly increased WUE;
- Increased NUE;
- Total food production increases (grain production remains unchanged);
- Not uniform effects on total gross margin;

Therefore it can be concluded that the simulation of the introduction of the marginal water price does not have uniform environmental and economic effects. Thus, it might not be an effective measure for all households to comply with the goals of this work.

6.6. Input Price Change: Pesticides

Pesticides also represent an important input for agricultural production in the NCP. The use of pesticides can also be related to negative environmental effects in the research area. Therefore this scenario tests the effects of an introduction of a policy which increases the price of pesticides. This scenario also aims at determining the effectivity of such a policy.

Normally (as described in part 5.2.2), pesticide costs are included in the specific costs. For this scenario, however, pesticide costs are integrated into the model as variables for the optimization of the households. Consequently the pesticide costs of each optimization option (see Table 73) were increased from the initial situation. Table 90 shows that the resulting combinations of optimization options in *Input Price Change: Pesticides* do not differ from *Optimization under Current Conditions* until the pesticide prices are increased by factor 23.33.

Table 90. Total Gross Margins in the Scenario *Input Price Change: Pesticides*

	Price Increase *(factor)*	**Total Gross Margin** (¥ *and initial Total Gross Margin)*
HH 1	23.33	¥4,037.76 (¥2,235.20)
HH 2	23.33	¥8,808.65 (¥7,462.85)
HH 3	23.33	¥8,063.06 (¥4,314.40)

Such a high price increase is unrealistic and not wanted; in addition it might not be politically realizable. Again, it should be noted that the characteristics of the model also have impacts on these results. The operational range of the model is limited as it is using fixed optimization options instead of continuous production functions and can, thus, occasionally only react stepwise. Therefore the model is sometimes limited to operating in optimum ranges rather than optimum points, as intermediate might be lacking. However, in order to be able to integrate the optimization options which are derived from other studies and experiments (management measures and innovations) it was necessary to formulate the model in this way. It can be assumed that in reality – when farmers are not limited to fixed optimization options – lower price changes would be necessary in order to make households react to changing pesticide prices. So the results in this scenario should be interpreted carefully.

The simulation showed that – within the limitations of the model – an increase of pesticide prices does not have a strong impact on the production strategies of the selected households. Consequently the environmental analysis for *Input Price Change: Pesticides* is not conducted – as the resulting production combinations are only differing from *Optimization under Current Conditions* when the pesticide prices are strongly increased.

Consequently it can be summarized that, according to the results from the simulation and considering the limitations of the model, increasing input prices for pesticides does not represent an effective measure to comply with the goals of this work. Therefore no sensitivity analysis will be conducted for this scenario.

6.7.Output Price Increase: Maize

The scenario *Output Price Increase: Maize* surveys the effects of rising prices for maize. This price increase can be the result of increased demand due to economic growth or increased demand for feed. It can also be the result of governmental support purchases or subsidies. This scenario aims at determining the effectivity of such a policy. The selling price of maize in the model is changed (from ¥1.46 per kg in the initial situation) to ¥3.08 per kg (by factor

2.11). It should be noted that in reality maize and wheat prices are linked up and that in the NCP maize is usually grown in combination with wheat, but the separate study of maize and wheat prices is, however, important for the analysis. Accordingly the price for buying maize is changed proportionally from ¥2.92 per kg in the initial situation to ¥6.16 per kg. Table 92 presents the results of the simulation of the scenario *Output Price Increase: Maize*.

Table 91. Simulation Results for the Scenario *Output Price Increase: Maize*

	SM-WW Balanced Input Use I *(mu and % of Total Available Area)*	**Total Used Area** *(mu and % of Total Available Area)*
HH 1	2.00 (100.00%)	2.00 (100.00%)
HH 2	4.80 (100.00%)	4.80 (100.00%)
HH 3	4.00 (100.00%)	4.00 (100.00%)

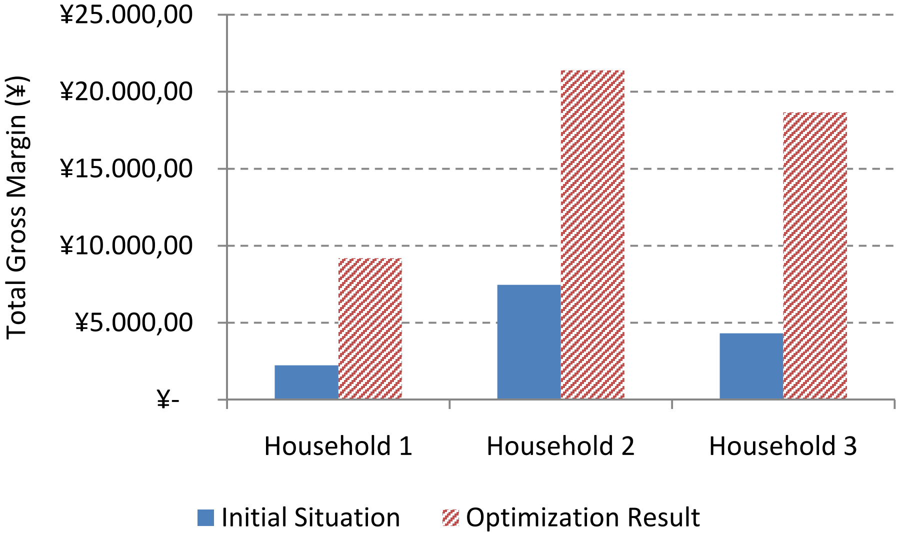
The optimization in the scenario *Output Price Increase: Maize* results in 100.00% land use of all selected households. It is remarkable that all selected households solely produce *SM-WW Balanced Input Use I* – this optimization option has very high maize yields and the second highest total grain yields. Table 92 presents the production characteristics of the simulation in the scenario *Output Price Increase: Maize*.

Table 92. Production Characteristics of the Simulation in the Scenario *Output Price Increase: Maize*

	Total Maize *(kg and initial Total Maize)*	**Total Wheat** *(kg and initial Total Wheat)*	**Total Other Crop** *(kg and initial Total Other Crops)*	**Bought Crops** *(kg)*	**Total Gross Margin** *(¥ and initial Total Gross Margin)*
HH 1	2,800.00 (1,600.00)	2,400.00 (1,700.00)	0.00 (0.00)	0.00	¥9,185.71 (¥2,235.20)
HH 2	6,720.00 (5,280.00)	5,760.00 (3,840.00)	0.00 (0.00)	0.00	¥21,394.01 (¥7,462.85)
HH 3	5,600.00 (3,200.00)	4,800.00 (3,200.00)	0.00 (0.00)	0.00	¥18,666.62 (¥4,314.40)

All households produce more grain than in the initial situation (HH1: +57.58%, HH2: +38.64% and HH3: +62.50%). As wheat is grown in combination with maize in the high yielding optimization option *SM-WW Balanced Input Use I*, also wheat production increases even though wheat prices remain constant in this scenario. No household begins to produce another crop in the scenario *Output Price Increase: Maize*. As displayed in Figure 53, the optimization results in increased total gross margins of all selected household.

Figure 53. Total Gross Margins in the Scenario *Output Price Increase: Maize*



In the scenario *Output Price Increase: Maize* the total gross margins of all selected households increase strongly (HH1: +310.96%, HH2: +186.67% and HH3: +332.66%). Consequently increased output prices for maize are potentially an adequate measure to increase gross margins and, thus, households' income. Table 93 displays which constraints are binding and which are not binding in this scenario.

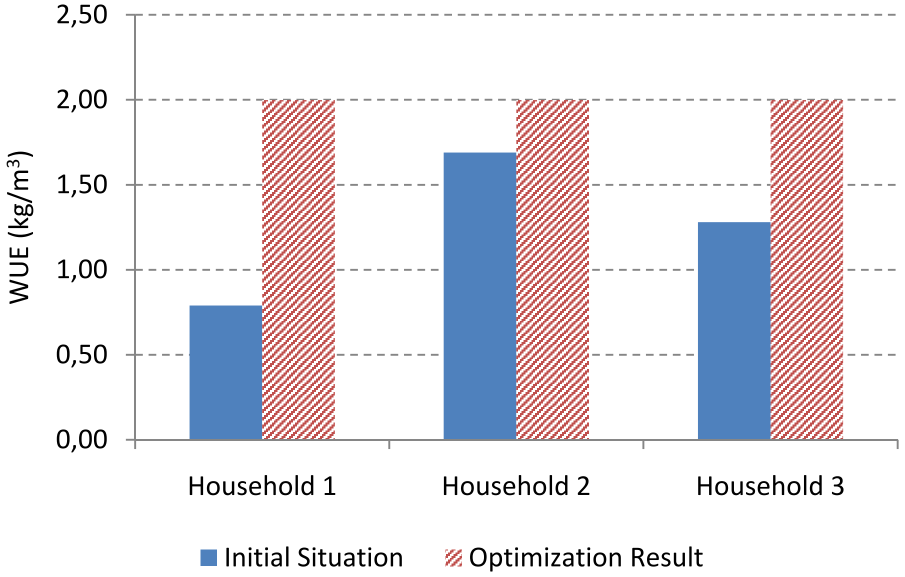
Table 93. **Binding and not binding Constraints in the Scenario *Output Price Increase: Maize***

	HH1	HH2	HH3
Labor	Not Binding	Not Binding	Not Binding
Area	Binding	Binding	Binding
Total Irrigation	Binding	Binding	Binding
Total N/P/K Fertilization	Binding	Binding	Binding
Total N/P/K Manure	Binding	Binding	Binding
Total Grain Production	Not Binding	Not Binding	Not Binding
Own Consumption Maize	Binding	Binding	Binding
Own Consumption Wheat	Binding	Binding	Binding

The constraints *Labor* and *Total Grain Production* are not binding in this scenario, because the households still have remaining labor capacities after the optimization and because the total grain production exceeds the minimum required amount. The sensitivity analysis, by means of the reduced cost values, surveys by which amount the value of the variable has to increase in order to change the current optimal solution. All variables which are included in the current optimum solution have reduced cost values of ¥0.00. Variables with low reduced cost values require only small changes to be included in a new optimal solution under unchanged conditions. The price increases of all variables (i.e. reduced cost values) which are necessary to change the optimal solution are displayed in Annex 21. The mean reduced cost value of the optimization options (excl. *Farmers' Practice*) is ¥1,483.75 – this indicates that the uncertainty of this scenario is low as most optimization options have high reduced costs. In the scenario *Output Price Increase: Maize*, the shadow price for area is ¥5,131.17 this means that one more mu land would increase the optimum result by the respective amount – this is the third highest result of all optimized results. The shadow price for total grain is ¥0.00 as the constraint is not binding in this scenario and production exceeds the minimum required amount. In the optimum solution, considering that the current prices of renting land in the research area are very low compared to the shadow price (see part 4.2.2), it would be advisable to rent additional land for the surveyed households.

To assess the environmental impacts of the optimization in the scenario *Output Price Increase: Maize* the performances of the selected environmental indicators are analyzed. Figure 54 displays the Total WUEs of maize and wheat after the optimization.

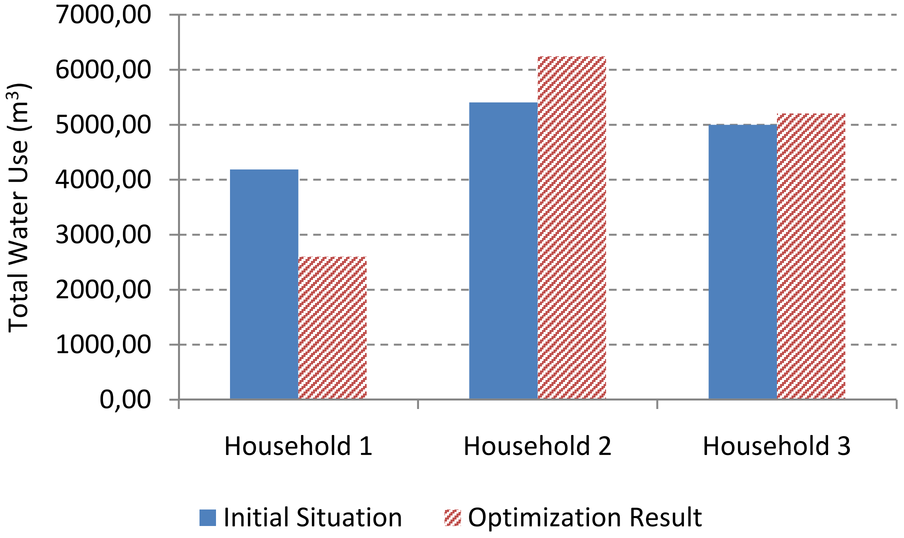
Figure 54. Total Water Use Efficiencies in the Scenario *Output Price Increase: Maize* *



NOTE: *of maize and wheat

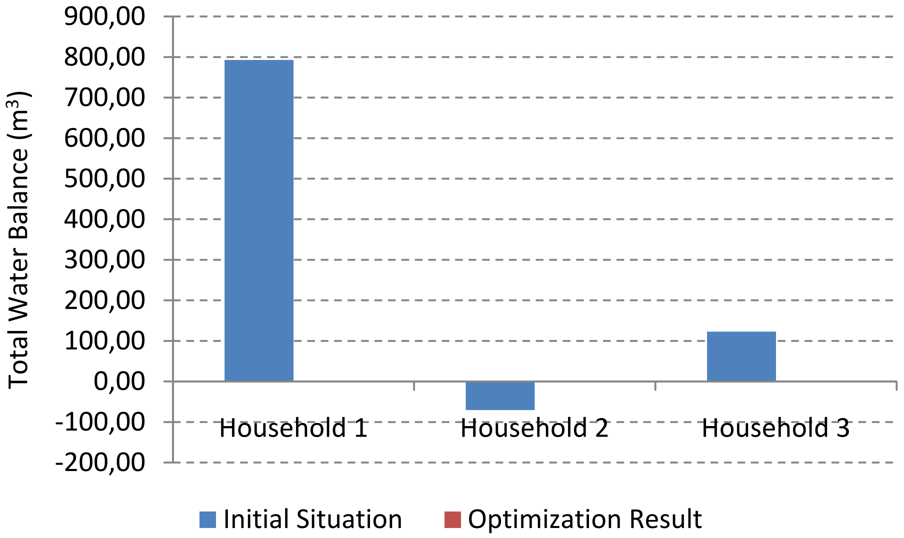
The output price increase for maize also has positive impacts on total WUEs of the selected households; it increases by +152.95% for HH1, by +18.24% for HH2 and by +56.12% for HH3. HH1 had the lowest total WUE in the initial situation, so the increase is the largest; HH2 had the highest WUE in the initial situation, so the increase is the smallest. Since all households produce solely *SM-WW Balanced Input Use I* the WUE of all households is 2.00 m^3 per kg – which represents a rough threshold for efficient water use. Therefore the effect of higher prices for maize on WUEs can be estimated to be positive. Figure 55 compares the total water use per household in the initial situation and after the optimization in the scenario *Output Price Increase: Maize*.

Figure 55. **Total Water Use in the Scenario *Output Price Increase: Maize***



The optimization results lead only for HH1 to decreased total water use (-37.85%) – which can be explained by the inefficient water use in the initial situation; for HH2 (+15.49%) and HH3 (+4.09%) the total water use is increasing. An increased total water use is not in accordance with the goals of this work. The resulting total water balances are displayed in Figure 56.

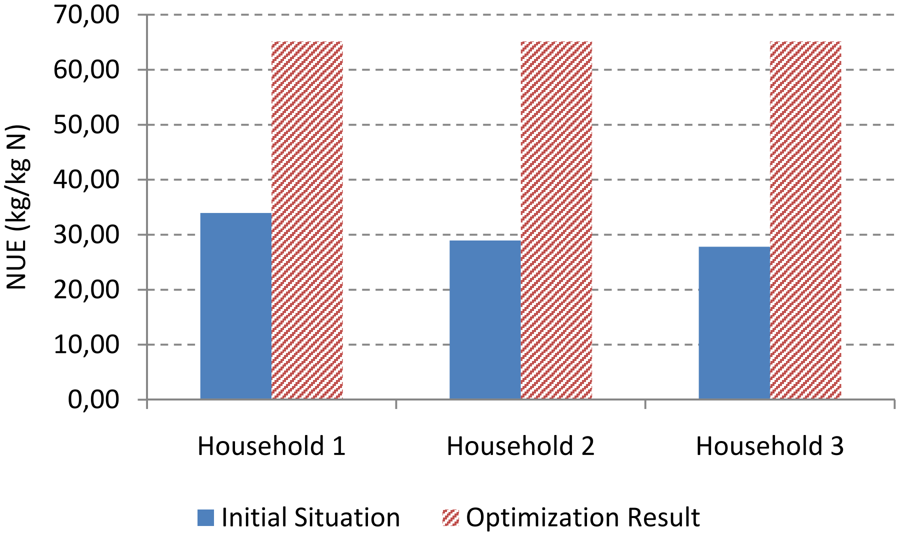
Figure 56. **Total Water Balance in the Scenario *Output Price Increase: Maize* *' ****



NOTE: *the calculation of the water balance is described in Table 62
**total water balance includes summer maize, spring maize and winter wheat

In *SM-WW Balanced Input Use I* only those amounts are irrigated which are needed to meet the expected potential water use, so the total water balance is evened out; therefore the total water balances in the scenario *Output Price Increase: Maize* are also equated. An even total water balance is a desired goal of this work. Figure 57 displays the resulting NUEs in the scenario *Output Price Increase: Maize*.

Figure 57. Total Nitrogen Use Efficiencies in the Scenario *Output Price Increase: Maize**

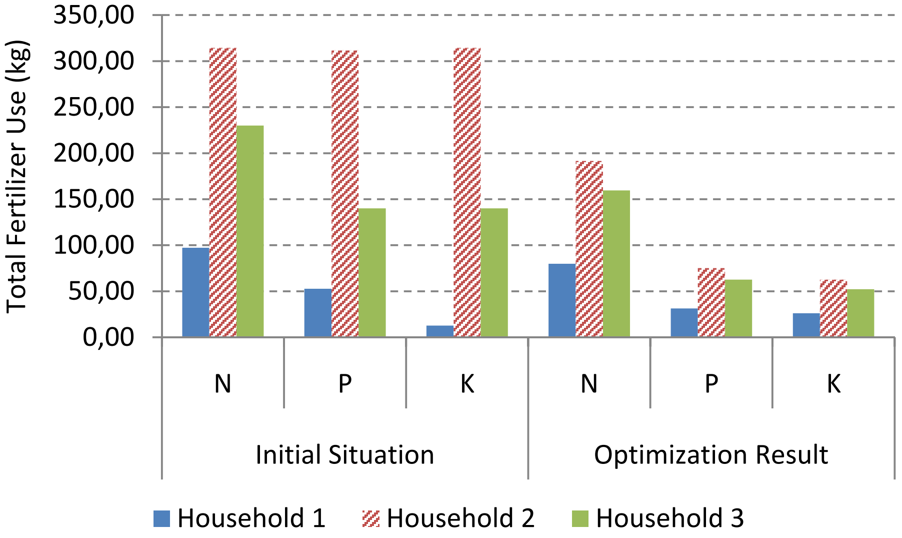


NOTE: *of fertilization

Figure 57 shows that the effect of the price increase of maize on NUEs is positive, as they increase for all integrated households. The NUE increases by +91.89% for HH1, by +124.95% for HH2 and by +134.09% for HH3. To improve resource use efficiency (for N fertilization) is a goal of this work. It is remarkable that all selected households have identical NUE values. This can be explained by the fact that solely *SM-WW Balanced Input Use I* is produced in the scenario *Output Price Increase: Maize* – this optimization option fertilizes only according to the demand of the crops.

Figure 58 compares the total fertilizer use in the initial situation and in the scenario *Output Price Increase: Maize*.

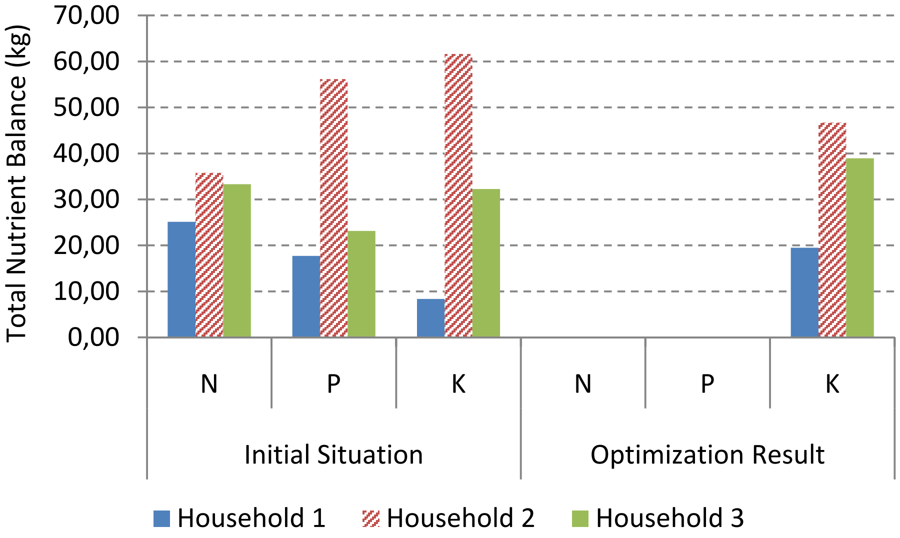
Figure 58. Total Fertilizer Use in the Scenario *Output Price Increase: Maize*



The results of the simulation in the scenario *Output Price Increase: Maize* indicate that total fertilizer use of the optimized households generally decreases. Except for K fertilization of

HH1, which increases by +103.91% (as in the initial situation HH1 was fertilizing maize with exceptionally small amounts and did not apply K fertilization for wheat (see Table 73). Otherwise all households apply fewer nutrients through fertilization: HH1 (N = -17.88% and P = -40.68%), HH2 (N = -39.07%, P = -75.87% and K = -80.08%) and HH3 (N = -30.59%, P = -55.26% and K = -62.71%). Decreasing total fertilizer use is in accordance with the goals of this work. The resulting total nutrient balances are displayed in Figure 59.

Figure 59. Total Nutrient Balances in the Scenario *Output Price Increase: Maize**



NOTE: * total nutrient balance includes summer maize, spring maize and winter wheat

In *SM-WW Balanced Input Use I* fertilization is adjusted according to the expected absorption of the expected yields so the nutrient balances are evened. Consequently also the resulting nutrient balances in the scenario *Output Price Increase: Maize* are evened out: N and P excesses are reduced by 100.00% for all selected households. The effects on the nutrient balance of K are diverse: the excesses of HH1 and HH3 are increased (+132.70% for HH1 and +20.71% for HH3), whereas the excess of HH2 is decreased (HH2: -24.19%). An evened nutrient balance is in accordance with the objectives of this work.

The simulated effects of the scenario *Output Price Increase: Maize* can be summarized:

- Total fertilizer use decreases;
- WUE improves;
- NUE improves;
- Total nutrient balances of N and P are evened out;
- Total water balances are evened out;
- Effects on total water use are inconclusive;
- Increases grain production;
- Strongly increased total gross margin.

If optimized management options are applied (like in the optimum result), increased prices of maize can even lead to improved environmental effects. However, it is doubtful that in reality – where farmers are not limited to the available optimization options – increased maize prices would always lead to improved environmental effects. Therefore the effectivity of such a policy and the transferability of the simulated results are questionable.

6.8. *Output Price Increase: Wheat*

Similar to the scenario *Output Price Increase: Maize*, the scenario *Output Price Increase: Wheat* surveys the effects of rising prices for wheat. This price increase can be the result of increased demand due to economic growth or increased demand for feed. It can also be the result of governmental support purchases or subsidies. This scenario aims at determining the effectivity of such a policy. The selling price of wheat in the model is changed (from ¥1.55 per kg in the initial situation) to ¥3.27 per kg (like in the scenario *Output Price Increase: Maize* by factor 2.11). It should be noted that in reality wheat and maize prices are linked up and that in the NCP wheat is usually grown in combination with maize, but the separate study of wheat and maize prices is, however, important for the analysis. Accordingly the price for buying wheat is changed proportionally from ¥3.10 per kg in the initial situation to ¥6.54 per kg. Table 94 presents the results of the simulation of the scenario *Output Price Increase: Wheat*.

Table 94. Simulation Results for the Scenario *Output Price Increase: Wheat*

	SM-WW Balanced Input Use I *(mu and % of Total Available Area)*	**Total Used Area** *(mu and % of Total Available Area)*
HH 1	2.00 (100.00%)	2.00 (100.00%)
HH 2	4.80 (100.00%)	4.80 (100.00%)
HH 3	4.00 (100.00%)	4.00 (100.00%)

The resulting combinations of production options equal those in *Output Price Increase: Maize*. The optimization in the scenario *Output Price Increase: Wheat* results in 100.00% land use of all selected households. It is remarkable that all selected households solely produce *SM-WW Balanced Input Use I* – this optimization option has the second highest total grain yields. As wheat is grown in combination with maize in the high yielding optimization option *SM-WW Balanced Input Use* I, also maize production increases even though maize prices remain constant in this scenario. Table 95 presents the total gross margins in the scenario *Output Price Increase: Wheat*.

Table 95. Total Gross Margins in the Scenario *Output Price Increase: Wheat*

	Price Increase *(factor)*	**Total Gross Margin** (*¥ and initial Total Gross Margin)*
HH 1	2.11	¥8,585.20 (¥2,235.20)
HH 2	2.11	¥21,862.21 (¥7,462.85)
HH 3	2.11	¥16,291.22 (¥4,314.40)

In the scenario *Output Price Increase: Wheat* the total gross margins of all selected households increase strongly (HH1: +284.09%, HH2: +192.95% and HH3: +277.60%). Consequently increased output prices for wheat are potentially an adequate measure to increase gross margins and, thus, households' income. However, compared to the scenario *Output Price Increase: Maize* the price increase in this scenario is smaller. Since the resulting production combinations are congruent with *Output Price Increase: Maize*, the environmental effects of this scenario can be consulted in 6.7.

The binding constraints are also equal to *Output Price Increase: Maize*, so they are displayed in Table 93. The sensitivity analysis, by means of the reduced cost values, surveys by which amount the value of the variable has to increase in order to change the current optimal solution. All variables which are included in the current optimum solution have reduced cost values of ¥0.00. Variables with low reduced cost values require only small changes to be included in a new optimal solution under unchanged conditions. The price increases of all variables (i.e. reduced cost values) which are necessary to change the optimal solution are displayed in Annex 22. The mean reduced cost value of the optimization options (excl. *Farmers' Practice*) is ¥2,051.37 – this indicates that the uncertainty of this scenario is low as most optimization options have high reduced cost values. In the scenario *Output Price Increase: Wheat*, the shadow price for area is ¥4,926.93 – this means that one more mu land would increase the optimum result by the respective amount. The shadow price for total grain is ¥0.00 as the constraint is not binding in this scenario and production exceeds the minimum required amount. In the optimum solution, considering that the current prices of renting land in the research area are very low compared to the shadow price (see part 4.2.2), it would be advisable to rent additional land for the surveyed households.

The simulated effects of the scenario *Output Price Increase: Wheat* can be summarized:

- Same resulting combination of production options and, thus, congruent environmental effects with *Output Price Increase: Maize*;
- Strongly increased total gross margin.

If optimized management options are applied (like in the optimum result), increased prices of wheat can even lead to improved environmental effects. However, it is doubtful that in reality – where farmers are not limited to the available optimization options – increased wheat prices would always lead to improved environmental effects. Therefore the effectivity of such a policy and the transferability of the simulated results are questionable.

6.9. Output Price Increase: SM-WW

Similar to the scenario *Output Price Increase: Maize* and *Output Price Increase: Wheat*, the scenario *Output Price Increase: SM-WW* surveys the effects of simultaneously rising prices for maize and wheat. These price increases can be the result of increased demand due to economic growth or increased demand for feed. It can also be the result of governmental support purchases or subsidies. The aim of this scenario is also to determine the effectivity of such a policy. Since maize and wheat are typically grown together, in this scenario both prices are raised simultaneously. The selling prices of maize and wheat in the model are increased by factor 1.5; for maize from ¥1.46 per kg in the initial situation to ¥2.19 per kg and for wheat from ¥1.55 per kg in the initial situation to ¥2.33 per kg. Consequently in this scenario maize and wheat prices are linked up. Accordingly the price for buying maize is changed proportionally from ¥2.92 per kg in the initial situation to ¥4.38 per kg and for wheat from ¥3.10 per kg in the initial situation to ¥4.65 per kg. Table 94 presents the results of the simulation of the scenario *Output Price Increase: SM-WW*.

Table 96. Simulation Results for the Scenario *Output Price Increase: SM-WW*

	SM-WW Balanced Input Use I *(mu and % of Total Available Area)*	**Total Used Area** *(mu and % of Total Available Area)*
HH 1	2.00 (100.00%)	2.00 (100.00%)
HH 2	4.80 (100.00%)	4.80 (100.00%)
HH 3	4.00 (100.00%)	4.00 (100.00%)

The resulting combinations of production options equal those in *Output Price Increase: Maize* and *Output Price Increase: Wheat* – as the scenarios have comparable aims. The optimization in the scenario *Output Price Increase: SM-WW* results in 100.00% land use of all selected households. It is remarkable that all selected households solely produce *SM-WW Balanced Input Use I* – this optimization option has the second highest total grain yields. Table 97 presents the total gross margins in the scenario *Output Price Increase: SM-WW*.

Table 97. Total Gross Margins in the Scenario *Output Price Increase: SM-WW*

	Price Increase *(factor)*	**Total Gross Margin** (*¥ and initial Total Gross Margin)*
HH 1	1.50	¥8,497.65 (¥2,235.20)
HH 2	1.50	¥20,686.28 (¥7,462.85)
HH 3	1.50	¥16,713.32 (¥4,314.40)

In the scenario *Output Price Increase: SM-WW* the total gross margins of all selected households increase strongly (HH1: +280.17%, HH2: +177.19% and HH3: +287.38%). Consequently increased output prices for maize and wheat are potentially an adequate measure to increase gross margins and, thus, households' income. However, compared to the scenario *Output Price Increase: Maize* the price increase in this scenario is smaller. Since the resulting production combinations are congruent with *Output Price Increase: Maize*, the environmental effects of this scenario can be consulted in 6.7.

The binding constraints are also equal to *Output Price Increase: Maize*, so they are displayed in Table 93. The sensitivity analysis, by means of the reduced cost values, surveys by which amount the value of the variable has to increase in order to change the current optimal solution. All variables which are included in the current optimum solution have reduced cost values of ¥0.00. Variables with low reduced cost values require only small changes to be included in a new optimal solution under unchanged conditions. The price increases of all variables (i.e. reduced cost values) which are necessary to change the optimal solution are displayed in Annex 23. The mean reduced cost value of the optimization options (excl. *Farmers' Practice*) is ¥1,675.76 – this indicates that the uncertainty of this scenario is low as most optimization options have high reduced costs. In the scenario *Output Price Increase: SM-WW*, the shadow price for area is ¥4,814.33 – this means that one more mu land would increase the optimum result by the respective amount. The shadow price for total grain is ¥0.00 as the constraint is not binding in this scenario and production exceeds the minimum required amount. In the optimum solution, considering that the current prices of renting land in the research area are very low compared to the shadow price (see part 4.2.2), it would be advisable to rent additional land for the surveyed households.

The simulated effects of the scenario *Output Price Increase: SM-WW* can be summarized:

- Same resulting combination of production options and, thus, congruent environmental effects with *Output Price Increase: Maize*;
- Strongly increased total gross margin.

If optimized management options are applied (like in the optimum result), increased prices of maize and wheat can even lead to improved environmental effects. However, it is doubtful that in reality – where farmers are not limited to the available optimization options – increased maize and wheat prices would always lead to improved environmental effects. Therefore the effectivity of such a policy and the transferability of the simulated results are questionable.

6.10.Output Price Increase: Soy

Similar to the previous output price increase scenarios, the scenario *Output Price Increase: Soy* surveys the effect of rising soybean prices. The price increase can be the result of increased demand for feed – considering the growing demand for meat in China. It can also be the result of governmental support purchases or subsidies to strengthen the national soybean production. The aim of this scenario is also to determine the effectivity of such a policy. The selling prices of soybeans in the model are increased from ¥2.96 per kg in the initial situation.

The simulation shows that only price increases by factor 3.59 (¥10.63 per kg) would create results which differ from the combination of production options in the scenario *Optimization under Current Conditions*. Such a strong price increase is not realistic, but – as can be seen in Table 98 – would have positive impacts on total gross margin.

Table 98. Total Gross Margins in the Scenario *Output Price Increase: Soy*

	Price Increase *(factor)*	**Total Gross Margin** (*¥ and initial Total Gross Margin)*
HH 1	3.59	¥5,894.77 (¥2,235.20)
HH 2	3.59	¥13,755.76 (¥7,462.85)
HH 3	3.59	¥11,690.22 (¥4,314.40)

It should be noted that the characteristics of the model also have impacts on these results. The operational range of the model is limited as it is using fixed optimization options instead of continuous production functions and can, thus, occasionally only react stepwise. Therefore the model is sometimes limited to operating in optimum ranges rather than optimum points, as intermediate might be lacking. However, in order to be able to integrate the optimization options which are derived from other studies and experiments (management measures and innovations) it was necessary to formulate the model in this way. It can be assumed that in reality – when farmers are not limited to fixed optimization options – lower price increases would be necessary in order to make households react to the increasing soybean prices. So the results in this scenario should be interpreted carefully. Considering the proportionally high price increase of soybeans the resulting increase of total gross margin is small compared to other scenarios. These findings suggest that – within the limitations of the model – an increase of soybean prices is not an appropriate measure, as the resulting production combination is congruent with the results in the scenario *Optimization under Current Conditions* – until strong price increases for soybean have been reached.

Consequently it can be summarized that, according to the results from the simulation and considering the limitations of the model, increasing output prices for soybeans does not represent an effective measure to comply with the goals of this work. Therefore no sensitivity analysis will be conducted for this scenario.

6.11. Output Price Increase: Peanut

Similar to the previous output price increase scenarios, the scenario *Output Price Increase: Peanut* surveys the effect of rising peanut prices. The price increase can be the result of increased demand. It can also be the result of governmental support purchases or subsidies to strengthen the national peanut production. The aim of this scenario is also to determine the effectivity of such a policy. The selling prices of peanuts in the model are increased (by factor 1.5) from ¥7.70 per kg in the initial situation to ¥11.55 per kg. Table 99 represents the results of the simulations in the scenario *Output Price Increase: Peanut*.

Table 99. Simulation Results for the Scenario *Output Price Increase: Peanut*

	SprM Peanut Intercropping *(mu and % of Total Available Area)*	**SM-WW Balanced Input Use I** *(mu and % of Total Available Area)*	**Total Used Area** *(mu and % of Total Available Area)*
HH 1	1.37 (68.50%)	0.63 (31.50%)	2.00 (100.00%)
HH 2	2.42 (50.42%)	2.38 (49.58%)	4.80 (100.00%)
HH 3	2.88 (72.00%)	1.12 (28.00%)	4.00 (100.00%)

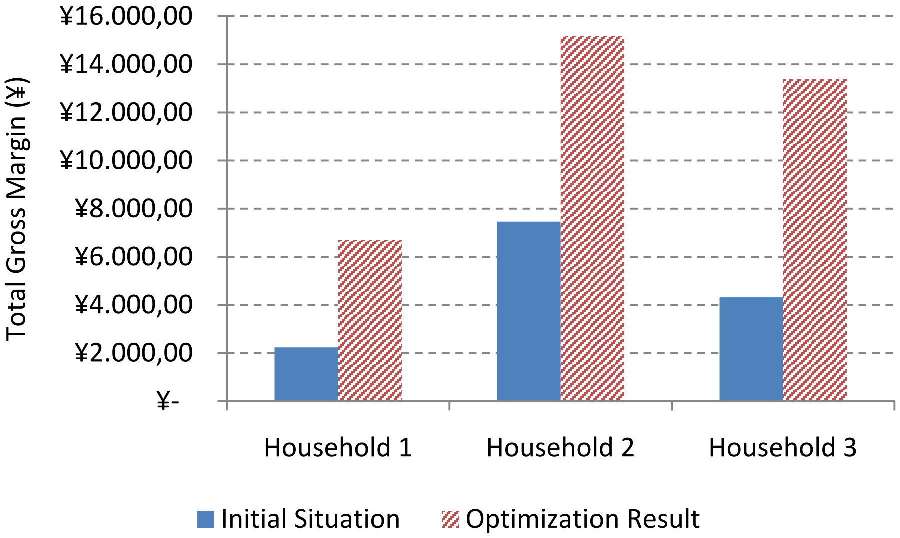
The optimization in the scenario Output Price Increase: Peanut results in 100.00% land use of all selected households. The optimized cropping strategies of the selected households are comparable: all households produce SprM Peanut Intercropping and SM-WW Balanced Input Use I with a tendency to produce SprM Peanut Intercropping on a larger scale. It should be noted that SprM Peanut Intercropping is the only optimization option which includes the production of peanuts. Table 100 displays the production characteristics of the optimized solution in the scenario Output Price Increase: Peanut.

Table 100. Production Characteristics of the Simulation in the Scenario *Output Price Increase: Peanut*

	Total Maize *(kg and initial Total Maize)*	**Total Wheat** *(kg and initial Total Wheat)*	**Total Other Crop** *(kg and initial Total Other Crops)*	**Bought Crops** *(kg)*	**Total Gross Margin** *(¥ and initial Total Gross Margin)*
HH 1	2,544.21 (1,600.00)	755.79 (1,700.00)	Peanut: 392.79 (0.00)	0.00	¥6,694.07 (¥2,235.20)
HH 2	6,267.66 (5,280.00)	2,852.34 (3,840.00)	Peanut: 694.62 (0.00)	0.00	¥15,169.25 (¥7,462.85)
HH 3	5,061.51 (3,200.00)	1,338.49 (3,200.00)	Peanut: 826.92 (0.00)	0.00	¥13,378.41 (¥4,314.40)

One of the restrictions of the model forces the households to produce – at least – the same amount of grains as in the initial situation. It is, thus, noteworthy that all households produce only exactly the amount of grains which they are required to produce in the model. Furthermore all households show a tendency to produce less wheat than in the initial situation and to substitute wheat with maize. The results of the scenario *Output Price Increase: Peanut* also show that all optimized households begin the production of peanuts. Figure 60 shows the effects of *Output Price Increase: Peanut* on total gross margins of the optimized households.

Figure 60. Total Gross Margins in the Scenario *Output Price Increase: Peanut*



The results indicate positive effects of an increase of an output price increase for peanuts; HH1 increase by +199.48%, HH2 by +103.26% and HH3 by +210.09%. Consequently increased output prices for peanuts are potentially an adequate measure to increase gross margins and, thus, households' income. Table 101 displays which constraints are binding and which are not binding in this scenario.

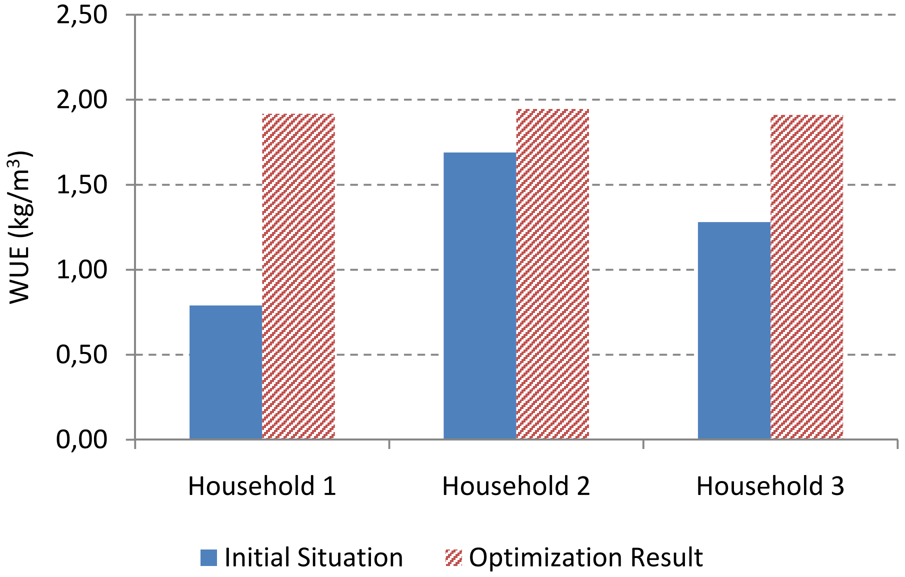
Table 101. Binding and not binding Constraints in the Scenario Output Price Increase: Peanut

	HH1	HH2	HH3
Labor	Not Binding	Not Binding	Not Binding
Area	Binding	Binding	Binding
Total Irrigation	Binding	Binding	Binding
Total N/P/K Fertilization	Binding	Binding	Binding
Total N/P/K Manure	Binding	Binding	Binding
Total Grain Production	Binding	Binding	Binding
Own Consumption Maize	Binding	Binding	Binding
Own Consumption Wheat	Binding	Binding	Binding

Only the constraint *Labor* is not binding in this scenario, because the households still have remaining labor capacities after the optimization. All other constraints are completely fulfilled. The sensitivity analysis, by means of the reduced cost values, surveys by which amount the value of the variable has to increase in order to change the current optimal solution. All variables which are included in the current optimum solution have reduced cost values of ¥0.00. Variables with low reduced cost values require only small changes to be included in a new optimal solution under unchanged conditions. The price increases of all variables (i.e. reduced cost values) which are necessary to change the optimal solution are displayed in Annex 24. The mean reduced cost value of the optimization options (excl. *Farmers' Practice*) is ¥1,786.44 – this indicates that the uncertainty of this scenario is low as most optimization options have high reduced costs. In the scenario *Output Price Increase: Peanut,* the shadow price for area is ¥5,218.64 this means that one more mu land would increase the optimum result by the respective amount – this is the second highest shadow price for land of all optimized results. The shadow price for total grain is ¥0.91 which means that if the minimum required amount for total grain production would increase by 1 kg, the optimal solution would decrease by that amount. In the optimum solution, considering that the current prices of renting land in the research area are very low compared to the shadow price (see part 4.2.2), it would be advisable to rent additional land for the surveyed households.

To assess the environmental impacts of the optimization in the scenario *Output Price Increase: Peanut* the performances of the selected environmental indicators are analyzed. Figure 61 displays the Total WUEs of maize and wheat after the optimization.

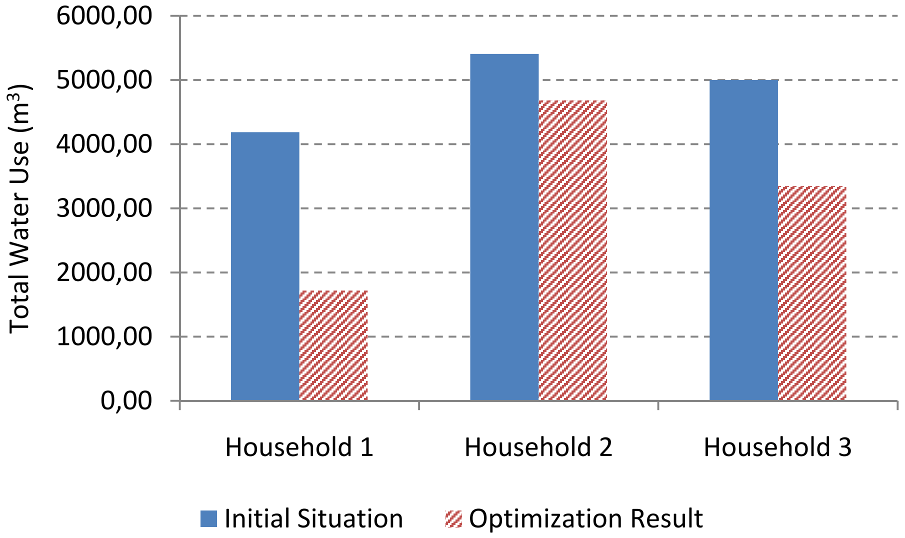
Figure 61. **Total Water Use Efficiencies in the Scenario *Output Price Increase: Peanut* ***



NOTE: *of maize and wheat

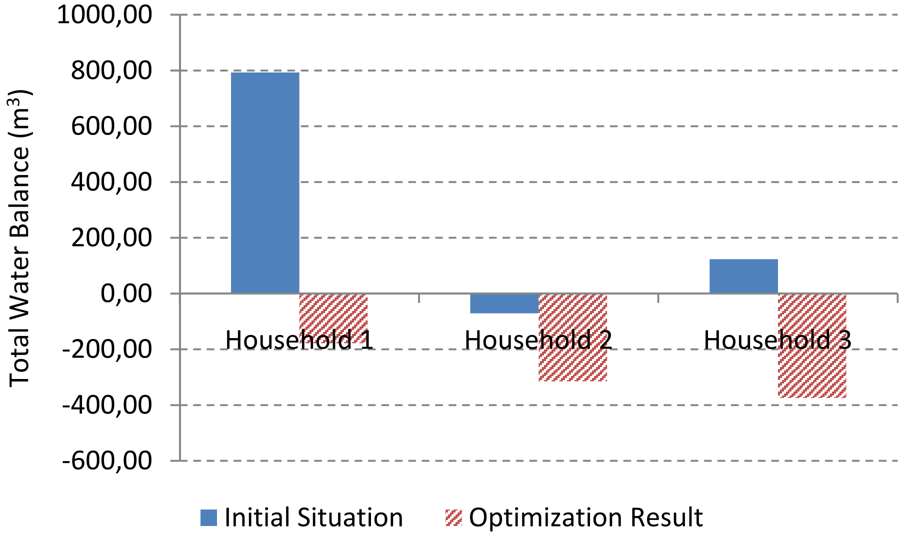
The increase of output prices for peanuts also has positive impacts on total WUEs of the selected households; it increases by +142.72% for HH1, by +15.14% for HH2 and by +49.28% for HH3. HH1 had the lowest total WUE in the initial situation, so the increase is the largest; HH2 had the highest WUE in the initial situation, so the increase is the smallest. Compared to other scenarios (e.g. *Output Price Increase: Maize* and *Introduction of Marginal Water Price*), the increase of WUE is small. However the effect of higher prices for peanuts on WUEs can still be estimated to be positive. Figure 62 compares the total water use per household in the initial situation and after the optimization in the scenario *Output Price Increase: Peanut*.

Figure 62. **Total Water Use in the Scenario *Output Price Increase: Peanut***



The optimization leads to decreased total water use for all selected households; HH1 reduces total water use by -58.89%, HH2 by -13.33% and HH3 by -33.01%. Decreased total water use of all selected households is in accordance with the goals of this work. The resulting total water balances are displayed in Figure 63.

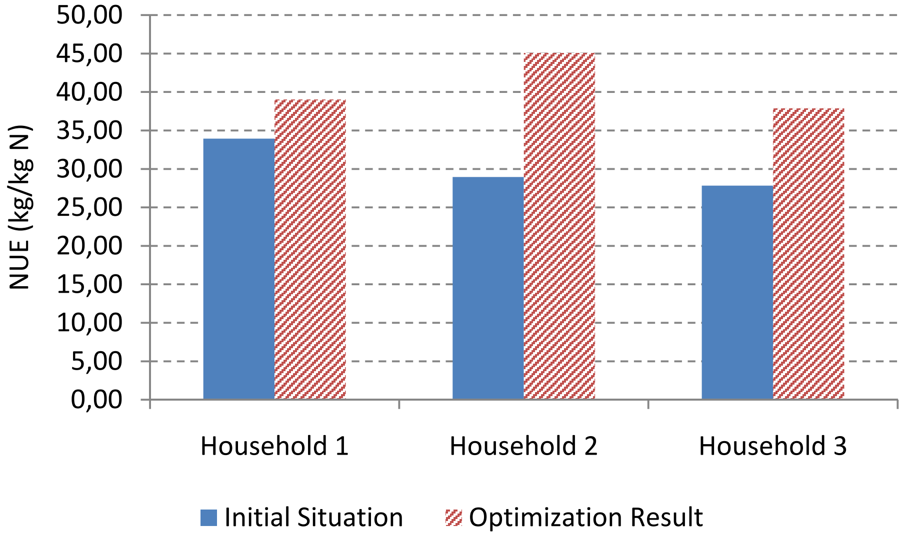
Figure 63. Total Water Balance in the Scenario *Output Price Increase: Peanut' ****



NOTE: *the calculation of the water balance is described in Table 62
**total water balance includes summer maize, spring maize and winter wheat

The results of scenario *Output Price Increase: Peanut* show that all optimized households have a negative water balance, which indicates undersupply of water. Such an undersupply of water cannot be assessed as sustainable and therefore this result is not in accordance with the goals of this work. Figure 64 presents the NUE values of the scenario *Output Price Increase: Peanut*.

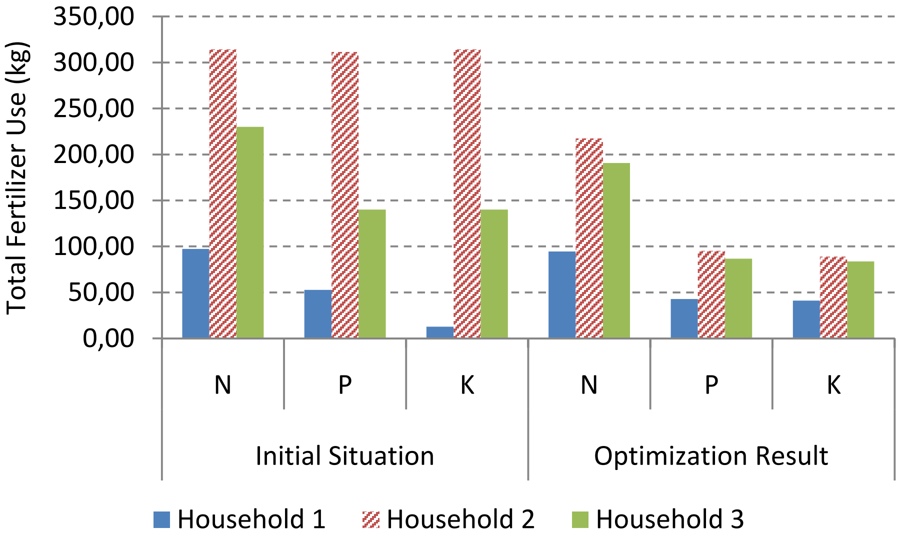
Figure 64. Total Nitrogen Use Efficiencies in the Scenario *Output Price Increase: Peanut**



NOTE: *of fertilization

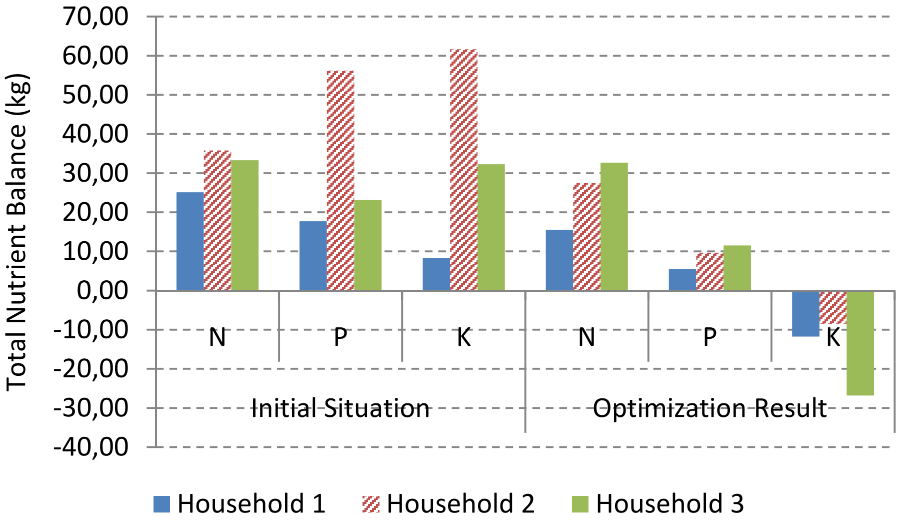
As can be seen in Figure 64, the NUEs of all households are increasing in the scenario *Output Price Increase: Peanut*. Such an increase – expressing improved resource use efficiency – is a goal of this work. The NUEs in the scenario *Output Price Increase: Peanut* are increasing by +15.04% (HH1), +55.73% (HH2) and +36.21% (HH3). Figure 65 compares the total fertilizer use in the initial situation and in the scenario *Output Price Increase: Peanut*.

Figure 65. **Total Fertilizer Use in the Scenario *Output Price Increase: Peanut***



The results of the simulation in the scenario *Output Price Increase: Peanut* indicate that total fertilizer use of the optimized households generally decreases, except for K fertilization of HH1 which increases by +221.12% (as in the initial situation HH1 is fertilizing maize with exceptionally small amounts and did not apply K fertilization to wheat, see Table 73. Otherwise all households apply fewer nutrients through fertilization: HH1 (N = -2.73% and P = -19.04%), HH2 (N = -30.78%, P = -69.38% and K = -71.64%) and HH3 (N = -17.11%, P = -38.07% and K = -40.15%). Decreasing total fertilizer use is in accordance with the goals of this work. The resulting total nutrient balances are displayed in Figure 66.

Figure 66. **Total Nutrient Balances in the Scenario *Output Price Increase: Peanut****



NOTE: * total nutrient balance includes summer maize, spring maize and winter wheat

The excesses in the total nutrient balances of the surveyed are reduced through the optimization in the scenario *Output Price Increase: Peanut*. However, the K balance for all households is negative, indicating an undersupply of K. A negative nutrient balance cannot be assessed as sustainable – consequently these results are not in accordance with the goals of this work.

The simulated effects of the scenario *Output Price Increase: Peanut* can be summarized:

- Total fertilizer use decreases;
- WUE improves;
- NUE improves;
- Nutrient excess decreases, but undersupply of K which endangers sustainability ;
- Total water use decreases, but all households show negative water balances which endanger sustainability;
- Total food production increases (grain production remains unchanged);
- Increased total gross margin.

The simulation in this scenario lead to environmental effects which are not sustainable, therefore increasing peanut prices does not represent an effective measure to comply with the goals of this work.

6.12.Output Price Increase: Cabbage

Similar to the previous output price increase scenarios, the scenario *Output Price Increase: Cabbage* surveys the effect of rising cabbage prices. The price increase can be the result of increased demand. It can also be the result of governmental support purchases or subsidies to strengthen the national cabbage production. The aim of this scenario is also to determine the effectivity of such a policy. The selling price of cabbage in the model is increased from ¥0.75 per kg in the initial situation. Even very strong price increases do not lead to results which differ from *Optimization under Current Conditions*. The main reason is that in *Optimization under Current Conditions* already substantial amounts of cabbage are grown. Another reason is that the model requires the optimized households to produce at least the same amount of grains like in the initial situation – the maize yields of *SprM Cabbage Intercropping* alone do not suffice to fulfill that requirement. However, it should be noted that the characteristics of the model also have impacts on these results. The operational range of the model is limited as it is using fixed optimization options instead of continuous production functions and can, thus, occasionally only react stepwise. Therefore the model is sometimes limited to operating in optimum ranges rather than optimum points, as intermediate might be lacking. However, in order to be able to integrate the optimization options which are derived from other studies and experiments (management measures and innovations) it was necessary to formulate the model in this way. It can be assumed that in reality – when farmers are not limited to fixed optimization options – lower price increases would be necessary in order to make households react to the increasing cabbage prices. So the results in this scenario should be regarded carefully.

Consequently it can be summarized that, according to the results from the simulation and considering the limitations of the model, increasing output prices of cabbage does not represent an effective measure to comply with the goals of this work. Consequently the sensitivity analysis is not conducted for this work.

6.13.Output Price Decrease: Maize

Opposite to the previous scenarios in which output prices were increased, *Output Price Decrease: Maize* surveys the effects of reduced output prices for maize. The price decrease could be the result of a tax or of excess supply. The aim of this scenario is also to determine the effectivity of such a policy. Therefore the output price for maize in the model is decreased by 50.00%, from ¥1.46 per kg to ¥0.75 per kg. Simultaneously the prices which the households have to pay for purchasing maize are decreased from ¥2.92 per kg to ¥1.46 per kg. The simulation shows that these price decreases would create results which do not differ from the combination of optimization options in the scenario *Optimization under Current Conditions*. Again, it should be noted that the characteristics of the model also have impacts on these results. The operational range of the model is limited as it is using fixed optimization options instead of continuous production functions and can, thus, occasionally only react stepwise. Therefore the model is sometimes limited to operating in optimum ranges rather than optimum points, as intermediate might be lacking. However, in order to be able to integrate the optimization options which are derived from other studies and experiments (management measures and innovations) it was necessary to formulate the model in this way. It can be assumed that in reality – when farmers are not limited to fixed optimization options – lower price decreases would be necessary in order to make households react to decreasing maize prices. So the results in this scenario should be interpreted carefully. A stronger price increase is not realistic, considering the government's aim to keep grain production in the NCP on a high level. As shown in Table 102, the decreased prices of maize would result in reduced total gross margins (compared to *Optimization under Current Conditions*).

Table 102. Total Gross Margins in the Scenario *Output Price Decrease: Maize*

	Total Gross Margin (*¥ and initial Total Gross Margin)*
HH 1	¥4,402.07 (¥2,235.20)
HH 2	¥10,296.91 (¥7,462.85)
HH 3	¥8,533.95 (¥4,314.40)

Nevertheless, these findings suggest that – within the limitations of the model – a decrease of maize prices is not an appropriate measure, as the resulting production combination is congruent with the results in the scenario *Optimization under Current Conditions*, but the households have comparably smaller total gross margins – and resulting negative effects on total household income.

Consequently it can be summarized that, according to the results from the simulation and considering the limitations of the model, decreasing output prices for maize does not represent an effective measure to comply with the goals of this work. Consequently the sensitivity analysis is not conducted for this work.

6.14.Output Price Decrease: Wheat

Similar to the Scenario *Output Price Decrease: Maize*, the scenario *Output Price Decrease: Wheat* surveys the effects of reduced output prices for wheat. The price decrease could be the result of a tax or of excess supply. The aim of this scenario is also to determine the effectivity of such a policy. Therefore the output price for wheat in the model is decreased by 50.00%, from ¥1.55 per kg to ¥0.78 per kg. Simultaneously the prices which the households have to pay for purchasing wheat are decreased from ¥3.10 per kg to ¥1.55 per kg. The simulation shows that these price decreases would create results which do not differ from the combination of optimization options in the scenario *Optimization under Current Conditions*. A stronger price increase is not realistic, considering the government's aim to keep grain production in the NCP on a high level. As demonstrated in Table 103, the decreased prices of wheat however would result in reduced total gross margins (compared to *Optimization under Current Conditions*).

Table 103. Total Gross Margins in the Scenario *Output Price Decrease: Wheat*

	Total Gross Margin (¥ *and initial Total Gross Margin)*
HH 1	¥5,294.77 (¥2,235.20)
HH 2	¥11,196.05 (¥7,462.85)
HH 3	¥10,910.73 (¥4,314.40)

Again, it should be noted that the characteristics of the model also have impacts on these results. The operational range of the model is limited as it is using fixed optimization options instead of continuous production functions and can, thus, occasionally only react stepwise. Therefore the model is sometimes limited to operating in optimum ranges rather than optimum points, as intermediate might be lacking. However, in order to be able to integrate the optimization options which are derived from other studies and experiments (management measures and innovations) it was necessary to formulate the model in this way. It can be assumed that in reality – when farmers are not limited to fixed optimization options – lower price decreases would be necessary in order to make households react to decreasing wheat prices. So the results in this scenario should be interpreted carefully. Nevertheless, these findings suggest that – within the limitations of the model – a decrease of wheat prices is not an appropriate measure, as the resulting production combination is congruent with the results in the scenario *Optimization under Current Conditions*, but the households have comparably smaller total gross margins – and resulting negative effects on total household income. However, compared to *Output Price Decrease: Maize*, the resulting negative impacts on total gross margin are smaller.

Consequently it can be summarized that, according to the results from the simulation and considering the limitations of the model, decreasing output prices for wheat does not represent an effective measure to comply with the goals of this work. Consequently the sensitivity analysis is not conducted for this work.

6.15. N Fertilization Cap

One policy option to reduce over fertilization is the introduction of maximum allowed amounts (i.e. a capping) of fertilization. For the scenario *N Fertilization Cap* the maximum amounts of N fertilization are based on the available household area. It would be administratively complex to cap fertilization according to the cropped specific plants and because the SM-WW double cropping system is typical in the research area. Therefore the level of fertilization cap is determined by the maximum N uptakes of maize and wheat in the research area (see Table 59): 21.65 kg N/mu for maize and 17.13 kg N/mu for wheat are defined as thresholds for over-fertilization. The survey showed that already now – for most nutrients – at least ~25% of stem from straw or manure. This share should by decreased, therefore the fertilization cap is defined as 17.50 kg N/mu per year; so 35.00 kg for a 2-year period. For comparison: the mean combined N fertilization (i.e. for maize and wheat) is 63.64 kg N/mu (for a 2-year period). This maximum amount of fertilizers can be allocated to all optimization options. This fertilization threshold is integrated as an additional restriction in the model. The aim of this scenario is also to determine the effectivity of such a governmental policy. Table 104 presents the results of the simulation in the scenario *N Fertilization Cap*.

Table 104. Simulation Results in the Scenario *N Fertilization Cap*

	SprM Cabbage Intercropping *(mu and % of Total Available Area)*	**SM-WW Balanced Input I** *(mu and % of Total Available Area)*	**SprM Balanced Input I** *(mu and % of Total Available Area)*	**Total Used Area** *(mu and % of Total Available Area)*
HH 1	0.94 (47.00%)	0.83 (41.50%)	0.23 (11.50%)	2.00 (100.00%)
HH 2	1.47 (30.63%)	2.68 (55.83%)	0.65 (13.54%)	4.80 (100.00%)
HH 3	2.00 (50.00%)	1.55 (38.75%)	0.45 (11.25%)	4.00 (100.00%)

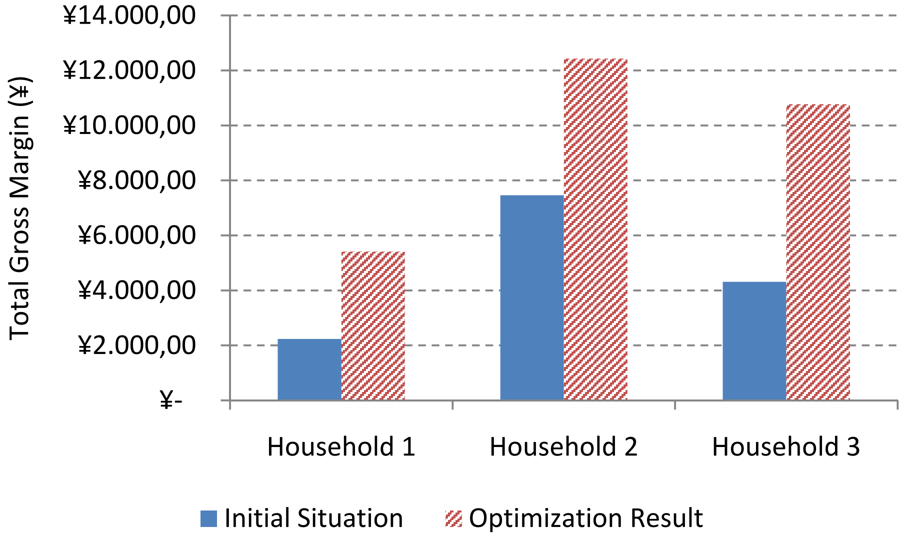
The scenario *N Fertilization Cap* results in a clear tendency towards producing the same combination of optimization options in comparable extends. All households use all available land areas in this scenario. Table 105 presents the production characteristics of the simulation in the scenario *N Fertilization Cap*.

Table 105. Production Characteristics of Simulation in the Scenario *N Fertilization Cap*

	Total Maize *(kg and initial Total Maize)*	**Total Wheat** *(kg and initial Total Wheat)*	**Total Other Crop** *(kg and initial Total Other Crops)*	**Bought Crops** *(kg)*	**Total Gross Margin** *(¥ and initial Total Gross Margin)*
HH 1	2,299.22 (1,600.00)	1,000.78 (1,700.00)	Cabbage: 3,865.59 (0.00)	0.00	¥5,419.45 (¥2,235.20)
HH 2	5,903.10 (5,280.00)	3,216.90 (3,840.00)	Cabbage: 6,073.18 (0.00)	0.00	¥12,435.44 (¥7,462.85)
HH 3	4,534.29 (3,200.00)	1,865.71 (3,200.00)	Cabbage: 8,243.63 (0.00)	0.00	¥10,774.97 (¥4,314.40)

The results of the simulation in the scenario *N Fertilization Cap* demonstrate that all households produce (slightly) less wheat than in the initial situation. The increased production amounts of maize are compensating for the decreased wheat production. It is notable that all households produce grains only enough to fulfill the restrictions of producing at least the same amounts as in the initial situation. All households start to grow considerable amounts of cabbage, so total food production increases. As can be seen in Figure 67, the simulation of the scenario *N Fertilization Cap* resulted in higher total gross margins of the optimized households.

Figure 67. Total Gross Margins in the Scenario *N Fertilization Cap*



The simulation showed that the introduction of the fertilization cap would result in strongly increased total gross margins for all households: +142.46% for HH1, +66.63% for HH2 and +149.74% for HH3. Therefore the impacts of this policy on household income could be assessed positively. Table 106 displays which constraints are binding and which are not binding in this scenario.

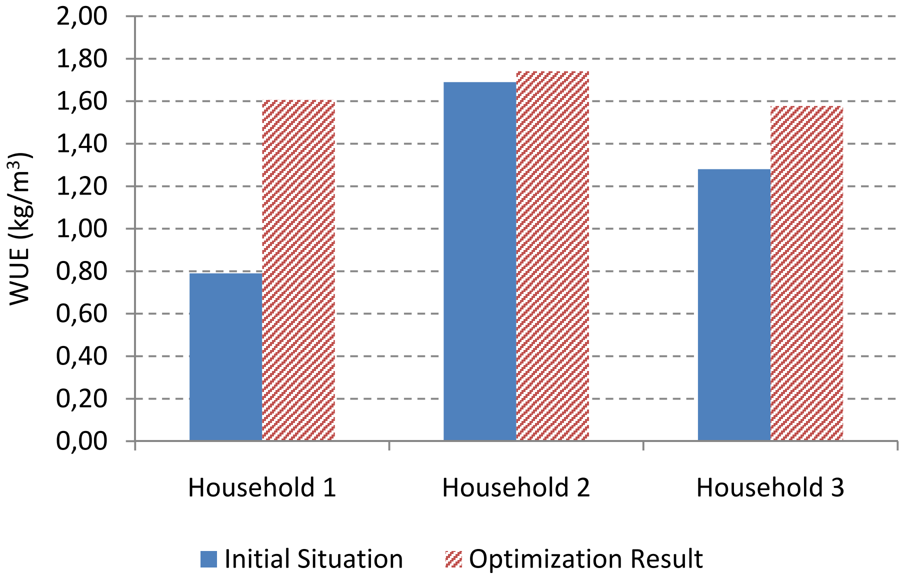
Table 106. Binding and not binding Constraints in the Scenario *N Fertilization Cap*

	HH1	HH2	HH3
Labor	Not Binding	Not Binding	Not Binding
Area	Binding	Binding	Binding
Total Irrigation	Binding	Binding	Binding
Total N/P/K Fertilization	Binding	Binding	Binding
Total N/P/K Manure	Binding	Binding	Binding
Total Grain Production	Binding	Binding	Binding
Own Consumption Maize	Binding	Binding	Binding
Own Consumption Wheat	Binding	Binding	Binding

Only the constraint *Labor* is not binding in this scenario, because the households still have remaining labor capacities after the optimization. All other constraints are completely fulfilled. The sensitivity analysis, by means of the reduced cost values, surveys by which amount the value of the variable has to increase in order to change the current optimal solution. All variables which are included in the current optimum solution have reduced cost values of ¥0.00. Variables with low reduced cost values require only small changes to be included in a new optimal solution under unchanged conditions. The price increases of all variables (i.e. reduced cost values) which are necessary to change the optimal solution are displayed in Annex 25. The mean reduced cost value of the optimization options (excl. *Farmers' Practice*) is ¥1,332.31 – this indicates that the uncertainty of this scenario is low as most optimization options have high reduced costs; however it is the second smallest reduced cost value of all optimized results. In the scenario *Fertilization Cap,* the shadow price for area is ¥1,426.58 this means that one more mu land would increase the optimum result by the respective amount – which is the smallest amount of all optimized results. The shadow price for total grain is ¥0.64 which means that if the minimum required amount for total grain production would increase by 1 kg, the optimal solution would decrease by that amount. In the optimum solution, considering that the current prices of renting land in the research area are very low compared to the shadow price see part 4.2.2, it would be advisable to rent additional land for the surveyed households.

In order to assess the environmental impacts of the optimization in the scenario *N Fertilization Cap* the performances of the selected environmental indicators are analyzed. The impacts of the introduction of a fertilization cap on the WUE are displayed in Figure 68.

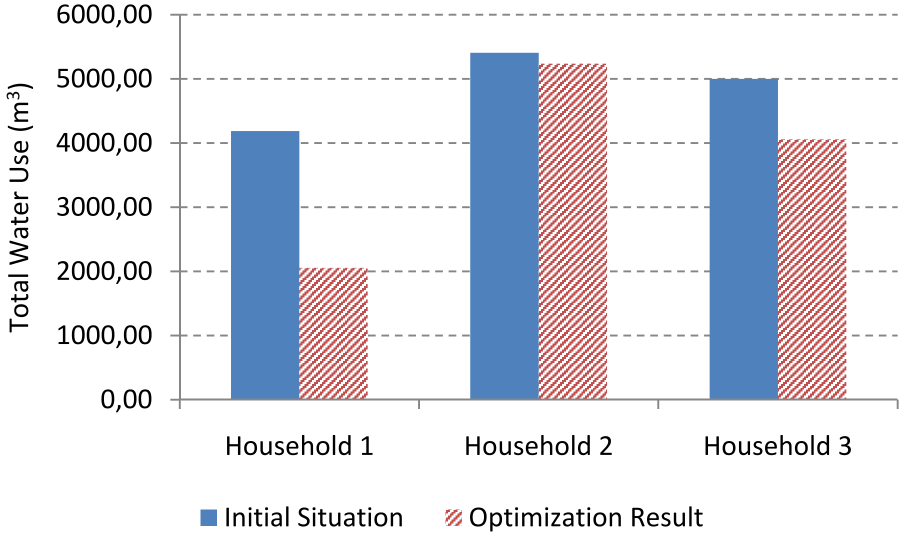
Figure 68. Total Water Use Efficiencies in the Scenario *N Fertilization Cap**



NOTE: *of maize and wheat

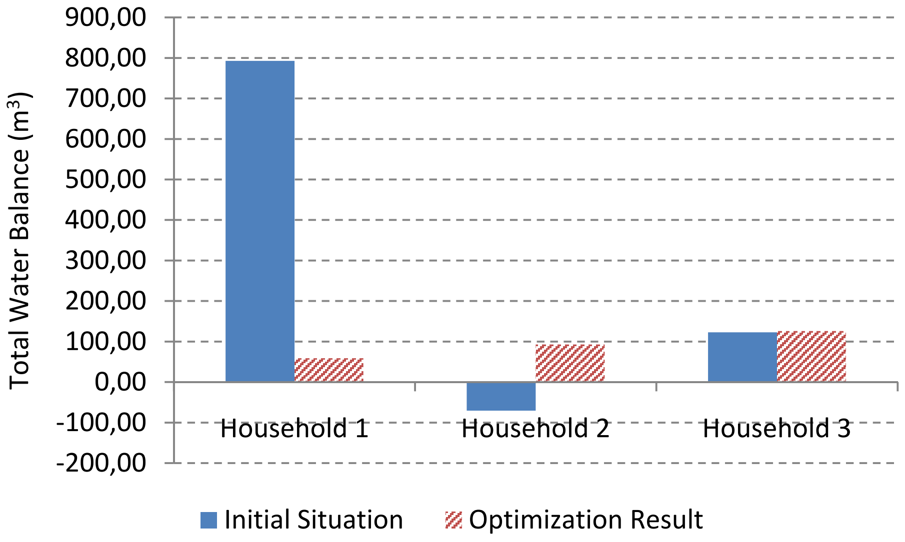
The simulation in the scenario *N Fertilization Cap* results in increased WUEs for all households: +103.35% for HH1, +3.05% for HH2 and +23.34% for HH3. The high increase of WUE for HH1 can be explained with the low WUE in the initial situation (see Table 62). Consequently, even though WUE is not in the focus of a policy of a fertilization cap, the impacts on WUE are positive. The resulting effects of limiting N fertilization on total water use are displayed in Figure 69.

Figure 69 . **Total Water Use in the Scenario *N Fertilization Cap***



The effects of the introduction of a fertilization cap on total water use are distinct – the results indicate that all households decrease total water use: -50.94% for HH1, -3.16% for HH2 and -18.85% for HH3. Again, as demonstrated in Table 73, in the initial situation the water balance of HH1 indicates a strong over use – so the effects of the optimization (i.e. the decreased total water use) are the largest for HH1. Figure 70 displays the total water balances in the scenario *N Fertilization Cap*.

Figure 70. **Total Water Balances in the Scenario *N Fertilization Cap*****

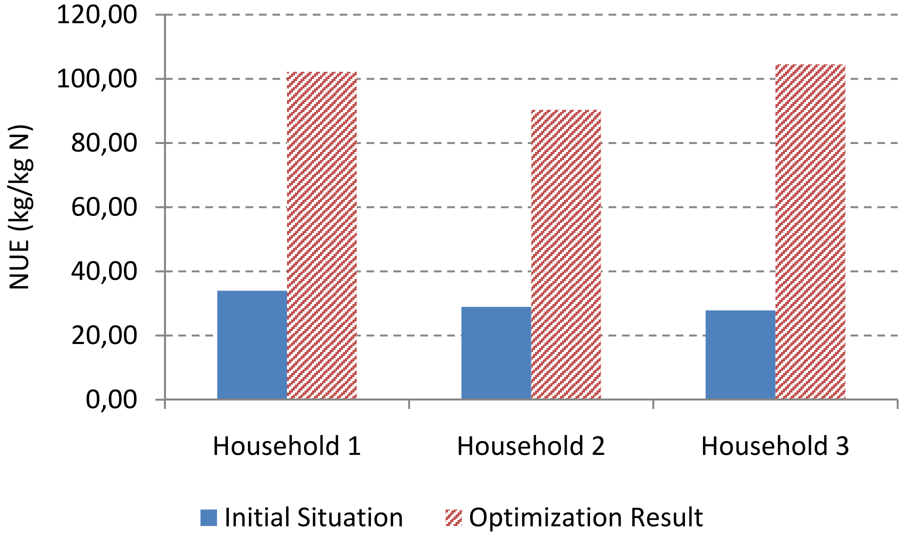


NOTE: *the calculation of the water balance is described in Table 62
**total water balance includes summer maize, spring maize and winter wheat

As can be seen in Figure 70, the simulation in the scenario *N Fertilization Cap* has diverse effects on the total water balances of the households: the strong overuse of HH1 turns into a slight overuse, the slight undersupply of HH2 turns into overuse and the overuse of HH3 is a little bit increased. Consequently the introduction of a fertilization cap does not seem to lead to uniformly balanced water use. However, the water use is more balanced in the sense that

– after the optimization – no household undersupplies water to maize and wheat. Figure 71 presents the resulting NUEs of fertilization in the scenario *N Fertilization Cap*.

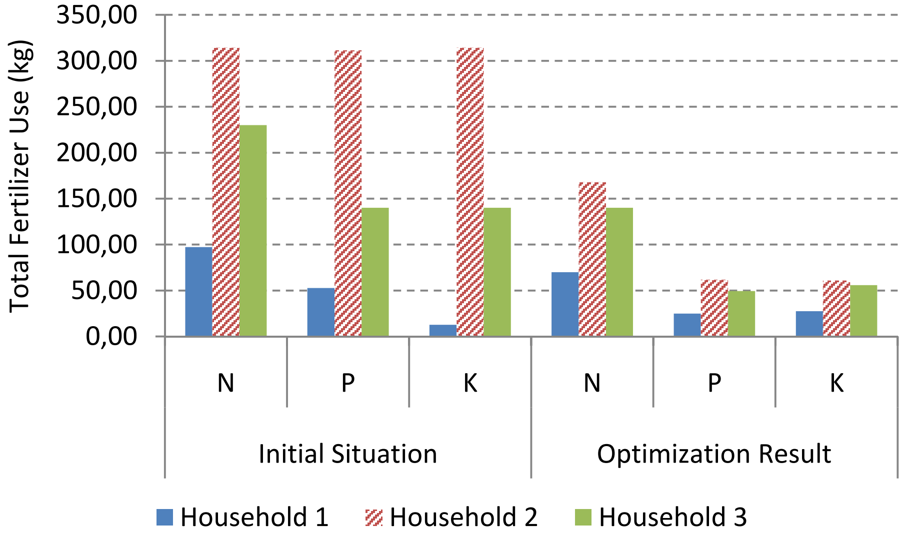
Figure 71. Total Nitrogen Use Efficiencies in the Scenario *N Fertilization Cap* *



NOTE: *of fertilization

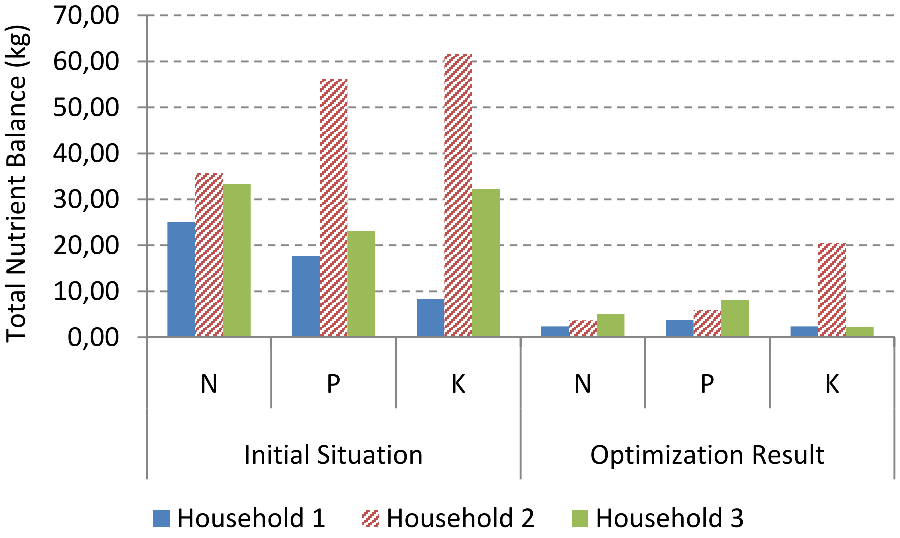
As can be seen in Figure 71, the effects of fertilization capping on NUE are clearly positive – all selected households improve NUE. In the scenario *N Fertilization Cap* the NUEs increase by +201.14% (HH1), +212.28% (HH2) and +275.84% (HH3). Such strongly increased NUE values are in accordance with the goals of this work. It should also be pointed out that the households apply manure in this scenario, which is positive, because – as shown in the previous parts – manure use in China dramatically decreased over the past decades and it has positive impacts on soil characteristics. Figure 72 compares the total fertilizer use in the initial situation and in the scenario *N Fertilization Cap*.

Figure 72. Total Fertilizer Use in the Scenario *N Fertilization Cap*



The results of the simulation in the scenario *N Fertilization Cap* indicate that total fertilizer use of the optimized households decreases, except for K fertilization of HH1 which increases by +114.91% (as in the initial situation HH1 was fertilizing maize with only very small amounts and did not apply K fertilization for wheat, see Table 73. Otherwise all households apply fewer nutrients through fertilization: HH1 (N = -27.98% and P = -52.89%), HH2 (N = -46.56%, P = -80.11% and K = -80.55%) and HH3 (N = -39.13%, P = -64.74% and K = -60.12%). These are the expected and aimed for result of a policy of a fertilization cap. Figure 73 compares the total nutrient balances of the initial situation and of the results of the optimization in the scenario *N Fertilization Cap*.

Figure 73. Total Nutrient Balance in the Scenario *N Fertilization Cap**



NOTE: * total nutrient balance includes summer maize, spring maize and winter wheat

As Figure 73 demonstrates, the optimization in the scenario *N Fertilization Cap* leads to a reduced excess of all nutrients. Therefore the total nutrient balances are closer to the equilibrium, which is a desired effect of a fertilization cap. Furthermore an evened nutrient balance is in accordance with the goals of this work.

The simulated effects of the introduction of a policy of capping the N fertilization amounts can be summarized:

- Total fertilizer use decreases;
- WUE improves;
- NUE improves strongly;
- Diverse effects on total water balance;
- Total nutrient balance is more even;
- Total water use decreases;
- Total food production increases (grain production remains unchanged);
- Increased total gross margin.

Even though such a policy would be difficult to implement and administer, the simulated effects of a fertilization cap indicate that it might be an effective measure to comply with goals of this work.

6.16. Irrigation Cap

The introduction of maximum allowed amounts (i.e. a capping) of disposable water is a policy option to reduce the use of scarce water resources. Such a policy would not be implementable under the current circumstances in the research area. A Precondition for the introduction of an irrigation cap is a functioning monitoring and control infrastructure, which – as explained in chapter 2 – is currently still widely lacking in the NCP. Still, the scenario *Irrigation Cap* surveys the effects of the introduction of a maximum amount of disposable irrigation water. Following the argumentation in the Scenario *Fertilization Cap*, the assumed maximum amount of disposable irrigation water is based per area. The baseline for the irrigation cap is determined by the minimum irrigation requirements of maize (140.00m^3/mu) and wheat (180.00m^3/mu) in the Hebei Province (YANG *et al.*, 2003). Consequently the annual water cap is 320.00 m^3 per mu; so 640.00 m^3/mu for a 2-year period. For comparison, currently the mean irrigation amount of the surveyed households for maize is 192.52 m^3/mu and for wheat it is 243.13 m^3/mu (see Table 62); this amounts to 435.65 m^3/mu for the SM-WW crop rotation (871.30 m^3/mu for a 2-year period). The maximum amount of water can be allocated to all optimization options. This limit is integrated as an additional restriction in the model. The aim of this scenario is also to determine the effectivity of such a governmental policy. Table 107 displays the results of the simulation in the scenario *Irrigation Cap*.

Table 107. Simulation Results for the Scenario *Irrigation Cap*

	SprM Cabbage Intercropping *(mu and % of Total Available Area)*	**SprM Balanced Input I** *(mu and % of Total Available Area)*	**Total Used Area** *(mu and % of Total Available Area)*
HH 1	1.11 (55.50%)	0.89 (44.50%)	2.00 (100.00%)
HH 2	1.96 (40.83%)	2.84 (59.17%)	4.80 (100.00%)
HH 3	2.34 (58.50%)	1.66 (41.50%)	4.00 (100.00%)

As can be seen in Table 107, the resulting combination of optimization options in the scenario *Irrigation Cap* do not differ from the results in *Optimization under Current Conditions* – as in *Optimization under Current Conditions* the optimized irrigation is already below the threshold of 640.00 m^3/mu for a 2-year period (HH1: 499.59 m^3/mu, HH2: 538.56 m^3/mu and HH3: 491.80 m^3/mu). To decrease the annual water cap below 320.00 m^3 per mu would not be advisable as this amount represents the minimum irrigation requirements. These findings suggest that an irrigation cap is not an efficient measure, as the resulting production combination is congruent with the results in the scenario *Optimization under Current Conditions* which already decreased irrigation strongly and does not require governmental interventions.

Consequently it can be summarized that, according to the results from the simulation, capping disposable water does not represent an effective measure to comply with the goals of this work. In addition, as mentioned before, such a policy is not realizable in the NCP due to the current lack of water monitoring equipment and infrastructure. Consequently a sensitivity analysis for this scenario is not conducted.

6.17. Total Area: Substitutability with Cotton

In the survey cotton generally had a higher gross margin than the SM-WW crop rotation (see part 4.5.4). Therefore the scenario *Total Area: Substitutability with Cotton* surveys whether the integrated optimization options are compatible with cotton. To do so, cotton is integrated into the model with the individual requirements of farmer's practice (see Annex 18). In the model maize and wheat optimization options can be substituted with cotton and vice versa. Since cotton is in competition with the SM-WW optimization options, the available household working time is larger than indicated in Table 73. Compared to the other scenarios the available household working time is increased by the amount which the respective household allocates to the production of cotton in the initial situation. Also the available area is extended by the area which is used for cotton in the initial situation, so the simulation in this scenario has the following area restrictions: HH2 = 6.10 mu and HH3 = 9.40 mu. Since HH1 is using its complete area for the SM-WW crop rotation and does not produce cotton, *Total Area: Substitutability with Cotton* can only be calculated for HH2 and HH3. The initial cotton price from the survey is ¥5.34 per kg. At the initial price from the survey cotton is not compatible with the SM-WW rotation. So the optimization leads to the same combinations of optimization options as in the Scenario *Optimization under Current Conditions*. In the survey cotton is slightly more profitable as the SM-WW crop rotation, but the optimization options offer more efficient combinations, for example in the resulting combination which is similar to the results in *Optimization under Current Conditions* (see Table 108). Therefore, at initial prices, cotton cannot substitute the SM-WW optimization options.

Table 108. Simulation Results for the Scenario *Total Area: Substitutability with Cotton*

	SprM Cabbage Intercropping *(mu and % of Total Available Area)*	**SM-WW Balanced Input Use I** *(mu and % of Total Available Area)*	**Total Used Area** *(mu and % of Total Available Area)*
HH 1	1.11 (55.50%)	0.89 (44.50%)	2.00 (100.00%)
HH 2	1.96 (40.91%)	2.84 (59.09%)	4.80 (100.00%)
HH 3	2.34 (58.44%)	1.66 (51.56%)	4.00 (100.00%)

The resulting combinations of production options equal those in *Optimization under Current Conditions*. The optimization in the scenario *Total Area: Substitutability with Cotton* results in 100.00% land use of all selected households. Only if the prices are strongly decreased, cotton becomes compatible with the SM-WW optimization options. Table 109 presents the necessary price increases (for cotton to become compatible) and the resulting total gross margins in the scenario *Total Area: Substitutability with Cotton*. The initial gross margin in Table 109 is calculated as the sum of total SM-WW and cotton production.

Table 109. Total Gross Margins in the Scenario *Total Area: Substitutability with Cotton*

	Price Increase *(factor)*	**Total Gross Margin** (¥ *and initial Total Gross Margin)*
HH 2	2.44	¥19,089.13 (¥8,033.81)
HH 3	2.23	¥29,735.14 (¥7,088.92)

The necessary price increase of cotton to become compatible with the optimized SM-WW crop rotation is unrealistically high. Such a high price increase cannot be expected and is politically not realizable, as costs for subsidies or other measures would be very high. Therefore it can be concluded that within a realistic range cotton is not compatible with the SM-WW optimization options. Therefore the resulting production combinations are congruent with *Optimization under Current Conditions*; the environmental effects of this scenario can be consulted in 0. In addition it should be noted that – even with such a high price increase – the simulation shows that HH2 only grows on 42.46% of the available land cotton and HH3 even produces more grains than required by the model.

In conclusion it can be summarized that under current conditions cotton is not competitive with the SM-WW optimization options. This finding is in accordance with the goals of this work, as it indicates that the SM-WW optimization options provide efficient options to ensure grain production in the NCP. As the resulting combination of production options is equal to those in *Optimization under Current Conditions*, a sensitivity analysis for this scenario is not conducted.

6.18.Less Available Labor

This scenario *Less Available Labor* surveys the effects of less available labor for the SM-WW optimization options. The decreased labor availability can be the result of off-farm activities or other orientations towards non-agricultural activities. Typically this scenario does not represent a policy; rather it is an analysis of projected development. Therefore the model assumes that the available household labor for the SM-WW crop rotation is decreased by half of the total available working time of a full time farm worker, which is 2,496.00 hours per year (see definition in part 4.5.1). According to the definition of this work half of the total available full time farm worker corresponds to 1,248.00 hours per year. So in the model these 1,248.00 hours are deducted from the available working time in the initial situation (see Table 73) on a monthly basis, so every month the selected households have 104.00 hours less available work (it should be noted that available working time cannot have negative values, so the minimum available working time is 0). Table 110 presents the results of the optimization in the scenario *Less Available Labor*.

Table 110. Simulation Results for the Scenario *Less Available Labor*

	SM-WW Balanced Input Use I *(mu and % of Total Available Area)*	**SprM Cabbage Intercropping** *(mu and % of Total Available Area)*	**SprM Peanut Intercropping** *(mu and % of Total Available Area)*	**SM-WW Improved Maize Seeds** *(mu and % of Total Available Area)*	**SM-WW Recommended Fertilization and Optimized Irrigation I** *(mu and % of Total Available Area)*	**Total Used Area** *(mu and % of Total Available Area)*
HH 1	0.81 (40.50%)	0.78 (38.85%)	0.41 (20.50%)	0.00 (0.00%)	0.00 (0.00%)	2.00 (100.00%)
HH 2	2.84 (59.09%)	1.96 (40.91%)	0.00 (0.00%)	0.00 (0.00%)	0.00 (0.00%)	4.80 (100.00%)
HH 3	0.00 (0.00%)	0.52 (13.13%)	0.00 (0.00%)	0.00 (0.00%)	0.00 (0.00%)	0.52 (13.13%)

HH1 and HH2 show different combinations of optimization options; both households use all available land areas in the scenario *Less Available Labor*. The resulting combinations of optimization options in the scenario *Less Available Labor* for HH2 show no difference from the results in *Optimization under Current Conditions*. Reasons for this are that HH2 has the highest number of household members and low share of off-farm income in the initial situation (see Table 72) – so HH2 does not have labor shortages. Due to labor shortages HH3 cannot use all available area; it only uses 13.13% of its available land (in April HH3 has only 0.00 and in September only 7.00 available labor hours for the SM-WW rotation). Considering the pressure on land and the need for grain production in the research area this findings are not in accordance with the goals of this work. In addition the results are not uniform (in the sense that every household selects different combination optimization options). Therefore the results of the optimization *Less Available Labor* are not in accordance with the goals of this work, as it can be concluded that less available labor (i.e. due to increased off-farm employment) endangers food security in the NCP. Consequently the economic and environmental effects of this scenario are not analyzed further. Also a sensitivity analysis for this scenario is not conducted.

6.19.Introduction of Price for Labor

The scenario *Introduction of Price for Labor* surveys the effects of the introduction of a labor price. The survey showed that nearly all work is done by family labor which does not receive payments for working. But, nowadays in the NCP, the opportunity costs of farm labor are foregone earnings from off-farm income. Therefore this scenario simulates the introduction of a price for labor: an estimated price of ¥10.00 per hour is integrated into the model. Also this scenario does not represent a policy; rather it is an analysis of a possible development (e.g. competition from off-farm employment). Table 111 presents the optimized result of *Introduction of Price for Labor*.

Table 111. Simulation Results for the Scenario *Introduction of Price for Labor*

	SM-WW Balanced Input Use I *(mu and % of Total Available Area)*	**Total Used Area** *(mu and % of Total Available Area)*
HH 1	2.00 (100.00%)	2.00 (100.00%)
HH 2	4.80 (100.00%)	4.80 (100.00%)
HH 3	4.00 (100.00%)	4.00 (100.00%)

As can be in Table 111, all households produce only the optimization option *SM-WW Balanced Input I* – which is the optimization option with the second highest total grain yield. In addition all households use all available land areas. This combination of production in *Introduction of Price for Labor* is identical with the results of *Output Price Increase: Maize*. Again, it should be noted that the characteristics of the model also have impacts on these results. The operational range of the model is limited as it is using fixed optimization options instead of continuous production functions and can, thus, occasionally only react stepwise. Therefore the model is sometimes limited to operating in optimum ranges rather than optimum points, as intermediate might be lacking. However, in order to be able to integrate the optimization options which are derived from other studies and experiments (management measures and innovations) it was necessary to formulate the model in this way. It can be assumed that in reality – when farmers are not limited to fixed optimization options –households might react differently to an introduction of a price for labor. So the results in this scenario should be interpreted carefully.

The environmental analysis, based on indicators, does not differ from the analysis in *Output Price Increase: Maize* (see 6.7). However, as demonstrated in Table 112, the economic impacts of *Introduction of Price for Labor* differ from *Output Price Increase: Maize*.

Table 112. Total Gross Margins in the Scenario *Introduction of Price for Labor*

	Total Gross Margin (*¥ and initial Total Gross Margin)*
HH 1	¥2,332.15 (¥2,235.20)
HH 2	¥5,764.18 (¥7,462.85)
HH 3	¥4,453.32 (¥4,314.40)

However it is questionable if the labor payments would have an impact on household income, as – as long as current structures do not change strongly – the money would stay within the household. So these results should be regarded as cost-accounting effects. However – even if household income remains unchanged – it is important to see that when prices for labor are introduced, the optimized results are changing. This is especially important when considering the increasing competition for labor between agricultural and non-agricultural activities. The effects of Introduction of Price for Labor on total gross margins are not uniform; HH1 and HH3 increase slightly (+3.89% and +3.22% respectively) whereas HH2 is decreasing (-22.76%).

The binding constraints are also equal to Output Price Increase: Maize, so they are displayed in Table 93. The sensitivity analysis, by means of the reduced cost values, surveys by which amount the value of the variable has to increase in order to change the current optimal solution. All variables which are included in the current optimum solution have reduced cost values of ¥0.00. Variables with low reduced cost values require only small changes to be included in a new optimal solution under unchanged conditions. The price increases of all variables (i.e. reduced cost values) which are necessary to change the optimal solution are displayed in Annex 26. The mean reduced cost value of the optimization options (excl. Farmers' Practice) is ¥1,485.58 – this indicates that the uncertainty of this scenario is low as most optimization options have high reduced costs. In the scenario Output Price Increase: SM-WW, the shadow price for area is ¥1,537.33 – this means that one more mu land would increase the optimum result by the respective amount. The shadow price for total grain is ¥0.00 as the constraint is not binding in this scenario and production exceeds the minimum required amount. In the optimum solution, considering that the current prices of renting land in the research area are very low compared to the shadow price (see part 4.2.2), it would be advisable to rent additional land for the surveyed households.

The simulated effects of the scenario *Introduction of Price for Labor* can be summarized:

- Same resulting combination of optimization options and, thus, congruent environmental effects with *Output Price Increase: Maize;*
- Unclear effects on total gross margins.

6.20.Area Subsidy: Wheat

The analysis in the previous part showed that wheat is the economically the most unprofitable crop, but its production is desired to fulfill goals of grain sufficiency. Therefore a policy of subsidizing areas on which wheat is grown can be an incentive to ensure wheat production. The aim of this scenario is also to determine the effectivity of such a policy. Since such a policy could foster monocultures, in the sense that similar systems are grown on the complete are. To avoid monocultures an additional restriction is integrated into the scenario *Area Subsidy: Wheat*; individual optimization options can only make up 50.00% of the available SM-WW area. So the scenario *Area Subsidy: Wheat* integrates a subsidy of ¥500.00 per mu per year into the model, but only for optimization options which include wheat in the respective year. The amount of ¥500.00 per mu roughly represents the price of land in the research are (see 4.2.2). So for the optimization options *Wheat-Soy-Maize 3-harvests-in-2-years* and *SM-WW-SprM 3-harvests-in-2-years I-II* the area subsidy is only granted during the year in which wheat is produced. As Table 113 shows, the scenario *Area Subsidy: Wheat* results in proportionally equal combinations of optimization options.

Table 113. Simulation Results for the Scenario *Area Subsidy: Wheat*

	SM-WW Recommended Fertilization and Optimized Irrigation I *(mu and % of Total Available Area)*	**SM-WW Balanced Input Use I** *(mu and % of Total Available Area)*	**Total Used Area** *(mu and % of Total Available Area)*
HH 1	1.00 (50.00%)	1.00 (50.00%)	2.00 (100.00%)
HH 2	2.40 (50.00%)	2.40 (50.00%)	4.80 (100.00%)
HH 3	2.00 (50.00%)	2.00 (50.00%)	4.00 (100.00%)

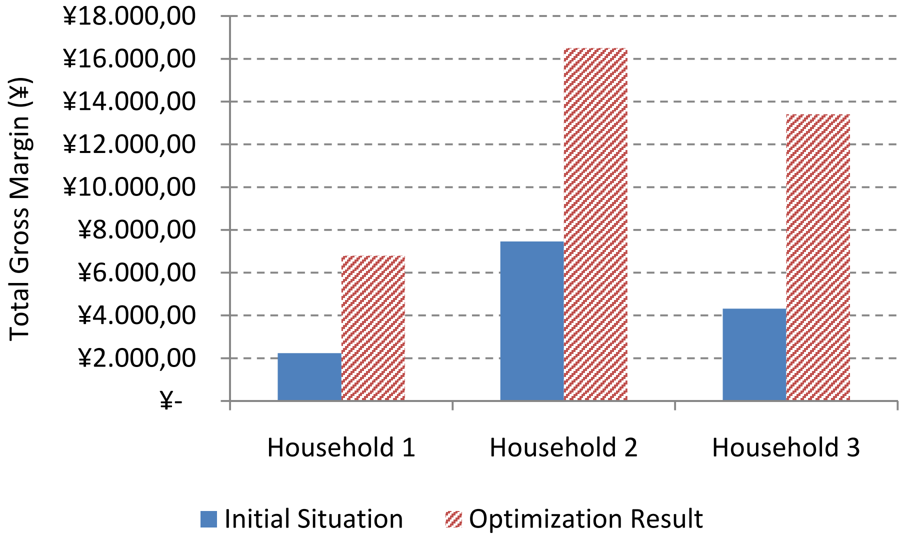
All households use all available land resources. The restriction that maximum 50.00% of available land can be used for one optimization option is also effective for all selected households. The optimization option *SM-WW Recommended Fertilization and Optimized Irrigation I* has the highest total grain production of all integrated optimization options. Table 114 presents the production characteristics of the simulation in the scenario *Area Subsidy: Wheat*.

Table 114. **Production Characteristics of Simulation in the Scenario *Area Subsidy: Wheat***

	Total Maize *(kg and initial Total Maize)*	**Total Wheat** *(kg and initial Total Wheat)*	**Total Other Crop** *(kg and initial Total Other Crops)*	**Bought Crops** *(kg)*	**Total Gross Margin** *(¥ and initial Total Gross Margin)*
HH 1	2,800.02 (1,600.00)	2,400.02 (1,700.00)	0.00 (0.00)	0.00	¥6,802.30 (¥2,235.20)
HH 2	6,720.05 (5,280.00)	5,760.05 (3,840.00)	0.00 (0.00)	0.00	¥16,516.55 (¥7,462.85)
HH 3	5,600.04 (3,200.00)	4,800.04 (3,200.00)	0.00 (0.00)	0.00	¥13,413.62 (¥4,314.40)

The results of the simulation in the scenario *Area Subsidy: Wheat* demonstrate that all households produce more grain than in the initial situation (HH1: +57.58%, HH2: +36.84% and HH3: 62.50%). This effect is in accordance with the goals of this work. Unlike in many other scenarios, the optimization in *Area Subsidy: Wheat* does not lead to the production of other crops. As can be seen in Figure 74, the simulation of the scenario *Area Subsidy: Wheat* resulted in higher total gross margins of the optimized households.

Figure 74. **Total Gross Margins in the Scenario *Area Subsidy: Wheat***



The simulation showed that the introduction of area subsidy for wheat would result in strongly increased total gross margins for all households: +204.33% for HH1, +121.32% for HH2 and +210.90% for HH3. Therefore the impacts of this policy on household income could be assessed positively. Table 115 displays which constraints are binding and which are not binding in this scenario.

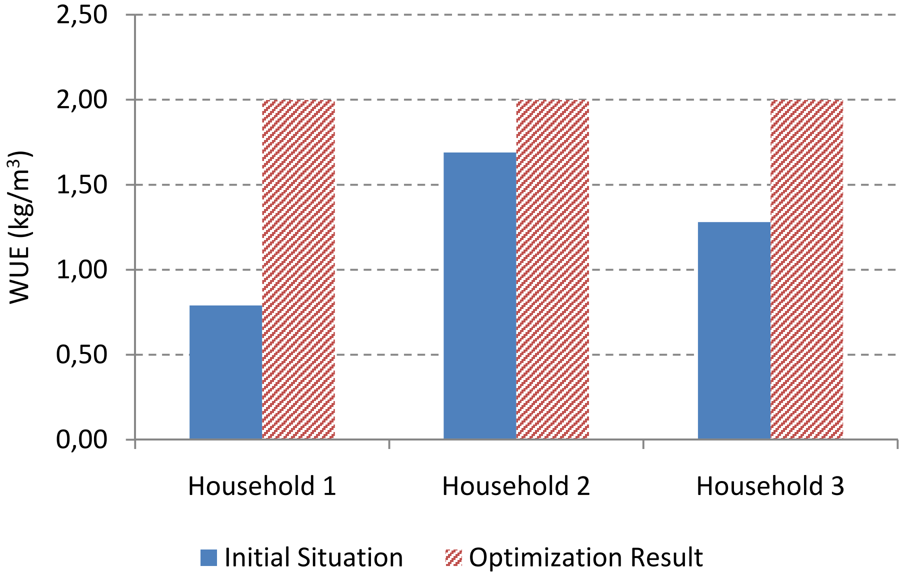
Table 115. Binding and not binding Constraints in the Scenario *Area Subsidy: Wheat*

	HH1	**HH2**	**HH3**
Labor	Not Binding	Not Binding	Not Binding
Area	Binding	Binding	Binding
Total Irrigation	Binding	Binding	Binding
Total N/P/K Fertilization	Binding	Binding	Binding
Total N/P/K Manure	Binding	Binding	Binding
Total Grain Production	Not Binding	Not Binding	Not Binding
Own Consumption Maize	Binding	Binding	Binding
Own Consumption Wheat	Binding	Binding	Binding

The constraints *Labor* and *Total Grain Production* are not binding in this scenario, because the households still have remaining labor capacities after the optimization and because the total grain production exceeds the minimum required amount. In addition the constraint that one optimization option can only make up 50.00% of the available area is also binding. The sensitivity analysis, by means of the reduced cost values, surveys by which amount the value of the variable has to increase in order to change the current optimal solution. All variables which are included in the current optimum solution have reduced cost values of ¥0.00. Variables with low reduced cost values require only small changes to be included in a new optimal solution under unchanged conditions. The price increases of all variables (i.e. reduced cost values) which are necessary to change the optimal solution are displayed in Annex 27. The mean reduced cost value of the optimization options (excl. *Farmers' Practice*) is ¥1,187.25 – this indicates that the uncertainty of this scenario is low as most optimization options have high reduced costs, even though it is the lowest mean reduced cost of all optimized results. In the scenario *Output Price Increase: Maize*, the shadow price for area is ¥1,692.48 – this means that one more mu land would increase the optimum result by the respective amount. The shadow price for total grain is ¥0.00 as the constraint is not binding in this scenario and production exceeds the minimum required amount. In the optimum solution, considering that the current prices of renting land in the research area are very low compared to the shadow price (see part 4.2.2), it would be advisable to rent additional land for the surveyed households.

To assess the environmental impacts of the optimization in the scenario *Area Subsidy: Wheat* the performances of the selected environmental indicators are analyzed. The impacts of the introduction of an area subsidy for the production for wheat on the WUE are displayed in Figure 75.

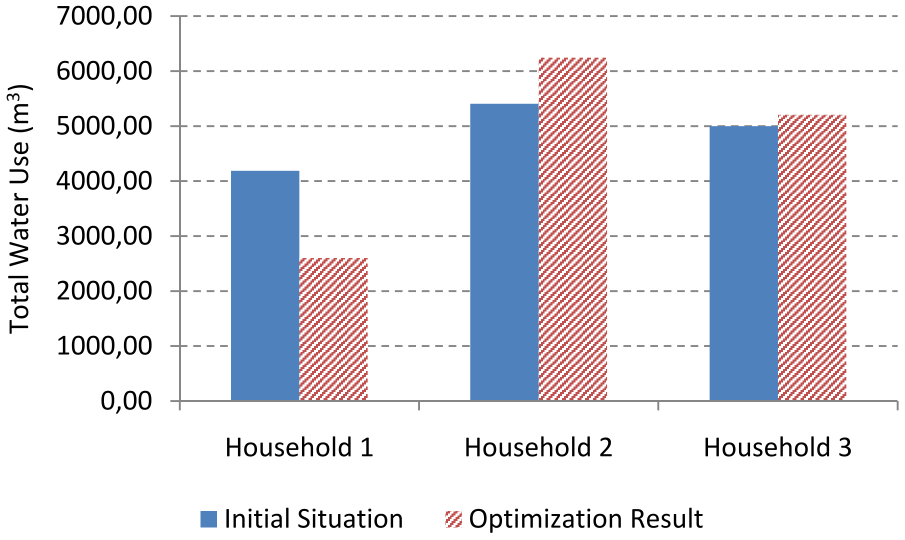
Figure 75. Total Water Use Efficiencies in the Scenario *Area Subsidy: Wheat* *



NOTE: *of maize and wheat

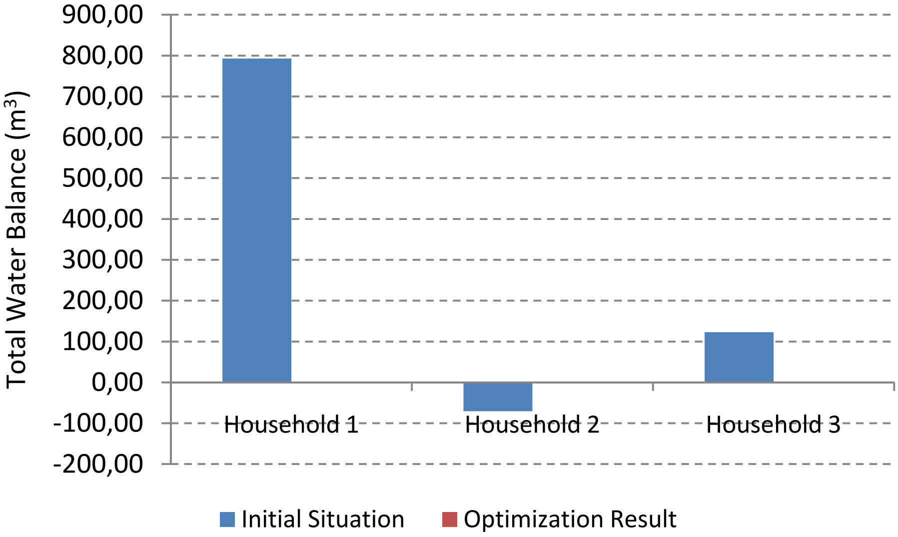
The simulation in the scenario *Area Subsidy: Wheat* results in increased WUEs for all households: +152.96% for HH1, +18.25% for HH2 and +56.12% for HH3. The high increase of WUE for HH1 can be explained with the low WUE in the initial situation (see Table 62). Consequently, even though WUE is not in the focus of a policy of a subsidy on wheat production areas, the impacts on WUE are positive. The resulting effects of limiting N fertilization on total water use are displayed in Figure 76.

Figure 76. Total Water Use in the Scenario *Area Subsidy: Wheat*



The effects of the introduction of a fertilization cap on total water use are varying: total water use of HH1 is decreasing by -37.85%, whereas total water use of HH2 and HH3 is (slightly) increasing (15.49% and 4.09% respectively). Increased total water use is not in accordance with the goals of this work. Again, as demonstrated in Table 62, in the initial situation the water balance of HH1 indicates a strong over use – that is why the effects of the optimization are the differing for HH1. Figure 77 displays the total water balances in the scenario *Area Subsidy: Wheat*.

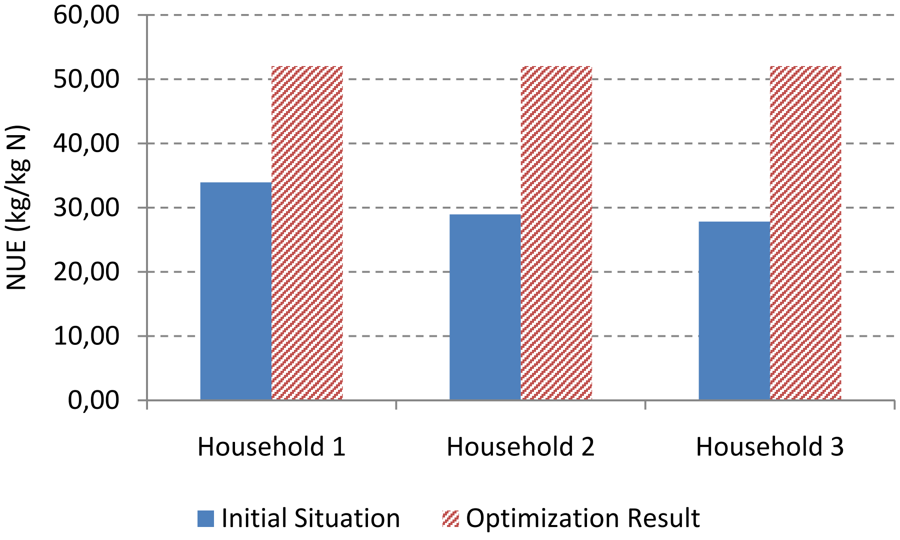
Figure 77. Total Water Balances in the Scenario *Area Subsidy: Wheat* *,**



NOTE: *the calculation of the water balance is described in Table 62
**total water balance includes summer maize, spring maize and winter wheat

As can be seen in Figure 77, the simulation in the scenario *Area Subsidy: Wheat* has positive effects on the total water balances of all households. The optimization leads to perfectly evened out water balances of all household – which is the optimum goal of this work regarding total water balance. The reason for this is that in the optimization options *SM-WW Balanced Input Use I* and *SM-WW Recommended Fertilization and Optimized Irrigation I* only those amounts are irrigated which are needed to meet the expected potential water use. Figure 78 displays the NUEs of the optimization in *Area Subsidy: Wheat*.

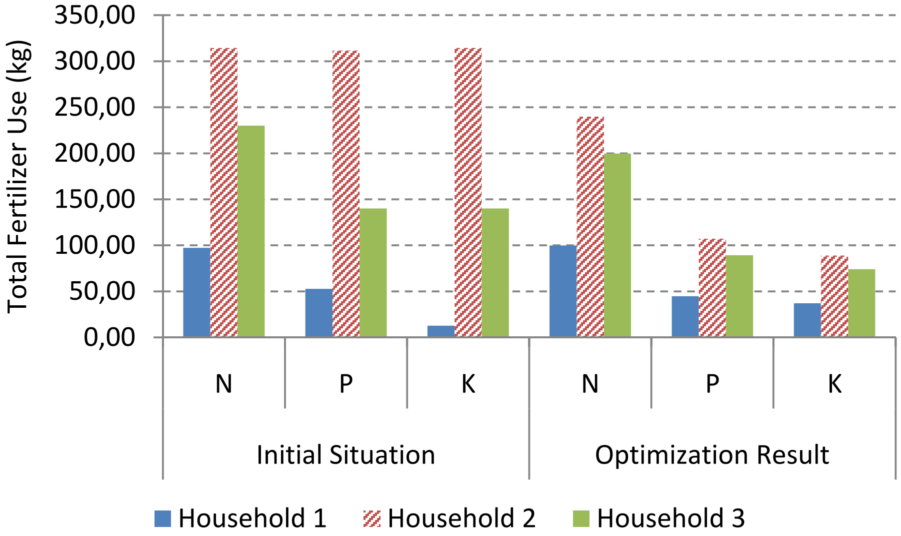
Figure 78. Total Nitrogen Use Efficiencies in the Scenario *Area Subsidy: Wheat**



NOTE: *of fertilization

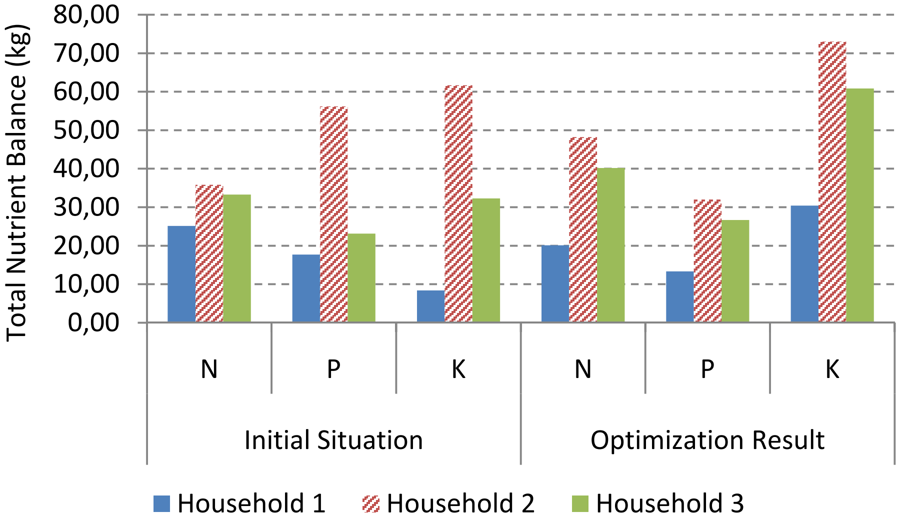
The optimization in the scenario *Area Subsidy: Wheat* leads to improved NUEs – which is in accordance with the aims of this work. The NUEs increase by +53.31% (HH1), +79.72% (HH2) and +87.02% (HH3). Figure 79 compares the total fertilizer use in the initial situation and in the scenario *Area Subsidy: Wheat*.

Figure 79. Total Fertilizer Use in the Scenario *Area Subsidy: Wheat*



The results of the simulation in the scenario *Area Subsidy: Wheat* indicate that the effects on total fertilizer use of the optimized households are not uniform. Total fertilizer use of N and K increase for HH1 (+2.79% and +198.45% respectively), whereas P fertilizer use decreases for HH1 (-15.42%). An explanation for the strong increase of K fertilization in HH1 is that in the initial situation it was fertilizing maize with only very small amounts and did not apply K fertilization for wheat (see Table 73). Increased total fertilizer use is against the goals of this work. The other 2 households apply fewer nutrients through fertilization: HH2 (N = -23.73%, P = -65.59% and K = -71.72%) and HH3 (N = -13.12%, P = -36.20% and K = -47.07%). Figure 80 compares the total nutrient balances of the initial situation and of the results of the optimization in the scenario *Area Subsidy: Wheat*.

Figure 80. Total Nutrient Balance in the Scenario *Area Subsidy: Wheat* *



NOTE: * total nutrient balance includes summer maize, spring maize and winter wheat

As Figure 80 demonstrates, the optimization in the scenario *Area Subsidy: Wheat* leads strongly varying effects on the nutrient balances of the surveyed households. The excess of K in the nutrient balance in the initial situation is increased for all households. Also the effects on the balances of N and P are varying. Increased nutrient excess is not in accordance with the goals of this work.

The simulated effects of the introduction of a policy subsidizing areas with wheat production can be summarized:

- Not uniform/meaningful results considering fertilization and nutrient balances;
- WUE improves;
- NUE improves;
- Perfectly evened out water balances;
- Diverse effects on total water use;
- Grain Production increases;
- Increased total gross margin.

The environmental impacts on fertilization, nutrient balance and total water use are not sustainable. Therefore *Area Subsidy: Wheat* does not provide an effective measure to comply with the goals of this work.

6.21.Yield Premium

This scenario surveys incentives for farmers to produce high grain yields. This incentive could be provided by a policy which pays the household a premium for higher yields. The aim of this scenario is also to determine the effectivity of such a policy. Therefore, in the scenario *Yield Premium*, when yield levels are above the yields of the 2-year period in the initial situation, the households receive a premium of ¥1.00 per kg grain which exceeds the original yield level (of maize and wheat). Therefore a premium of ¥1.00 per kg is included in the model if the households obtain total grain yields[28] which are larger than 3,300.00 kg (HH1), 9,120.00 kg (HH2) or 6,400.00 kg (HH3). Table 116 presents the optimized result of *Yield Premium*.

Table 116. Simulation Results for the Scenario *Yield Premium*

	SM-WW Balanced Input Use I *(mu and % of Total Available Area)*	**Total Used Area** *(mu and % of Total Available Area)*
HH 1	2.00 (100.00%)	2.00 (100.00%)
HH 2	4.80 (100.00%)	4.80 (100.00%)
HH 3	4.00 (100.00%)	4.00 (100.00%)

As can be in Table 116, all households produce only the optimization option *SM-WW Balanced Input I* – which is the optimization option with the second highest total grain yield. In addition all households use all available land areas. This combination of optimization options in *Yield Premium* is identical with the results of *Output Price Increase: Maize*. This can be explained by similar goals of the scenarios: in both cases the farmers benefit from high grain yields. Therefore the environmental analysis, based on indicators, does not differ from the analysis in *Output Price Increase: Maize* (see 6.7). However, as demonstrated in Table 117, the economic impacts of *Yield Premium* differ from *Output Price Increase: Maize*.

Table 117. Total Gross Margins in the Scenario *Yield Premium*

	Total Gross Margin (*¥ and initial Total Gross Margin)*
HH 1	¥6,872.15 (¥2,235.20)
HH 2	¥15,484,18 (¥7,462.85)
HH 3	¥13,754.32 (¥4,314.40)

The effects of a yield premium for increased grain yields on total gross margins are significantly positive, the total gross margins of the selected households increase strongly (HH1: +207.45%, HH2: +107.48% and HH3: +218.80%). With such strong increases of total gross margins, it can be estimated that the effects on rural households' incomes are positive. However, on a large scale such a policy would be extremely costly for the government – so it is questionable if it would be realizable.

The binding constraints are also equal to *Output Price Increase: Maize*, so they are displayed in Table 93. The sensitivity analysis, by means of the reduced cost values, surveys by which amount the value of the variable has to increase in order to change the current optimal solution. All variables which are included in the current optimum solution have reduced cost values of ¥0.00. Variables with low reduced cost values require only small changes to be included in a new optimal solution under unchanged conditions. The price increases of all variables (i.e. reduced cost values) which are necessary to change the optimal solution are displayed in Annex 28. The mean reduced cost value of the optimization options (excl. *Farmers' Practice*) is ¥1,893.84 – this indicates that the uncertainty of this scenario is low as most optimization options have high reduced costs. In the scenario *Output Price Increase: SM-WW*, the shadow price for area is ¥5,462.33 – this means that one more mu land would

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[28] For the 2-year period of the model

increase the optimum result by the respective amount. The shadow price for total grain is ¥0.00 as the constraint is not binding in this scenario and production exceeds the minimum required amount. In the optimum solution, considering that the current prices of renting land in the research area are very low compared to the shadow price (see part 4.2.2), it would be advisable to rent additional land for the surveyed households.

The simulated effects of the scenario *Yield Premium* can be summarized:

- Same resulting combination of optimization options and, thus, congruent environmental effects with *Output Price Increase: Maize;*
- Clearly positive effects on total gross margins.

The simulated effects of this policy are in accordance with the goals of this work. However, it should be considered that such a policy would be associated with high governmental expenditures.

6.22.Premium for Reduced Water Use

In the scenario *Premium for Reduced Water Use* a policy is introduced which pays a premium for decreased water use. The aim of this policy is to provide incentives for less or more efficient water use. The aim of this scenario is also to determine the effectivity of such a policy. After a period of 2 years, the households receive ¥5.00 for each m^3 below the initial total water use during the same period. These ¥5.00 per m3 roughly correspond to the marginal water price of ¥5.20/m^3. The initial total water usages of the selected households are[29]:

- HH1: 2,880.00 m^3;
- HH2: 2,880.00 m^3;
- HH3: 3,000.00 m^3.

It should be noted that such a policy would be difficult to implement and monitor in the research area, as it is currently hardly possible to control and monitor the applied irrigation amounts in the NCP (see part 2.4.2). Nevertheless it is important to estimate the effectiveness of such a policy. Table 118 presents the optimized result of *Premium for Reduced Water Use*.

Table 118. Simulation Results for the Scenario *Premium for Reduced Water Use*

	SprM Peanut Intercropping *(mu and % of Total Available Area)*	**Optimized SM-WW** *(mu and % of Total Available Area)*	**Total Used Area** *(mu and % of Total Available Area)*
HH 1	1.24 (62.00%)	0.76 (38.00%)	2.00 (100.00%)
HH 2	1.94 (40.42%)	2.86 (59.58%)	4.80 (100.00%)
HH 3	2.66 (66.50%)	1.34 (33.50%)	4.00 (100.00%)

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[29] For the 2-year period of the model

As can be seen in Table 118 the optimization in the scenario *Premium for Reduced Water Use* results in a 100.00% land use of all selected households. The optimized cropping strategies of the selected households are comparable. This combination of optimization options in *Premium for Reduced Water Use* is identical with the results of *Introduction of Marginal Water Price* – which is a scenario with comparable aims and impacts: in *Introduction of Marginal Water Price* the households pay for water use whereas in *Premium for Reduced Water Use* the households receive a premium for using less water. Therefore the environmental analysis, based on indicators, does not differ from the analysis in *Introduction of Marginal Water Price* (see 6.56.7). However, as demonstrated in Table 119, the economic impacts of *Premium for Reduced Water Use* differ from *Introduction of Marginal Water Price*; both scenarios result in increased WUEs, but – unlike *Introduction of Marginal Water Price – Premium for Reduced Water Use* clearly increases total gross margins.

Table 119. Total Gross Margins in the Scenario *Premium for Reduced Water Use*

	Total Gross Margin (*¥ and initial Total Gross Margin)*
HH 1	¥17,076.06 (¥2,235.20)
HH 2	¥19,499.22 (¥7,462.85)
HH 3	¥20,413.54 (¥4,314.40)

The effects of the premium for reduced water use on total gross margins are significantly positive, the total gross margins of the selected households increase strongly (HH1: +663.96%, HH2: +161.28% and HH3: +373.15%). With such strong increases of total gross margins, it can be estimated that the effects on rural households' incomes are positive. However, on a large scale such a policy would be extremely costly for the government – so it is questionable if it would be realizable.

The binding constraints are also equal to *Introduction of Marginal Water Price*, so they are displayed in Table 89. The sensitivity analysis, by means of the reduced cost values, surveys by which amount the value of the variable has to increase in order to change the current optimal solution. All variables which are included in the current optimum solution have reduced cost values of ¥0.00. Variables with low reduced cost values require only small changes to be included in a new optimal solution under unchanged conditions. The price increases of all variables (i.e. reduced cost values) which are necessary to change the optimal solution are displayed in Annex 29. The mean reduced cost value of the optimization options (excl. *Farmers' Practice*) is ¥2,407.08 – this indicates that the uncertainty of this scenario is low as most optimization options have high reduced costs, in addition it is the second highest mean reduced cost value of the optimized results. In the scenario *Premium for Reduced Water Use*, the shadow price for area is ¥3,796.52 – this means that one more mu land would increase the optimum result by the respective amount. The shadow price for total grain is ¥1.26 per kg, which means that if the minimum required amount for total grain production would increase by 1 kg, the optimal solution would decrease by that amount. In the optimum solution, considering that the current prices of renting land in the research area are very low compared to the shadow price (see part 4.2.2), it would be advisable to rent additional land for the surveyed households.

The simulated effects of the scenario *Premium for Reduced Water Use* can be summarized:

- Same resulting combination of optimization options and, thus, congruent environmental effects with *Introduction of Marginal Water Price;*
- Clearly positive effects on total gross margins.

Such a policy is difficult to implement and administer, as under current conditions it is hardly possible to control and monitor applied water amounts. The simulated environmental effects are equal to *Introduction of Marginal Water Price* – which are not in accordance with the goals of this work. Consequently *Premium for Reduced Water Use* should be evaluated similarly.

6.23.Premium for Reduced Fertilizer Use

Similar to the scenario *Premium for Reduced Water Use*, the scenario *Premium for Reduced Fertilizer Use* introduces a policy which pays a premium for decreased N fertilization to the rural households. The aim of this policy is to provide incentives for less of more efficient fertilizer use. This scenario aims at determining the efficiency of such a policy. After a period of 2 years, the households receive ¥4.00 for each kg below the initial total N fertilizer use during the same period. These 4.00 per kg roughly correspond to the initial price of N fertilizers (¥3.95 per kg). It should be noted that such a policy would be difficult to implement and monitor in the research area. Nevertheless it is important to estimate the effectiveness of such a policy. Therefore Table 120 presents the simulated results in the scenario *Premium for Reduced Fertilizer Use*.

Table 120. Simulation Results for the Scenario *Premium for Reduced Fertilizer Use*

	SprM Cabbage Intercropping *(mu and % of Total Available Area)*	**SM-WW Balanced Input Use I** *(mu and % of Total Available Area)*	**Total Used Area** *(mu and % of Total Available Area)*
HH 1	1.11 (55.50%)	0.89 (44.50%)	2.00 (100.00%)
HH 2	1.96 (40.91%)	2.84 (59.09%)	4.80 (100.00%)
HH 3	2.34 (58.44%)	1.66 (51.56%)	4.00 (100.00%)

The optimization in the scenario *Premium for Reduced Fertilizer Use* results in 100.00% land use of all selected households. The resulting combinations of production options equal those in *Optimization under Current Conditions* – which already achieved low fertilizer use and high NUE values. Therefore the resulting production combinations are congruent with *Optimization under Current Conditions*; the environmental effects of this scenario can be consulted in 0. However, the economic effects differ from *Optimization under Current Conditions*, thus Table 121 presents the resulting total gross margins in the scenario *Premium for Reduced Fertilizer Use*.

Table 121 Total Gross Margins in the Scenario *Premium for Reduced Fertilizer Use*

	Total Gross Margin (*¥ and initial Total Gross Margin)*
HH 1	¥5,970.46 (¥2,235.20)
HH 2	¥14,259.92 (¥7,462.85)
HH 3	¥11,990.11 (¥4,314.40)

The impacts of a premium for reduced fertilizer use are clearly positive: HH1 increases by +167.11%, HH2 by +91.08% and HH3 by +177.91%. With such strong increases of total gross margins, it can be estimated that the effects on rural households' incomes are positive. However, on a large scale such a policy would be extremely costly for the government – so it is questionable if it would be realizable.

In addition, again, it should be noted that the characteristics of the model also have impacts on these results. The operational range of the model is limited as it is using fixed optimization options instead of continuous production functions and can, thus, occasionally only react stepwise. Therefore the model is sometimes limited to operating in optimum ranges rather than optimum points, as intermediate might be lacking. However, in order to be able to integrate the optimization options which are derived from other studies and experiments (management measures and innovations) it was necessary to formulate the model in this way. It might be that in reality – when farmers are not limited to fixed optimization options –households react differently to a premium for reduced fertilizer use. So the results in this scenario should be interpreted carefully.

Consequently it can be summarized that, according to the results from the simulation and considering the limitations of the model, a policy of introducing a premium for reduced fertilization does not represent an effective measure to comply with the goals of this work. Already *Optimization under Current Conditions* (without high governmental investments) leads to equal environmental effects. Therefore a sensitivity analysis is not conducted for this scenario.

6.24.Environmental Fee

The scenario *Environmental Fee* surveys the effects of payments for environmental degradation. The fee represents a combination of the polluter pays principle (for fertilization) and the resource use fee (for water). The aim of these policies is to increase resource use efficiency and to limit pollution. This scenario aims at determining the efficiency of such a policy. Therefore a tax of ¥4.00 per kg N fertilization combined with a tax of ¥5.20 per m^3 water (which equals the marginal water price) is introduced. Even though these prices do not exactly represent the costs of pollution or resource use, this scenario simulates the effects of such a measure as it is important to estimate the effectiveness of such a policy. It should be noted that, similar to *Premium for Reduced Water Use* and *Premium for Reduced Fertilizer Use*, such a policy would be difficult to implement and monitor in the research area. Table 122 presents the optimized result of *Environmental Fee*.

Table 122. Simulation Results for the Scenario *Environmental Fee*

	SprM Peanut Intercropping *(mu and % of Total Available Area)*	**Optimized SM-WW** *(mu and % of Total Available Area)*	**Total Used Area** *(mu and % of Total Available Area)*
HH 1	1.24 (62.00%)	0.76 (38.00%)	2.00 (100.00%)
HH 2	1.94 (40.42%)	2.86 (59.58%)	4.80 (100.00%)
HH 3	2.66 (66.50%)	1.34 (33.50%)	4.00 (100.00%)

As can be in Table 122 the optimization in the scenario *Environmental Fee* results in a 100.00% land use of all selected households. The optimized cropping strategies of the selected households are comparable. The combinations of optimization options in *Environmental Fee* are identical with the results of *Introduction of Marginal Water Price* – as the aims of both scenarios are comparable and have comparable impacts. Therefore the environmental analysis, based on indicators, does not differ from the analysis in *Introduction of Marginal Water Price* (see 6.5). However, as demonstrated in Table 123, the economic impacts of *Environmental Fee* differ from *Introduction of Marginal Water Price*.

Table 123. Total Gross Margins in the Scenario *Environmental Fee*

	Total Gross Margin (¥ *and initial Total Gross Margin)*
HH 1	¥2,187.02 (¥2,235.20)
HH 2	¥3,892.85 (¥7,462.85)
HH 3	¥4,440.89 (¥4,314.40)

The effects of the introduction of an environmental fee on total gross margins of the integrated households are not clear; the total gross margin of HH1 decreases slightly (by -2.16%), for HH2 it decreases strongly (by -47.48%) and for HH3 it increases slightly (by +2.93%). Therefore it is difficult to assess the impacts of *Environmental Fee* on total gross margins, but in any case the total gross margins are lower than in *Introduction of Marginal Water Price*.

The binding constraints are also equal to *Introduction of Marginal Water Price*, so they are displayed in Table 89. The sensitivity analysis, by means of the reduced cost values, surveys by which amount the value of the variable has to increase in order to change the current optimal solution. All variables which are included in the current optimum solution have reduced cost values of ¥0.00. Variables with low reduced cost values require only small changes to be included in a new optimal solution under unchanged conditions. The price increases of all variables (i.e. reduced cost values) which are necessary to change the optimal solution are displayed in Annex 30. The mean reduced cost value of the optimization options (excl. *Farmers' Practice*) is ¥2,489.19 – this indicates that the uncertainty of this scenario is low as most optimization options have high reduced costs; in addition it is the highest mean reduced cost value of all optimized results. In the scenario *Output Price Increase: SM-WW*, the shadow price for area is ¥3,596.40 – this means that one more mu land would increase the optimum result by the respective amount. The shadow price for total grain is ¥1.29 per kg, which means that if the minimum required amount for total grain production would increase by 1 kg, the optimal solution would decrease by that amount – this is the highest shadow price for grain within the optimized results. In the optimum solution, considering that the current prices of renting land in the research area are very low compared to the shadow price (see part 4.2.2), it would be advisable to rent additional land for the surveyed households.

The simulated effects of the scenario *Environmental Fee* can be summarized:

- Same resulting combination of optimization options and, thus, congruent environmental effects with *Introduction of Marginal Water Price;*
- Unclear effects on total gross margins.

Such a policy is difficult to implement and administer, as under current conditions it is hardly possible to control and monitor applied water amounts. The simulated environmental effects are the same as in *Introduction of Marginal Water Price* – which are not in accordance with the goals of this work. Consequently *Environmental Fee* should be evaluated similarly – especially since farmers are taxed twice (for water and fertilization) without any additional benefit.

6.25.Regional Transferability of Simulation Results

Due to the available data, all households which are integrated into the model operate in Quzhou County (in the Hebei Province). However, it can be assumed that the results of the simulation can be applied to larger areas of the NCP, because Quzhou County and the Hebei Province are typical agricultural areas of the NCP and the main cropping patterns of the surveyed households (SM-WW crop rotation and cotton) and the climate are characteristic for the NCP. Furthermore, in terms of key characteristics the randomly selected surveyed households are comparable to the official data for the Hebei Province and other studies in the NCP (see chapter 4). Consequently it can be assumed that the findings of this work are not restricted to Quzhou County and that they can be applied to larger areas of the NCP. However it should be kept in mind that the specific regional characteristics should always be regarded when transferring results to a larger – especially when developing policy recommendations.

Moreover it is important to conduct further studies on the regional impacts. As some of the results like the production of cabbage or peanut could – if produced on a large scale – could result in price effects which are not integrated in the model of this work. Therefore –when looking at larger areas – the conclusions should be critically reviewed.

6.26.Summary of Results of Simulations

The analysis showed that not one single strategy exists which complies with the goals of this work, but in fact several strategies exist for the specific scenarios. Consequently it was proven that the hypothesis that “a change of the management system is able to meet the production goals, to achieve a higher input-output efficiency and to reduce negative environmental impacts” is valid. The optimized results comply with the requirements for total grain production, own consumption, increased total gross margin and improved environmental performance. The improved environmental performance refers to improved resource use efficiency and decreased resource use of water and fertilization. Table 124 presents an overview of the results of the simulations in the respective scenarios.

Table 124. Overview of the Simulation Results in the Scenarios

Scenario	Simulation Results
Optimization under Current Conditions	• Decreased total fertilizer use, total water use and nutrient excess (but undersupply of K which endangers sustainability) • Improved WUE and NUE • No uniform effects on total water balance • Increased total food production (unchanged grain production) • Increases total gross margin
Optimization under Current Conditions – no Grain Production Requirements	• Wheat is not competitive with other crops • Grain self-sufficiency is endangered • Results not in accordance with goals of this research
Input Price Increase: Fertilization	• Increasing fertilizer prices does not represent an effective measure to comply with the goals of this work • Only unrealistically high price changes in order to differ from results in *Optimization under Current Conditions*
Input Price Change: Fertilization Subsidy	• Subsidizing fertilizer prices does not represent an effective measure to comply with the goals of this work • Only unrealistically high price changes in order to differ from results in *Optimization under Current Conditions*
Input Price Change: Introduction of Marginal Water Price	• Not uniform results for fertilizer use, nutrient balance and gross margin • Decreased total water use • Increased WUE, NUE and food production • Environmental effects are do not uniformly comply with the goals of this work • Introducing the marginal water price might not be an effective measure to comply with the goals of this work
Input Price Change: Pesticides	• Increasing input prices does not represent an effective measure to comply with the goals of this work • Only unrealistically high price changes in order to differ from results in *Optimization under Current Conditions*
Output Price Increase: Maize	• Decreased total fertilizer use • Improved WUE and NUE • Evened out balances for N and P as well as water use • Inconclusive effects on total water use • Increased grain production • Strongly increased gross margin • Transferability of simulated results is questionable
Output Price Increase: Wheat	• Same results like in *Output Price Increase: Maize* (see above)
Output Price Increase: SM-WW	• Same results like in *Output Price Increase: Maize* (see above)
Output Price Increase: Soy	• Increasing soybean prices does not represent an effective measure to comply with the goals of this work • Only unrealistically high price changes in order to differ from results in *Optimization under Current Conditions*

Table 124. – Continued – Overview of the Simulation Results in the Scenarios

Output Price Increase: Peanut	• Decreased total fertilizer use • Improved WUE and NUE • Decreased nutrient excess (but undersupply of K) and water use (but but negative water balance): endanger sustainability • Increased total food production • Increased total gross margin • Environmental effects are not sustainable, therefore increasing peanut prices are not does not represent an effective measure to comply with the goals of this work
Output Price Increase: Cabbage	• Increasing cabbage prices does not represent an effective measure to comply with the goals of this work • Not even unrealistically high price changes in order to differ from results in *Optimization under Current Conditions*
Output Price Decrease: Maize	• Same results as in *Optimization under Current Conditions* (see above) but comparably decreased total gross margin • Congruent environmental effects as in *Optimization Under Current Conditions* (see above) • Decreasing maize prices does not represent an effective measure to comply with the goals of this work
Output Price Decrease: Wheat	• Same combination of optimization options as in *Optimization under Current Conditions* (see above) but comparably decreased total gross margin • Congruent environmental effects as in *Optimization Under Current Conditions* (see above) • Decreasing wheat prices does not represent an effective measure to comply with the goals of this work
N Fertilization Cap	• Decreased total fertilizer use and water use • Improved WUE and NUE • Diverse effects on total water balance • More evened total nutrient balance • Increased total food production and gross margin • A N fertilization cap might be an effective measure to comply with the goals of this work
Irrigation Cap	• Same combination of optimization options as in *Optimization Under Current Conditions*, which does not require governmental intervention (see above) • Congruent environmental effects as in *Optimization Under Current Conditions* (see above) • A irrigation cap does not represent an effective measure to comply with the goals of this work
Total Area: Substitutability with Cotton	• Same results like in *Optimization Under Current Conditions* (see above) • Congruent environmental effects as in *Optimization Under Current Conditions* (see above) • Under current conditions cotton is not competitive with the SM-WW optimization options
Less Available Labor	• Less available labor endangers food security in the NCP, which does not comply with the goals of this work

Table 124. – Continued – Overview of the Simulation Results in the Scenarios

Introduction of Price for Labor	• Same combination of optimization options as in *Output Price Increase: Maize* (see above) • Congruent environmental effects as in *Output Price Increase: Maize* (see above) • Unclear effects of total gross margin
Area Subsidy: Wheat	• Not uniform results for fertilization, nutrient balance and total water use • Improved WUE and NUE • Evened out total water balance • Increased grain production and total gross margin • Unsustainable environmental effects, so *Area Subsidy: Wheat* does not represent an effective measure to comply with the goals of this work
Yield Premium	• Same combination of optimization options as in *Output Price Increase: Maize* (see above) • Congruent environmental effects as in *Output Price Increase: Maize* (see above) • Increased total gross margin • High costs for government make effectiveness questionable
Premium for Reduced Water Use	• Same combination of optimization options as in *Input Price Change: Introduction of Marginal Water Price* (see above) • Congruent environmental effects as in *Input Price Change: Introduction of Marginal Water Price* (see above) • Increased total gross margin • Environmental effects are do not comply with the goals of this work
Premium for Reduced Fertilizer Use	• Same combination of optimization options as in *Optimization under Current Conditions* (see above) • Congruent environmental effects as in *Optimization under Current Conditions* (see above) • *Optimization under Current Conditions* does not include government expenditure and leads to equal results, therefore *Premium for Reduced Fertilizer Use* does not represent an effective measure to comply with the goals of this work
Environmental Fee	• Same combination of optimization options as in *Input Price Change: Introduction of Marginal Water Price* (see above) • Congruent environmental effects as in *Input Price Change: Introduction of Marginal Water Price* (see above) • Not uniform effects on total gross margin • Environmental effects are do not comply with the goals of this work

Except for the scenario *Optimization under Current Conditions – no Grain Production Requirements* all optimization processes met the production goals, as the model required producing at least the same amounts of grains as in the initial situation. Current grain production levels were met and in some scenarios this requirement was even exceeded. These scenarios resulted in the largest increase of total grain production (in combination with management measures from optimization options):

- *Output Price Increase: Maize;*
- *Output Price Increase: Wheat;*
- *Output Price Increase: SM-WW;*
- *Yield Premium*;
- *Introduction of Price for Labor*.

Many scenarios led to increased total gross margins (with probable positive effects on total household income). The scenario *Premium for Reduced Water Use* resulted in the highest combined total gross margin of the selected households.

The input-output efficiencies for the important resources water and fertilizer were assessed based on the indicators water use efficiency (WUE) and nitrogen use efficiency (NUE). More efficient factor inputs could be achieved for water and fertilizers. The highest WUE values were achieved in the following scenarios:

- *Input Price Change: Introduction of Marginal Water Price;*
- *Premium for Reduced Water Use;*
- *Environmental Fee.*

Optimization under Current Conditions resulted in the largest NUE values for the integrated households.

Other indicators assessed the environmental performances of the scenarios. The smaller total water use, the fewer is the pressure on water resources in the research area. The smallest total water use was achieved in the following scenarios (in combination with management measures from optimization options):

- *Input Price Change: Introduction of Marginal Water Price;*
- *Premium for Reduced Water Use;*
- *Environmental Fee.*

The aim of this work is to achieve a perfectly evened out water balance in which only as much water is applied as the crops need. The following scenarios resulted in perfectly evened out water balances (in combination with management measures from optimization options):

- *Output Price Increase: Maize;*
- *Output Price Increase: Wheat;*
- *Output Price Increase: SM-WW;*
- *Yield Premium*;
- *Introduction of Price for Labor*;
- *Area Subsidy: Wheat*.

It should be noted that the above policies (increasing output prices, yield premium, etc.) do not aim at evened out water balances. As mentioned in the previous sub-chapters due to the construction and characteristics of the model these results might be an unintended side-effect of the optimization. Therefore, even though the above results represent optimized management measures, the significance of the causal connection between the policies and the effects on the water balance is might be questionable.

The smaller total fertilizer use, the less negative environmental effects are resulting in the research area. The smallest total fertilizer use (combined for N/P/K) was achieved in the scenario *Fertilization Cap* (in combination with management measures from optimization options).

The aim of this work is to achieve a perfectly evened out nutrient balance in which only as much fertilizers are applied as the crops need. The scenario *Fertilization Cap* resulted in the smallest difference towards the balanced nutrient supply (in combination with management measures from optimization options).

Within the limitations and characteristics of the model, the following scenarios were assessed as not efficient measures to reach the aims of this work:

- *Optimization under Current Conditions – no Grain Production Requirements;*
- *Input Price Increase: Fertilization;*
- *Input Price Change: Fertilization Subsidy;*
- *Output Price Increase: Soy;*
- *Output Price Decrease: Maize;*
- *Output Price Decrease: Wheat;*
- *Premium for Reduced Fertilizer Use.*

The sensitivity analysis showed that all optimized results have low uncertainties. The scenario with the lowest uncertainty is *Environmental Fee* as it has the highest mean reduced cost value. The scenario *Yield Premium* resulted in the highest shadow price for land – this can be interpreted in the sense that this scenario generates the highest per area values of the land. The scenario *Environmental Fee* resulted in the highest shadow price for additional grain, which indicates that grain production is the least profitable in this scenario.

Some optimization options were not included in any optimized result. It can, thus, be assumed that these optimization options do not provide efficient solutions in within the aims of this work and the regarded scenarios. In no scenario maize or wheat was bought – which indicates that own production is more efficient. It should also be noted that not one optimization options which stems from the survey (and i.e. represents current practices) was included in the optimum results – this indicates that current practices do not provide efficient solutions.

7. Discussion of Strategies

The aim of this chapter is to discuss possible strategies to reduce environmental impacts of farming in the NCP – considering the objectives of this work: sustainability and food security. The discussion of this part integrates findings from the descriptive analysis in chapter 4, from the simulation in chapter 6 as well as findings from the review of literature. The simulation showed that grain production could be maintained and even increased. This can have positive impacts on rural household income. It should be noted that rising incomes of farmers might create new sources of pollution, as they might consume more (PROSTERMAN *et al.*, 2009). However, restricting rural development is no option. In addition, as was shown in 2.4.4, the negative impacts of climate change on agriculture in the NCP are expected to aggravate existing problems.

The survey showed that – for the cultivation methods which the farmers apply currently – the SM-WW production is economically not compatible with cotton. Only when optimized/improved management measures are applied, grain production becomes economically more attractive – these findings have important implications for food security. This study also showed that wheat is the economically least attractive main crop, but highly important for own consumption and, thus, for food security. The discussion focuses on the two main environmental problems in the research area: fertilization (see part 7.1) and water (see part 7.2).

7.1.Fertilization

This part aims at discussing possible strategies to limit the overuse and inadequate applications of fertilization in the research area. The analysis showed that, compared to fertilization, manure represents the cheaper form of plant nutrients (see 4.3.5). Manure can be associated with positive effects on soil characteristics. However, as studies showed, the application of manure can lead to increased greenhouse gas emissions in the research area. The potential of improved land management and soil C management (e.g. the return of residues or the use of slow release fertilizers) on greenhouse gas emissions and C sequestration potential is emphasized by several studies (e.g. LI *et al.*, 2003).

In order to reduce N over-fertilization and related environmental impacts a price increase of N fertilizers appears to be an appropriate instrument. BARNING (2008), however, showed that a price increase of 20% reduces the N surplus by only 9.5%. Therefore this instrument poses financial burdens on the farmers in the NCP without tackling the problem of N over use effectively. This is in accordance with the results of the simulation of this study: it was demonstrated that fertilization pricing policies do not provide efficient measures to reduce over fertilization. However, as mentioned in 6.3, this result might originate from the limitations of the model. Consequently it is doubtful that a definite causal relation exists and that this conclusion can be applied comprehensively – especially when considering that such an assumption would presume absolutely uneconomic behavior of the farmers, as it implies that farmers fertilize regardless of costs.

Command-and-control policies with compulsory rules and controlled N application rates are a strategy to reduce N fertilization. Such policies are successfully implemented in some developed countries, but China does not have a fertilization norm or ordinance. JU *et al.* (2004) state that such policies are not directly transferable to the NCP – due to the different setting and system. Furthermore the fragmented farming sector in the NCP, which is dominated by small-scale farms with a low level of technology, lacks adapted production techniques. Therefore widely adapted comprehensive standards and limits may not be applicable for the diverse conditions of the NCP. Nonetheless specific recommendations could reduce over-fertilization. The simulation in chapter 6 showed that a policy of capping fertilizer use in the research area can be an efficient solution. However, the implementation and monitoring of such a policy is sumptuous.

BARNING (2008) and JU *et al.* (2004) revealed that the level of education of farmers is low and that knowledge transfer systems are deficient – leading many farmers to unconsidered use of environmental resources or pollution. Basic education and agricultural knowledge are essential to understand and consider fundamental agronomic or economic criteria. Optimized or modified management strategies can potentially reduce the environmental burden of farming in the NCP (JU *et al.*, 2006). Hereby extension services can play a vital role by supporting knowledge transfer to farmers. Therefore MACK *et al.* (2005) promote that simple and effective support decision methods should be developed and taught to farmers in order to increase environmental awareness. Promoting environmental awareness among farmers, e.g. via television programs, can be essential to prevent negative environmental effects (KOLBE and ZHANG, 2000). Knowledge transfer programs might offer a potential for improvement. When looking at chapter 4, the majority of the surveyed households base their strategic production decisions on their own experience. Considering that the surveyed households hardly had any contact with extension services or any agricultural training, it can be concluded that the degree of methodological knowledge is low – consequently, it is doubtful that this decision making strategy leads to optimum results. According to the results of the simulation also demand-driven fertilization represents a promising management strategy to optimize nutrient input. But in order to be able to determine the nutrient demand, the farmers require methodological knowledge as well as facilities and support for (soil) analysis. Therefore the introduction of innovative management practices should be supported by the government through e.g. subsidies, but also through the extension services and knowledge transfer. Also JIANG (2009) stresses the importance of research-based, data-driven decision support systems, knowledge transfer and capacity building for policy design concerning water resources and concludes that “China can afford to invest in scientific research and developing and maintaining complete information systems”.

Technological development can potentially help to achieve reasonable N inputs. Innovative methods have to be compared against the costs of their implementation and impacts on labor, income and natural resources have to be considered. For example, in order to optimize irrigation and fertilization management, MACK *et al.* (2005) suggest that GIS-based applications may be used. Even though such technologies might work effective, it is questionable if stakeholders in the NCP are able and willing to make such investments. Furthermore the adaptation process is crucial for the success of innovations. The adaptation process depends largely on knowledge transfer systems – which are deficient in the NCP (see above). Once knowledge transfer systems are improved, innovations can be a promising tool to reduce the environmental impacts of farming in the NCP. ZHANG *et al.* (2009) suggest new fertilization strategies for the SM-WW double cropping system in the NCP: adjustment of the amount of fertilization according to soil fertility conditions, increase use of organic fertilizers and the usage of fertilizers should be combined high yielding plantation technologies. The simulation in chapter 6 showed that the optimization under current conditions (i.e. with no policy influence) resulted in the highest nitrogen use efficiencies – so optimization can lead to improved resource use efficiency. Also for example organic farming practices can have positive environmental effects in the research area, as they ban the use of chemical fertilization. In addition some characteristics (e.g. abundant labor) of the households in the research area fit requirements of organic farming.

The important role of contractors was shown in chapter 4. Their existence represents a successful strategy to overcome the lack of resources which are required for investments in machinery which enables the farmers to mechanize certain production steps. However, it was shown that the use of machinery is still limited and selected – this can be associated to positive environmental impacts through low degrees of emissions and other problems related to the use of agricultural machinery (e.g. compacted/hardened soil). Machinery endowment can be also an important factor for the introduction of innovative production measures.

7.2.Water Management

This part aims at discussing strategies aiming at improving water availability and water quality in the NCP. China has to feed its growing population based on a small and even declining area of fertile land. Recent programs like the construction of channels from the South to the North were initiated to satisfy the needs of water of populous towns and the main agricultural areas in the North (ZHU, 2006).

The review of literature and the simulation show that management measures exits which can reduce the problems related to water management in the NCP. For example WANG et al. (2004) suggest to plant winter wheat in a bed planted, furrow irrigated system as their experiments showed a positive impact on water use efficiency and physical soil properties, in addition it is possible to apply post-emerge N by band incorporation in furrow and the humidity in the crop canopy can be decreased, which is helpful to reduce crop lodging and disease incidences. On the other hand this practice requires sophisticated efforts and has more demand on work or tools – which might exceed the farms' resources and abilities. According to the simulation, optimized irrigation strategies exist (i.e. demand-driven irrigation) which ensure productivity but reduce stress on resources, but – again – methodological knowledge as well as facilities and support for analysis are required. Another recommended strategy to improve water use efficiency is to the reduce evapotranspiration by mulching (WANG *et al.*, 2001). The survey showed that plastic mulching is already widespread for cotton production in the research area and that related costs are low – so it can be assumed that it could also be applied for maize in the SM-WW crop rotations. However, KENDY *et al.* (2003) argue that water saving methods in the NCP which reduce pumping of groundwater do not save water as long as the cropped area remains constant, because decreased pumping causes a corresponding reduction of groundwater recharge from excess irrigation, while precipitation and crop evapotranspiration remain unchanged. Therefore the only way to save water in the NCP would be to reduce the only significant outflow of the hydrologic system: evapotranspiration. This can be achieved by a reduction of the cropped area, which is unlikely because the agricultural outputs from the NCP are needed to sustain China's food supply and ensure grain self-sufficiency – especially in face of rising food demand.

As described in the previous chapters, winter wheat requires the biggest share of irrigation in the predominant SM-WW crop rotation. Since wheat is one of China's most important staple foods, it is no option to reduce its cultivation. Therefore BINDER *et al.* (2007) suggest several agronomic practices to reduce the water amount used by the agricultural sector in the NCP: changes of irrigation schedules to reduce total amount of water use by applying knowledge about water stress, changes of the cropping systems, using drip irrigation instead of the predominant flood irrigation, mulching to prevent soil evaporation and breeding for improved transpiration efficiency. Some of these suggestions are, however, in contrast to the argumentation of KENDY *et al.* (2003), yet they agree on the fact that demand management has a higher potential to alleviate regional water shortages than supply management (i.e. diverting water from the Yangtze River). Also VARIS and VAKKILAINEN (2001) emphasize the need to increase water use efficiency and the abetment of environmental degradation in the NCP, instead of supply management. (i.e. diverting water from the Yangtze River). Therefore YANG *et al.* (2003) state that "improving irrigation efficiency through better management and the adoption of water-saving technologies is the ultimate way to deal with the challenges facing irrigated agriculture". This is in accordance with the results from the simulation of this work which showed that management options (i.e. optimization options) with higher water use efficiencies and less total water use are available. The following policies (in combination with optimized management measures) resulted in the highest WUE values and the smallest total water use: introduction of the marginal water price, premium for reduced water use and environmental fees – but also in not uniformly positive effects for other environmental indicators (see chapter 6).

However, water pricing or taxing is a controversial subject. There are many ways to regulate water use to a sustainable level, for example by adjusting the prices of electricity or fuel for running pumps or by introducing prices for the use of water, also specific fees or taxes to cover the economic and environmental costs of water consumption and pollution could be introduced. According to GALE (2005) low marginal prices of water in China lead to overuse. Also HUANG *et al.* (2008) regard water as severely underpriced in China. Following this argumentation, current water pricing policies in the agricultural sector have not been effective in providing incentives for users to save water. Consequently ZHEN and ROUTRAY (2002) strongly recommend water pricing policies. But increased water prices represent a financial burden to the already needy farmers. As was shown in 2.1, farmers in Northern China are within the poorest groups and increased water prices might have considerable effects on inter-sectoral equity, by making farmers even more worse off in comparison to the urban population (WEBBER *et al.*, 2008). On the other hand ZHANG *et al.* (2008) point out that the price of pumped water in most cases reflects a market price based on the costs for the electricity for the pump. To some extent indirect water prices also reflect water scarcity – as markets for groundwater markets develop faster when the groundwater tables decline. These indirect volumetric prices were also identified in the survey of this work: none of the households had to pay directly for the use of water, but all farmers had to pay indirectly through the costs of the electricity or fuel necessary to run the pumps. Moreover it was demonstrated that indirect water prices are within the major cost factors of the main crops. These results reveal that the surveyed households are already (indirectly) paying for the use of water according to the consumed amount. Since the farmers are somehow paying for the consumed quantities of water, the effectiveness of an introduction of water tax mechanisms might be questionable, as the costs for irrigation are already increasing the more water they are using – so an introduction of water taxation might only represent an additional cost factor – thus it is doubtful if water pricing provides an effective measure. On the other hand the simulation showed that for some households the introduction of the marginal water price – in combination with optimized management measures – can result in efficient solutions. However, due to the privately run decentralized pumping facilities; hardly any controls about the amounts of pumped groundwater exist. Therefore the implementation and enforcement of water pricing policies seem to be difficult in the institutional setting of the NCP.

Higher water prices including negative externalities could lead to declining winter wheat production as it demands more irrigation than maize, due to watering in winter. Such a production drop could endanger the food security of China. Consequently higher water prices would need to be covered through either higher consumer prices or transfer schemes from the society, i.e. by environmental taxing. Nowadays, in the NCP, water is mostly regarded a common good which can be used without directly paying for it. Therefore it is firstly necessary to estimate the response of the farmers to price incentives and to better monitor and regulate the private water pumping facilities in order to survey the real amounts of water pumped and to calculate the amount of water used. In many developed countries demand for water is inelastic, therefore “it is important to learn about the nature of responses when planning price interventions” (HUANG *et al.*, 2008). In addition water pricing might not serve the purpose of water conservation, as it provides little incentives for water authorities to change supply and farmers are not motivated to adopt water-saving technologies (YANG *et al.*, 2003). That is why WEBBER *et al.* (2008) conclude that water pricing can only by effective if the policies are tailored for the specific physical, institutional, development and social realities of North China. Also other studies emphasize the importance to avoid uniform nation-wide approaches (i.e. by integrating local governments and considering local conditions) when reforming policies in the Chinese water sector (HUANG *et al.*, 2009).

Many studies (e.g. YANG *et al.*, 2003) call for institutional changes in the Chinese water sector. As was outlined in 2.4.2, the institutional set-up is one of the main challenges of the Chinese water sector. In order to increase the functionality and efficiency it is also important that clearly defined and legally enforceable water use rights are introduced. The lack of transparent and secure water rights can decrease the responsibilities towards water resources and can lower the incentives to apply water saving measures. Therefore enforced and clear water rights are essential for long-term sustainable farming strategies.

Farmers in the NCP are often supplied by private decentralized pumping facilities instead of public pipelines – which limit control mechanisms. The survey showed that water meters or other measure instruments hardly exist on village level, which complicates the control of used amounts. Consequently it is firstly necessary to better monitor and regulate the private water pumping facilities in order to survey the real amounts of pumped water and to calculate the water use, to prevent i.e. drilling of private wells and to manage the water resources on a local level – which represents a complex task for the government. In 2.4.2 it was also shown that the infrastructure represents a major source of inefficiencies and water loss. Consequently money should be transferred to water management agencies and spent to reduce losses and increase reliability of services (WEBBER *et al.*, 2008).

Command-and-control policies with compulsory rules and controlled rates of applied inputs are a strategy to reduce resource pollution and usage. When regarding the Polluter-Pays-Principle, a challenge lies in the fact that in the rural areas of the NCP mostly everyone is polluter and aggrieved party at the same time: the polluters are paying already indirectly through i.e. negative health effects or decreased yields. However, as was shown in 4.4.5, the surveyed households have a low environmental awareness. In addition, the surveyed households hardly had any contact with extension services or agricultural training. Consequently, these answers indicate a lack of information and methodological knowledge. Thus it is questionable if farmers are aware of this vicious circle and the relations between pollution and the impacts on their living conditions.

8. Conclusions

This work provided a detailed in-depth description of the farming practices in the NCP. The analysis showed that current farming practices in the research area are not sustainable and can, thus, threaten future the food security in China. The dilemma of the research area is that intensive agricultural production cannot be reduced because high yields are needed to feed the growing demand from a (economically) growing population. Simultaneously high resource consumption and pollution from farming cannot continue as that could eventually result in irreversible damage to agriculture in the NCP and also threatens livelihoods. In this final part, mainly based on the findings from the descriptive analysis in chapter 4, the simulation in chapter 6 and the discussion in chapter 7, strategic policy recommendations, characteristics of improved management practices and recommendations for further research are presented. These recommendations can play an important role in decision guiding for policy makers.

After reviewing other studies in the NCP, it has to be concluded that this work represents one of the most comprehensive analysis of the agricultural practices in the Hebei Province. Based on the wide-ranging dataset and the descriptive analyses of this work other studies in the fields of agricultural, environmental and economic sciences can be conducted. This work provided a detailed analysis of one area in the NCP, Quzhou County. However, as demonstrated in 0, it can be assumed that the findings can be applied to larger areas of the NCP, but when doing so it is important that specific regional characteristics are considered. Nevertheless, a following step might be to extend the research area and to compare the results of this work with data from other regions in the NCP, for example by means of GIS applications. Regionalized results could provide valuable information to policy and decision makers.

Improved management practices were characterized in chapter 5. It was shown that management practices for maize and wheat exist which can result in higher input-output efficiency and that they are economically more profitable – especially production options which include intercropping of other crops or demand-driven fertilization and irrigation. The hypothesis that “a change of the management systems is able to meet the production goals, to achieve a higher input-output efficiency and to reduce negative environmental impacts” was tested to be valid. The simulation of optimization options showed that economically more profitable production options exist. These optimized production options are characterized by a more efficient factor input (mainly water and fertilization) and resulting decreased environmental impacts. The policy of a premium for reduced water use resulted in the highest simulated increases of total gross margins with simultaneously partially reduced negative environmental impacts. However the simulation also revealed that, in order to ensure food security, incentives for producing wheat should be provided as it is the economically least profitable main crop, but it has important functions for own consumption. The simulation also revealed that policies aimed at increasing output prices of the main crops (in combination with optimized production options) can result in total higher gross margins and decreased negative environmental impacts and higher resource use efficiency. It should be noted that all optimum results did not integrate production options which the surveyed farmers are currently applying – this indicates that current practices are not efficient.

This study showed that farmland in the research area is fragmented. Land fragmentation can have beneficial impacts on risk managements and seasonal labor supply, but it also increase production costs and reduces agricultural efficiency (TAN *et al.*, 2008). Consequently the impacts of land fragmentation on the environment under the specific conditions of the NCP have to be researched further.

Currently agricultural labor in the NCP is abundant. But the survey showed that already 48.44% of the households have off-farm income. Non-farm revenue makes up 46.15% of mean net household revenues of the surveyed households – which is comparable to the mean net revenues from farming. This reveals – in accordance with other studies – the increasing importance of off-farm income sources in the NCP. Off-farm income offers alternative income sources, so the households' dependence on land might decrease which might lead to decreased incentives for long-term sustainable farming strategies. In the future land might only be needed for own consumption requirements or in order to diversify income sources – which would impede the chances of knowledge transfer and the introduction of sustainable practices. Therefore further research is needed concerning the developments of off-farm income and its implications for agriculture in the NCP.

Many studies state that knowledge transfer systems and extension services in the NCP are deficient. The survey showed that 96.87% of the households did not have contact with the extension services in the last 36 months and, moreover, 84.38% of the households never received agricultural training. A knowledge transfer program can be an efficient tool to reduce environmental impacts of farming in the NCP. The benefits of such a program might even surpass the target of reducing environmental impacts, because improved and updated knowledge is the basis of advances of rural development and can foster farmers' participation. In addition specific recommendations and systems under consideration of socio-economic approaches have to be developed to improve knowledge transfer and services to farmers in the NCP. Appropriate decision support systems for efficient land use in the research area have to be developed.

The lack of methodological agricultural knowledge is also the result of policy failures, as the government failed to maintain high quality extension services over the past 2-3 decades (see 2.1). The extension services which functioned well in the 1980's are nowadays – as described above – nearly non-existent in the research area. Also the lack of environmental awareness of the stakeholders can be partially associated with policies which strongly concentrated on raising yield levels. This study showed that laws and regulations regarding environmental impacts exist (e.g. for preventing burning crop residues), but they are not reliably enforced. Many studies state that the current institutional framework for water management is inadequate and that it, thus, represents one of the causes for the overexploitation of water resources. Therefore the responsibilities should be clearly defined in order to be able to create incentives for saving water and to increase efficiencies. Furthermore, farmers' water rights are not secure and not transparent. Therefore plans, based on scientific estimations for water supply and demand, are needed to clearly define and enforce water use rights. Besides clearly defined and enforced water use rights, also longer, enforced and secure land-use rights might facilitate the adoption of sustainable farming practices. In addition the impacts of a more dynamic agricultural land market should be researched. Also the institutional set-up complicates the implementation of policies. Therefore institutional change with coordinated efforts is needed.

Decentralized and regionalized administrations might increase the effectiveness of policies. In addition the institutional framework has to be updated to the specific requirements in the NCP. One of the main reasons for problems related to water management is that it represents a mostly unregulated resource in the NCP. The survey revealed that water consumption is only indirectly paid according to the used amount through energy or pumping cost – so somehow volumetric water prices exist. The topic of water pricing or taxation is controversially discussed for the NCP. The simulation showed that for some households the introduction of a marginal water price (in combination with optimized management measures) can result in higher WUEs and lower water consumption.

The current water infrastructure is a main source of inefficiencies: water is lost when being transported to users and monitoring equipment is lacking. A precondition for policies related to water use is the installation of sufficient monitoring equipment in the research area. Therefore investments in the water infrastructure are needed now to be able to install appropriate control mechanisms in the long term.

The simulation demonstrated that innovative cropping systems (i.e. inter-cropping with cabbage or peanuts) exist which result in more efficient practices with decreased negative environmental impacts. However, the effects of changed farm management measures in the NCP have to be continuously researched. For example, the potentials for the use of slow-releasing fertilizers, integrated pest and fertilizer management or increased use of modern machinery, like innovative sprayers, in the NCP should be estimated on farm level. The possibilities for research in this field are wide: change of varieties, irrigation, crop rotation etc. should be considered. Suitable farm management practices for the NCP have to be continuously developed – taking into account modern practices and innovations. Hereby technological development can play a vital role. Further research into other impacts of agriculture in the NCP is needed. The effects of fertilization and water management are already considered by several studies (including this study), but – for example – the effects on water pollution and pesticide use and related practices should be studied more intensively, in order to be able to analyze the agricultural system in the NCP and to comprehensive provide policy recommendations.

The survey showed that fertilizer use is strongly varying, overuse and undersupply occur in the research area. The strongly varying and inadequate fertilizer applications endanger the sustainability of the agricultural systems in the NCP. The simulation showed that fertilizer pricing might not provide efficient measures to change fertilization practices. As mentioned before, due to the characteristics of the model, this result should be regarded with caution as might not have a significant causal relationship. However fertilization and total nutrient input should be differentiated, as total nutrient input tends to show more explicit signs of over-supply. The optimization under current conditions (no policy scenario) resulted in the highest NUE values of the simulation. The simulation of a policy of capping fertilizer use resulted in the lowest total fertilizer use. The survey also revealed a strong variation and inadequate water use. The current production of maize shows a tendency for over-use of water; wheat shows frequent occurrences of over- and undersupply. Even a tendency for under-supply of water could be identified for cotton.

Land conservation efforts in the research area need to be increased. The analysis showed that the organic matter contents in the soils are too low. Therefore conservation measures, e.g. preventing the burning of crop residues and returning them to the fields, aimed at increasing soil organic content should be initiated. Some characteristics of the NCP seem to be suitable for organic farming (e.g. abundant labor and high degree of manual labor and low degree of mechanization) – therefore options and possible impacts of organic farming as well as related implications for land conservation in the NCP should be researched. The survey also revealed that the farmers in the research area are not informed about the quality of their soils. Integrated into knowledge transfer programs, providing opportunities for soil analysis to the local farmers could result in fertilization practices which are based on the nutrient contents of the soil and, thus, are more efficient.

Studies indicate that improved land management “would provide a considerable potential soil organic carbon in China and thus may considerably contribute to sequestrate carbon from the atmosphere” (WU *et al.*, 2003). Therefore monitoring and research in carbon sequestration potentials of the common cropping systems under the specific conditions of the NCP and related greenhouse gas emissions should be intensified. In addition, for the environmental assessment it is important to collect data about gas and particulate matter emissions. Based on these findings more comprehensive management recommendations could be worked out. Also approaches like Life Cycle Assessment for the main agricultural products could provide valuable information about environmental issues in the production chain.

Many researchers agree that supply management might be a necessary and helpful tool, but increasing water use efficiency and changing local strategies to more sustainable water use (i.e. demand management) represent the most effective strategy to ensure the sustainability of farming in the NCP. Furthermore, water supply could be coordinated according to the demand-peaks from agriculture. However, besides these large projects initiated by the Chinese central government which are aimed at the supply of water, the situation might also be further improved through leverage effects of regional and local strategies, as well as farm management measures. The results of this study indicate that optimized farming strategies in combination with policies like introduction of the marginal water price, premium for reduced water use or environmental fees can result in increased water use efficiencies.

The study revealed that private service providers play an important part in agriculture in the NCP. Therefore research on the role of contractors and private tubewell managers and the implications for access to water and future agricultural development should be conducted. Contractors could also participate in knowledge transfer programs, as they usually cover large areas and contact many farmers. With proper training they could support the dissemination of information and raise awareness.

Structural development projects in the Chinese rural areas need to be continued, especially in the research are, to avoid a rural exodus. The living conditions in the rural areas – in terms of income, education and health services – are still not comparable with the conditions in urban areas. However the surveyed households have a high share of education-related expenses (17.64% of mean total household expenses) which might indicate that the educational level of the rural households will be increased in the future. To conclude, the main short-term goals are:

- Structural/institutional change (increasing efficiencies of institutions, clearly dividing responsibilities and providing enforceable land and water rights to farmers);
- Improving and investments in rural and agricultural infrastructure;
- Forster adoption of improved/optimized agricultural management measures (e.g. demand-oriented irrigation and fertilization, intercropping);
- Improve services to farmers (extension or facilities for analysis).

The above short-term goals should lead to the long-term goal, which is to create sustainable farming systems in the NCP. More specifically the long-term goals are:

- Prevent the further decline of groundwater levels;
- Install control and monitoring equipment (especially for water);
- Increased education and methodological knowledge of farmers which could raise environmental awareness and lead to more conscious resource and input use;
- Opportunities for the population in the rural areas have to be created by improving the living conditions.

Micro and macro-economic costs of the current practices have to be quantified by approaches related to environmental and resource economics. The current use of water represents a strain on a natural resource – which creates remarkable external costs. To estimate the costs of using a scarce natural resource and damaging the ecosystems in the NCP has therefore the potential to influence policy makers and farmers towards sustainable strategies.

Chinese policy has to focus on stopping the further decline of the ground water tables. Furthermore a conscious water use and environmental awareness for all stakeholders has to be created in order to avoid that pollution or resource scarcity and misuse will further reduce agricultural production in the NCP. Obligatory goals and timeframes need to be set to avoid a further decline of groundwater tables in the research area – especially when considering that climate change is expected to aggravate existing environmental problems. The social costs of strongly decreased agricultural production in the NCP would be unbearable.

9. Summary

The increased use of agricultural inputs like fertilizers and pesticides led to wide-spread negative environmental impacts of agriculture in the North China Plain (NCP). The context of this research is that, due to continued growth of the population and the economy, the demand for agricultural products in China is gradually rising. However resources like land and water are scarce in China. Therefore new strategies need to be developed which do not put additional strains on the environment but meet the expected demand. The NCP is regarded as China's most important agricultural region. This work aims at describing and discussing the environmental effects of agriculture in the NCP. The extent of these environmental impacts is presented. An essential part of this work is the in-depth description and analysis of the current cropping systems and farming practices, which is based on the findings a household survey. The central hypothesis of this work is that a change of the management systems is able to meet the production goals, to achieve a higher input-output efficiency and to reduce negative environmental impacts. Embedded in the objectives of this work, the main goals are the description of current agricultural practices and related negative environmental impacts, the definition of agro-environmental management and policy measures, impact analysis of management and policy measures and the development of suggestions for further research.

The second chapter aims at introducing the background of this research, i.e. the environmental impacts of agriculture. Hereby the focus lies on the introduction of relevant and characteristic farming practices and on the related institutional setting. Then the processes of data acquisition and data handling for this work are described. The descriptive analysis presents the findings from a survey in July 2008; it aims at describing the characteristics of the surveyed farm households. Chapter 5 describes the methodologies which are applied for the analysis in this work. The first part describes the methodology of Linear Programming and its selection process. The second part explains the selection process for the integrated households. The last part describes the processes of environmental assessment by means of selected indicators. In chapter 6 the model is applied to simulate and analyze the selected households in changing scenarios. Each Scenario is described individually. Then the simulation results are presented and discussed. In chapter 7 possible strategies to reduce environmental impacts of farming in the NCP – considering the objectives of this work: sustainability and food security – are discussed. The discussion focuses on the two main problems in the research area: fertilization and water.

The analysis showed that current farming practices in the research area are not sustainable and can, thus, threaten future food security in China. The dilemma of the research area is that intensive agricultural production cannot be reduced because high yields are needed to feed the growing demand from a (economically) growing population. Simultaneously high resource consumption and pollution from farming cannot continue as that could eventually result in irreversible damage to agriculture in the NCP and also threatens livelihoods. Finally strategic policy recommendations, characteristics of improved management practices and

recommendations for further research are presented. These recommendations can play an important role in decision guiding for policy makers. After reviewing other studies in the NCP, it has to be concluded that this work represents one of the most comprehensive analysis of the agricultural practices in the Hebei Province.

It was demonstrated that management practices for maize and wheat exist which can result in higher input-output efficiency and which are economically more profitable – especially production options which include intercropping of other crops or demand-driven fertilization and irrigation. The hypothesis was tested to be valid. The simulation of optimization options showed that economically more profitable production options exist. These optimized production options are characterized by a more efficient factor input (mainly water and fertilization) and resulting decreased environmental impacts. The policy of a premium for reduced water use resulted in the highest simulated increases of total contribution margins with simultaneously partially reduced negative environmental impacts. However the simulation also revealed that, in order to ensure food security, incentives for producing wheat should be provided as it is the economically least profitable main crop, but it has important functions for own consumption. The simulation also revealed that policies aimed at increasing output prices of the main crops (in combination with optimized production options) can result in total higher contribution margins and decreased negative environmental impacts and higher resource use efficiency. It should be noted that the optimum results did not integrate production options which the surveyed farmers are currently applying – this indicates that current practices are not efficient.

Many studies state that knowledge transfer systems and extension services in the NCP are deficient. The survey showed that the majority of the households did not have contact with the extension services, and, moreover, most of the households never received agricultural training. A knowledge transfer program can be an efficient tool to reduce environmental impacts of farming in the NCP. In addition specific recommendations and systems under considerations of socio-economic approaches have to be developed to improve knowledge transfer and services to farmers in the NCP. Appropriate decision support systems for efficient land use in the research area have to be developed.

This study showed that laws and regulations regarding environmental impacts exist, but they are not reliably enforced. Many studies state that the current institutional framework for water management is inadequate and that it, thus, represents one of the causes for the overexploitation of water resources. Therefore the responsibilities should be clearly defined in order to be able to create incentives for saving water and to increase efficiencies. Furthermore, farmers' water rights are not secure and transparent. Therefore plans, based on scientific estimations for water supply and demand, are needed to clearly define and enforce water use rights. Besides clearly defined and enforced water use rights, also longer, enforced and secure land-use rights might facilitate the adoption of sustainable farming practices. Also the institutional set-up complicates the implementation of policies. Therefore institutional change with coordinated efforts is needed. Decentralized and regionalized administrations might increase the effectiveness of policies. In addition the institutional framework has to be updated to the specific requirements in the NCP. One of the main reasons for problems related to water management is that it represents a mostly unregulated resource in the NCP.

The survey showed that fertilizer use is strongly varying, overuse and undersupply occur in the research area. The strongly varying and inadequate fertilizer applications endanger the sustainability of the agricultural systems in the NCP. Furthermore the organic matter contents in the soils are too low. The survey also revealed that the farmers in the research area are not informed about the quality of their soils. Integrated into knowledge transfer programs, providing opportunities for soil analysis to the local farmers could result in fertilization practices which are based on the nutrient contents of the soil and, thus, are more efficient.

Structural development projects in the Chinese rural areas need to be continued, especially in the research are, to avoid a rural exodus. The living conditions in the rural areas – in terms of income, education and health services – are still not comparable with the conditions in urban areas. Chinese policy has to focus on stopping the further decline of the ground water tables. Furthermore a conscious water use and environmental awareness for all stakeholders has to be created in order to avoid that pollution or resource scarcity and misuse will further reduce agricultural production in the NCP. The social costs of further decreased agricultural production in the NCP would be unbearable.

10. Zusammenfassung

Der erhöhte Einsatz von landwirtschaftlichen Betriebsstoffen (wie z.B. Düngemittel und Pestizide) hat zu weit verbreiteten negativen Umweltauswirkungen der Landwirtschaft in der Nordchinesischen Tiefebene (NCP) geführt. Der Kontext dieser Arbeit ist der fortschreitende Anstieg der Nachfrage nach Agrarprodukten aufgrund des kontinuierlichen Wachstums der Chinesischen Wirtschaft und Bevölkerung. Ressourcen wie Land und Wasser sind jedoch knapp in China. Daher müssen neue Strategien entwickelt werden, welche keine weiteren Belastungen für die Umwelt darstellen, aber den erwarteten Bedarf decken. Die NCP wird als wichtigste Agrarregion Chinas angesehen. Diese Arbeit analysiert und beschreibt die Umweltauswirkungen der Landwirtschaft in der NCP. Der Umfang dieser Umweltauswirkungen wird vorgestellt. Ein wesentlicher Teil dieser Arbeit ist die gründliche Beschreibung und Analyse der derzeitigen Anbausysteme und Bewirtschaftungsmethoden, welche sich auf die Ergebnisse einer Haushaltsbefragung stützen. Die zentrale Hypothese dieser Arbeit ist, dass eine Veränderung der Managementsysteme die Produktionsziele erfüllen kann, die input-output Effizienz erhöhen und die negativen Umweltauswirkungen verringern kann. In diesem Kontext lauten die Ziele der Arbeit: die Darstellung der derzeitigen Bewirtschaftungsmethoden und der zugehörigen Umweltauswirkungen, die Definition von Agrar- und Umweltbewirtschaftungs- und Politikmaßnahmen, die Analyse der Auswirkungen von Bewirtschaftungs- und Politikmaßnahmen und die Entwicklung von Vorschlägen für weitere Forschung.

Das zweite Kapitel stellt die Hintergründe dieser Arbeit vor, d.h. im speziellen die Umweltauswirkungen der Landwirtschaft. Hierbei liegt der Fokus auf der Beschreibung der relevanten und charakteristischen Bewirtschaftungsmethoden, sowie dem institutionellen Rahmen. Dann werden die Prozesse der Datenbeschaffung und der Datenhandhabung dargestellt. Die beschreibende Analyse stellt die Ergebnisse der Haushaltsuntersuchung vom Juli 2008 vor; die Kenndaten der untersuchten Haushalte werden in diesem Kapitel beschrieben. Kapitel 5 erklärt die Analysemethoden dieser Arbeit. Zuerst werden die Auswahlprozesse und die Methoden der linearen Programmierung erklärt. Der zweite Teil stellt den Auswahlprozess für die Haushalte dar. Der letzte Teil erklärt die Umweltbewertung anhand von ausgewählten Umweltindikatoren. Im 6. Kapitel wird das Model angewandt, um die ausgewählten Haushalte in verschiedenen Szenarien zu simulieren und zu analysieren. Im Anschluss werden die Ergebnisse der Simulation beschrieben und analysiert. In Kapitel 7 werden – unter Berücksichtigung der Zielsetzung dieser Arbeit – die möglichen Strategien, um die Umweltauswirkungen der Landwirtschaft in der NCP zu reduzieren, diskutiert. Diese Diskussion konzentriert sich auf die beiden Hauptprobleme der Forschungsregion: Düngung und Bewässerung. Im letzten Teil dieser Arbeit werden strategische Politikempfehlungen, die Charakteristika von verbesserten Bewirtschaftungsmaßnahmen und Vorschläge für weitere Forschung vorgestellt. Diese Empfehlungen können bei der Entscheidungsfindung von politischen Entscheidungsträgern eine wichtige Rolle spielen.

Die Analyse hat gezeigt, dass die derzeitigen Anbausysteme in der Forschungsregion nicht nachhaltig sind und daher die zukünftige Ernährungssicherung in China bedrohen können. Das Dilemma der Forschungsregion ist, dass die intensive landwirtschaftliche Produktion nicht verringert werden kann, da hohe Erträge benötigt werden, um die (ökonomisch) wachsende Chinesische Bevölkerung zu ernähren. Gleichzeitig können der hohe Ressourcenverbrauch und die Umweltverschmutzung der Landwirtschaft nicht fortgeführt werden, da dies letztendlich zu irreversiblen Schäden in der Landwirtschaft in der NCP führen könnte, die dann die Existenzgrundlagen bedrohen. Nach der Revision von anderen Studien in der NCP wurde festgestellt, dass diese Arbeit eine der umfangreichsten Analysen der landwirtschaftlichen Praxis in der Hebei Provinz darstellt.

Es konnte gezeigt werden, dass Bewirtschaftungsmaßnahmen für Mais und Weizen existieren, welche zu einer verbesserten input-output Effizienz führen und ökonomisch profitabler sind – speziell Maßnahmen mit Zwischenfruchtanbau oder bedarfsorientierter Düngung und Bewässerung. Die Gültigkeit der Hypothese konnte also bewiesen werden. Die Simulation von Optimierungsoptionen hat gezeigt, dass Anbaumaßnahmen existieren, welche ökonomisch profitabler sind. Diese optimierten Anbaumethoden sind durch einen effizienteren Faktoreneinsatz (hauptsächlich Wasser und Düngung) und resultierende geringere Umweltauswirkungen charakterisiert. Die Politikmaßnahme der Prämienzahlung für reduzierten Wasserverbrauch hat zu den höchsten simulierten Gesamtdeckungsbeiträgen und gleichzeitigen reduzierten Umwelteinflüssen geführt. Die Simulation hat auch gezeigt, dass Anreize für die Produktion von Weizen geschaffen werden sollten, da Weizen ökonomisch die am wenigsten profitable Hauptfrucht ist aber eine wichtige Rolle für den Eigenverbrauch in der NCP spielt. Die Simulation hat auch gezeigt, dass Politikmaßnahmen welche auf höhere Marktpreise für die Hauptfrüchte zielen (in Verbindung mit optimierten Anbaumaßnahmen) zu erhöhten Gesamtdeckungsbeiträgen, verminderten Umweltauswirkungen sowie verbesserter Ressourcennutzungseffizienz führen können. Es sollte noch angemerkt werden, dass in den optimierten Ergebnissen keine Anbausysteme die momentan von den Haushalten angewendet werden integriert sind. Dies deutet darauf hin, dass die momentanen Anbaustrategien nicht effizient sind.

Viele Studien sind der Auffassung, dass Wissenstransfersysteme und staatlich Beratungssysteme in der NCP unzulänglich sind. Die Untersuchung hat gezeigt, dass die Mehrheit der Haushalte keinen Kontakt zu Beratungsinstitutionen hatte und darüber hinaus die meisten Haushalte auch keinerlei landwirtschaftliche Ausbildung erhalten haben. Ein Wissenstransferprogramm kann daher ein effizientes Instrument darstellen, um die Umweltauswirkungen der Landwirtschaft in der NCP zu reduzieren. Darüber hinaus müssen spezifische Empfehlungen und Systeme – unter Berücksichtigung von Sozio-ökonomischen Ansätzen – entwickelt werden, um den Wissenstransfer und die Dienste für die Landwirte in der NCP zu verbessern. Adäquate Entscheidungshilfesysteme für effiziente Landnutzung in der Forschungsregion müssen entwickelt werden.

Diese Untersuchung hat gezeigt, dass zwar Gesetze und Regulierungen für die Umwelteinflüsse existieren, diese aber nicht verlässlich durchgesetzt werden. Viele Studien sehen den derzeitigen institutionellen Rahmen für das Wassermanagement als nicht adäquat an und sehen in ihm einen der Gründe für die Übernutzung der Wasserressourcen. Daher sollten die Verantwortlichkeiten klar aufgeteilt werden, um Anreize zum Wassersparen bieten zu können und um die Effizienz zu erhöhen. Darüber hinaus sind auch die Rechte der Landwirte hinsichtlich Wasser nicht sicher und transparent. Basierend auf wissenschaftlichen Einschätzungen für den Wasserverbrauch und das Wasservorkommen werden Pläne benötigt, um Wasserrechte eindeutig zu definieren und durchzusetzen. Neben definierten und durchgesetzten Wasserrechten könnten auch längerfristige, durchgesetzte und sichere Landrechte die Adoption von nachhaltigen Bewirtschaftungsmethoden erleichtern. Auch der institutionelle Aufbau verkompliziert die Durchführung von Politikmaßnahmen. Daher ist institutioneller Wandel mit koordinierten Anstrengungen notwendig. Dezentralisierte und regionalisierte Verwaltungen können die Effektivität von Politikmaßnahmen erhöhen. Zusätzlich muss der institutionelle Aufbau den spezifischen Gegebenheiten der NCP angepasst werden. Eines der Hauptprobleme bezüglich des Wassermanagements ist, dass Wasser eine größtenteils unkontrollierte Ressource in der NCP darstellt.

Die Untersuchung hat gezeigt, dass die Düngeranwendung stark variiert; Über- und Unterdosierung treten in der Forschungsregion auf. Stark variierende und inadäquate Düngeranwendung gefährden die Nachhaltigkeit der landwirtschaftleichen Systeme in der NCP. Des Weiteren ist der Gehalt an organischer Substanz im Boden zu gering. Die Umfrage hat gezeigt, dass die Landwirte in der Forschungsregion nicht über die Qualität ihrer Böden informiert sind. Integriert in Wissenstransferprogramme, dass zur Verfügung stellen von Möglichkeiten für die Analyse von Böden könnte zu Düngeranwendungen führen, welche auf dem Nährstoffgehalt der Böden basieren und daher effizienter sind.

Strukturelle Entwicklungsprojekte in den ländlichen Regionen Chinas müssen fortgeführt werden, um weitere starke Landflucht zu vermeiden – speziell in der Forschungsregion. Die Lebensbedingungen in den ländlichen Gegenden, hinsichtlich Einkommen, Bildungs- und Gesundheitsdiensten, sind immer noch nicht vergleichbar mit den urbanen Gebieten. Die Chinesische Politik muss sich auf die Beendigung des weiteren Absinkens des Grundwasserniveaus konzentrieren. Des Weiteren müssen eine sparsamere Wassernutzung und ein Umweltbewusstsein für alle Beteiligten geschaffen werden, um zu verhindern, dass Verschmutzung, Ressourcenmangel und –fehlgebrauch die landwirtschaftliche Produktion in der NCP weiter reduzieren. Die sozialen Kosten der weiteren Verringerung der landwirtschaftlichen Produktion in der NCP wären nicht tragbar.

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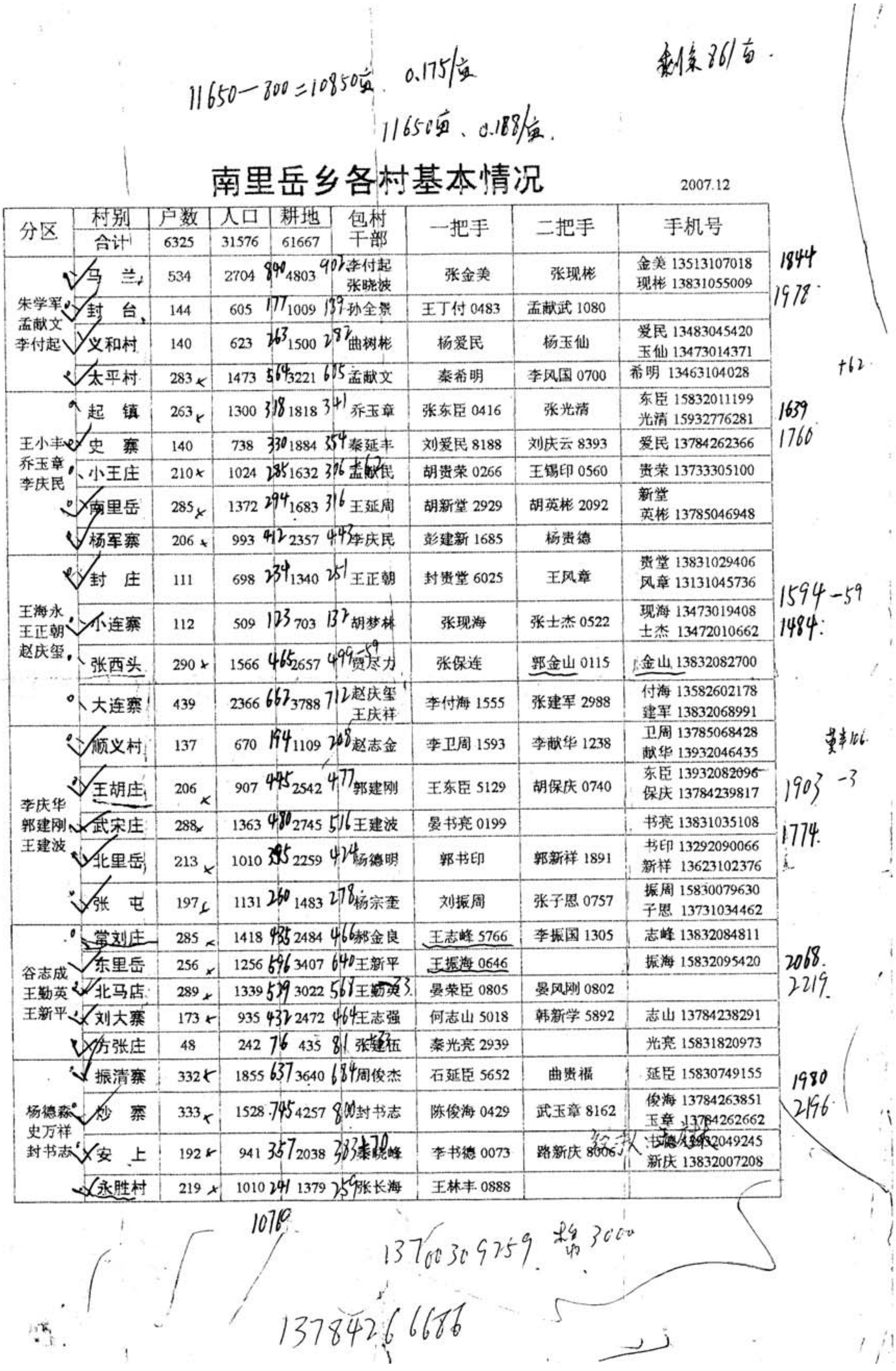
12.Annex

Annex 1. Village List of Nanliyue Town



11650−800=10850亩. 0.175/亩

11650亩、0.188/亩.

剩余361亩.

南里岳乡各村基本情况

2007.12

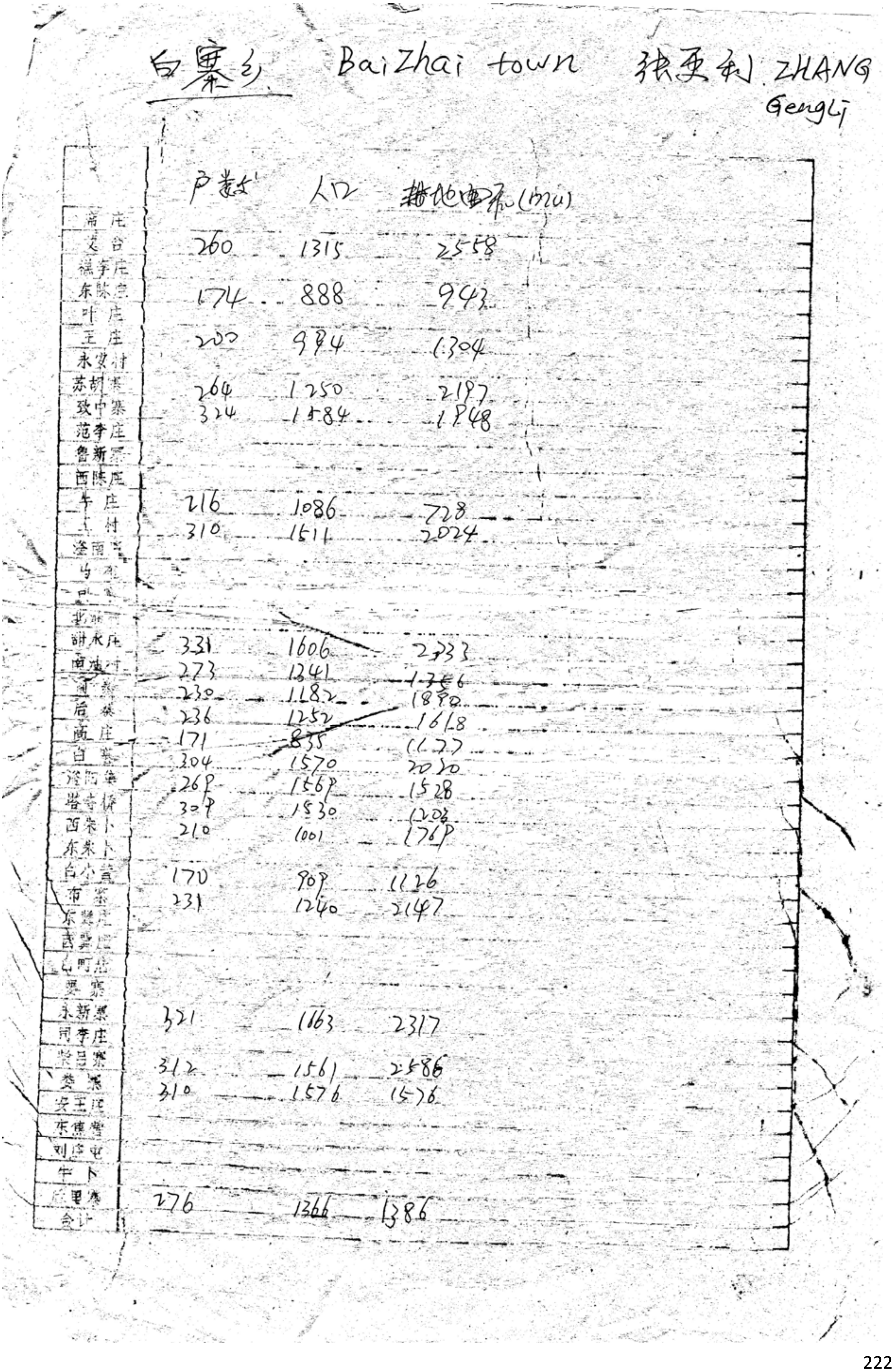
分区	村别	户数	人口	耕地	包村干部	一把手	二把手	手机号	
	合计	6325	31576	61667					
朱学军 孟献文 李付起	马兰	534	2704	890 4803	907 李付起 张晓波	张金美	张现彬	金美 13513107018 现彬 13831055009	1844
	封台	144	605	177 1009	139 孙全景	王丁付 0483	孟献武 1080		1978
	义和村	140	623	263 1500	282 曲树彬	杨爱民	杨玉仙	爱民 13483045420 玉仙 13473014371	
	太平村	283	1473	564 3221	605 孟献文	秦希明	李风国 0700	希明 13463104028	+62
王小丰 乔玉章 李庆民	起镇	263	1300	318 1818	341 乔玉章	张东臣 0416	张光清	东臣 15832011199 光清 15932776281	1639
	史寨	140	738	330 1884	354 秦延丰	刘爱民 8188	刘庆云 8393	爱民 13784262366	1760
	小王庄	210	1024	285 1632	306 孟献民	胡贵荣 0266	王锡印 0560	贵荣 13733305100	
	南里岳	285	1372	294 1683	316 王延周	胡新堂 2929	胡英彬 2092	新堂 英彬 13785046948	
	杨军寨	206	993	412 2357	443 李庆民	彭建新 1685	杨贵德		
王海永 王正朝 赵庆玺	封庄	111	698	234 1340	251 王正朝	封贵堂 6025	王风章	贵堂 13831029406 风章 13131045736	1594−59
	小连寨	112	509	123 703	132 胡梦林	张现海	张士杰 0522	现海 13473019408 士杰 13472010662	1484.
	张西头	290	1566	465 2657	499−59 贾尽力	张保连	郭金山 0115	金山 13832082700	
	大连寨	439	2366	667 3788	712 赵庆玺 王庆祥	李付海 1555	张建军 2988	付海 13582602178 建军 13832068991	
李庆华 郭建刚 王建波	顺义村	137	670	194 1109	208 赵志金	李卫周 1593	李献华 1238	卫周 13785068428 献华 13932046435	黄丰106.
	王胡庄	206	907	445 2542	477 郭建刚	王东臣 5129	胡保庆 0740	东臣 13932082096 保庆 13784239817	1903 −3
	武宋庄	288	1363	480 2745	516 王建波	晏书亮 0199		书亮 13831035108	1774.
	北里岳	213	1010	395 2259	424 杨德明	郭书印	郭新祥 1891	书印 13292090066 新祥 13623102376	
	张屯	197	1131	260 1483	278 杨宗奎	刘振周	张子恩 0757	振周 15830079630 子恩 13731034462	
谷志成 王勤英 王新平	常刘庄	285	1418	435 2484	466 郝金良	王志峰 5766	李振国 1305	志峰 13832084811	
	东里岳	256	1256	596 3407	640 王新平	王振海 0646		振海 15832095420	2068.
	北马店	289	1339	539 3022	561 王勤英	晏荣臣 0805	晏风刚 0802		2219
	刘大寨	173	935	432 2472	464 王志强	何志山 5018	韩新学 5892	志山 13784238291	
	方张庄	48	242	76 435	81 张建伍	秦光亮 2939		光亮 15831820973	
杨德森 史万祥 封书志	振清寨	332	1855	637 3640	684 周俊杰	石延臣 5652	曲贵福	延臣 15830749155	1980
	炒寨	333	1528	745 4257	800 封书志	陈俊海 0429	武玉章 8162	俊海 13784263851 玉章 13784262662	2196
	安上	192	941	357 2038	383 秦晓峰	李书德 0073	路新庆 8006	书德 [illegible]2049245 新庆 13832007208	
	永胜村	219	1010	241 1379	259 张长海	王林丰 0888			

1078

13700309759 [illegible] 3000

13784266686

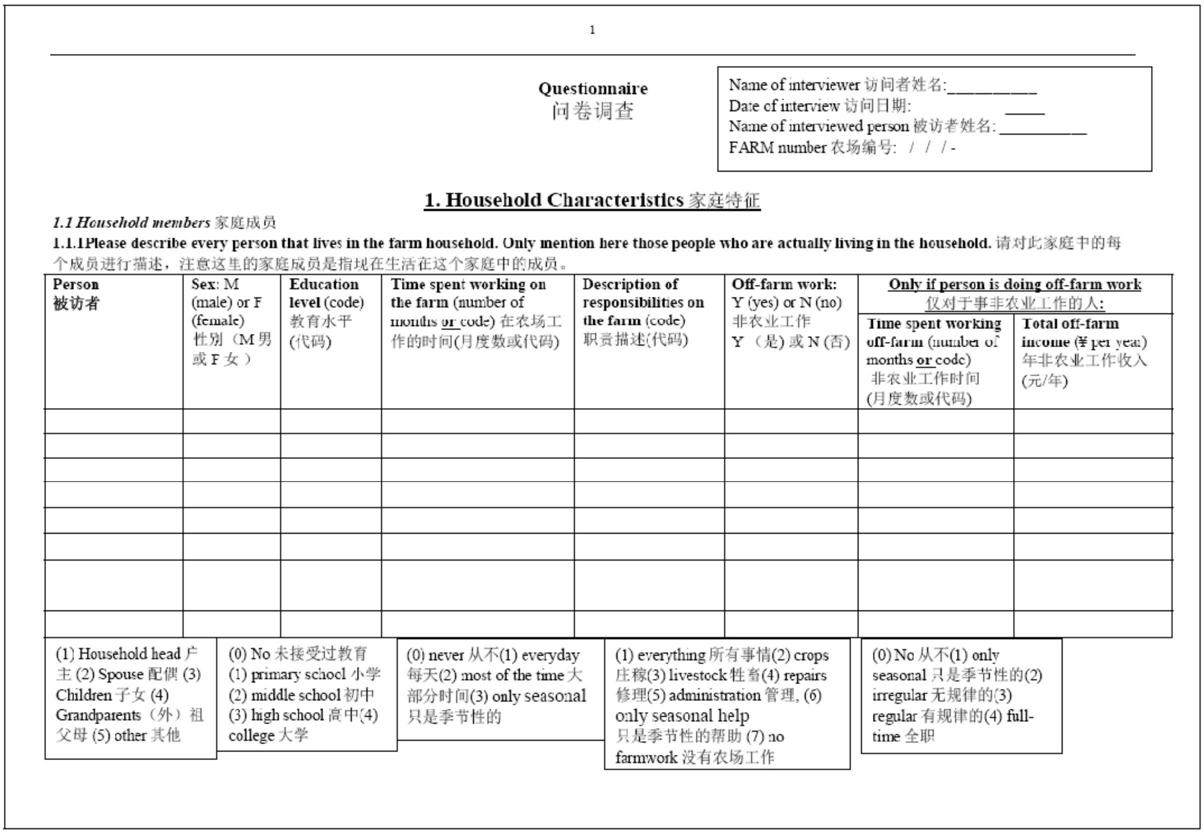
Annex 2. Village List of Baizhai Town



白寨乡 Bai Zhai town 张更利 ZHANG Gengli

	户数	人口	耕地面积(mu)
常庄			
艾台	260	1315	2558
祺李庄			
东陈庄	174	888	943
叶庄			
王庄	202	994	1304
永安村			
苏胡寨	264	1250	2197
致中寨	324	1584	1848
范李庄			
鲁新寨			
西陈庄			
牛庄	216	1086	728
[illegible]村	310	1511	2024
泾南[illegible]			
[illegible]			
[illegible]			
北[illegible]			
胡水庄	331	1606	2333
南油村	273	1341	1366
[illegible]寨	230	1182	1890
后寨	236	1252	1618
高庄	171	835	1177
白寨	304	1570	2020
泾阳集	268	1568	1528
塔寺桥	308	1530	1208
西朱卜	210	1001	1768
东朱卜			
白小营	170	908	1126
布寨	231	1240	2147
东[illegible]庄			
西[illegible]庄			
[illegible]町庄			
[illegible]寨			
永新寨	321	1663	2317
司李庄			
[illegible]吕寨	312	1561	2586
娄寨	310	1576	1576
安王庄			
东焦营			
刘庄屯			
牛卜			
[illegible]里寨	276	1366	1386
合计			

Annex 3. Questionnaire



Questionnaire
问卷调查

Name of interviewer 访问者姓名:__________
Date of interview 访问日期: ____
Name of interviewed person 被访者姓名: __________
FARM number 农场编号: / / / -

1. Household Characteristics 家庭特征

1.1 Household members 家庭成员

1.1.1Please describe every person that lives in the farm household. Only mention here those people who are actually living in the household. 请对此家庭中的每个成员进行描述，注意这里的家庭成员是指现在生活在这个家庭中的成员。

Person **被访者**	**Sex:** M (male) or F (female) 性别（M 男或 F 女）	**Education level** (code) 教育水平 (代码)	**Time spent working on the farm** (number of months or code) 在农场工作的时间(月度数或代码)	**Description of responsibilities on the farm** (code) 职责描述(代码)	**Off-farm work:** Y (yes) or N (no) 非农业工作 Y （是) 或 N (否)	**Only if person is doing off-farm work** 仅对于事非农业工作的人:	
						Time spent working off-farm (number of months or code) 非农业工作时间 (月度数或代码)	**Total off-farm income** (¥ per year) 年非农业工作收入 (元/年)

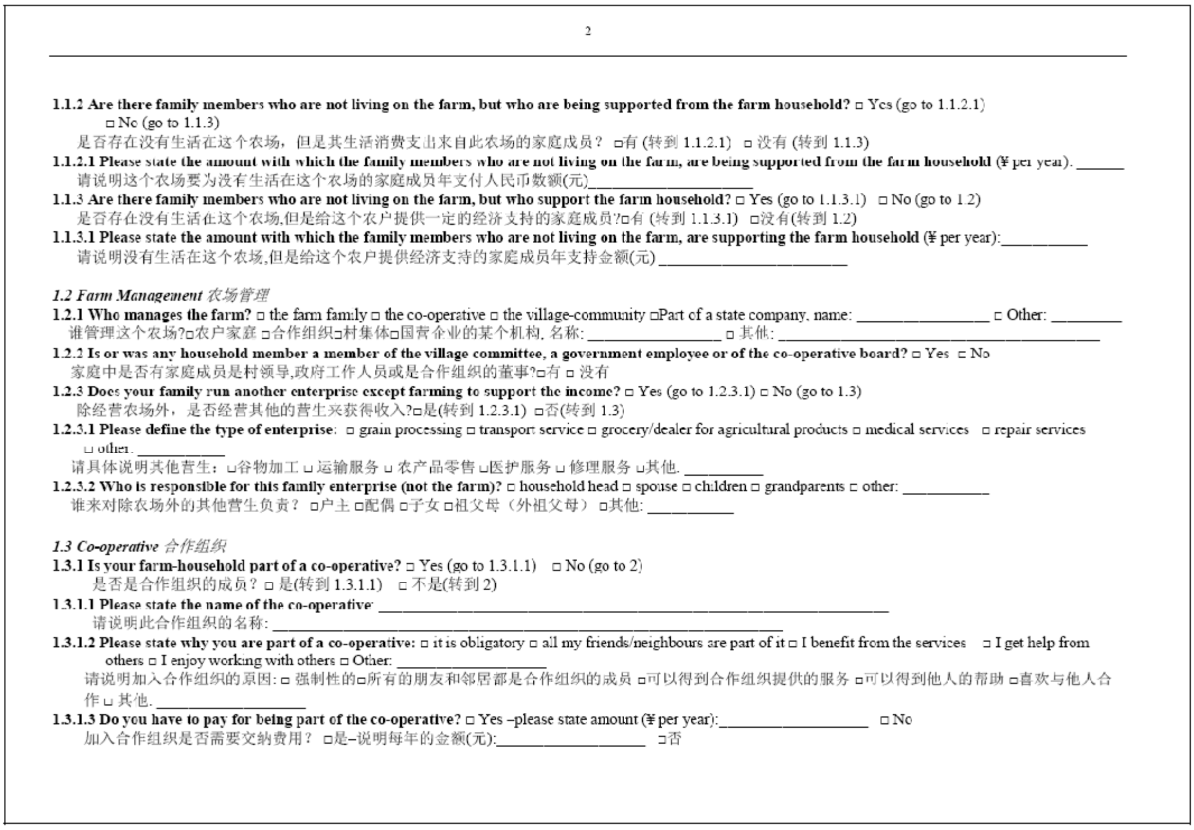
(1) Household head 户主 (2) Spouse 配偶 (3) Children 子女 (4) Grandparents（外）祖父母 (5) other 其他

(0) No 未接受过教育 (1) primary school 小学 (2) middle school 初中 (3) high school 高中(4) college 大学

(0) never 从不(1) everyday 每天(2) most of the time 大部分时间(3) only seasonal 只是季节性的

(1) everything 所有事情(2) crops 庄稼(3) livestock 牲畜(4) repairs 修理(5) administration 管理, (6) only seasonal help 只是季节性的帮助 (7) no farmwork 没有农场工作

(0) No 从不(1) only seasonal 只是季节性的(2) irregular 无规律的(3) regular 有规律的(4) full-time 全职



1.1.2 Are there family members who are not living on the farm, but who are being supported from the farm household? □ Yes (go to 1.1.2.1) □ No (go to 1.1.3)
是否存在没有生活在这个农场，但是其生活消费支出来自此农场的家庭成员？ □有 (转到 1.1.2.1) □ 没有 (转到 1.1.3)

1.1.2.1 Please state the amount with which the family members who are not living on the farm, are being supported from the farm household (¥ per year). ______
请说明这个农场要为没有生活在这个农场的家庭成员年支付人民币数额(元)__________________

1.1.3 Are there family members who are not living on the farm, but who support the farm household? □ Yes (go to 1.1.3.1) □ No (go to 1.2)
是否存在没有生活在这个农场,但是给这个农户提供一定的经济支持的家庭成员?□有 (转到 1.1.3.1) □没有(转到 1.2)

1.1.3.1 Please state the amount with which the family members who are not living on the farm, are supporting the farm household (¥ per year):__________
请说明没有生活在这个农场,但是给这个农户提供经济支持的家庭成员年支持金额(元) ______________________

1.2 Farm Management 农场管理

1.2.1 Who manages the farm? □ the farm family □ the co-operative □ the village-community □Part of a state company, name: ________________ □ Other: ________
谁管理这个农场?□农户家庭 □合作组织□村集体□国营企业的某个机构, 名称: ________________ □ 其他: ______________________________________

1.2.2 Is or was any household member a member of the village committee, a government employee or of the co-operative board? □ Yes □ No
家庭中是否有家庭成员是村领导,政府工作人员或是合作组织的董事?□有 □ 没有

1.2.3 Does your family run another enterprise except farming to support the income? □ Yes (go to 1.2.3.1) □ No (go to 1.3)
除经营农场外，是否经营其他的营生来获得收入?□是(转到 1.2.3.1) □否(转到 1.3)

1.2.3.1 Please define the type of enterprise: □ grain processing □ transport service □ grocery/dealer for agricultural products □ medical services □ repair services □ other. __________
请具体说明其他营生：□谷物加工 □ 运输服务 □ 农产品零售 □医护服务 □ 修理服务 □其他. __________

1.2.3.2 Who is responsible for this family enterprise (not the farm)? □ household head □ spouse □ children □ grandparents □ other: __________
谁来对除农场外的其他营生负责？ □户主 □配偶 □子女 □祖父母（外祖父母） □其他: __________

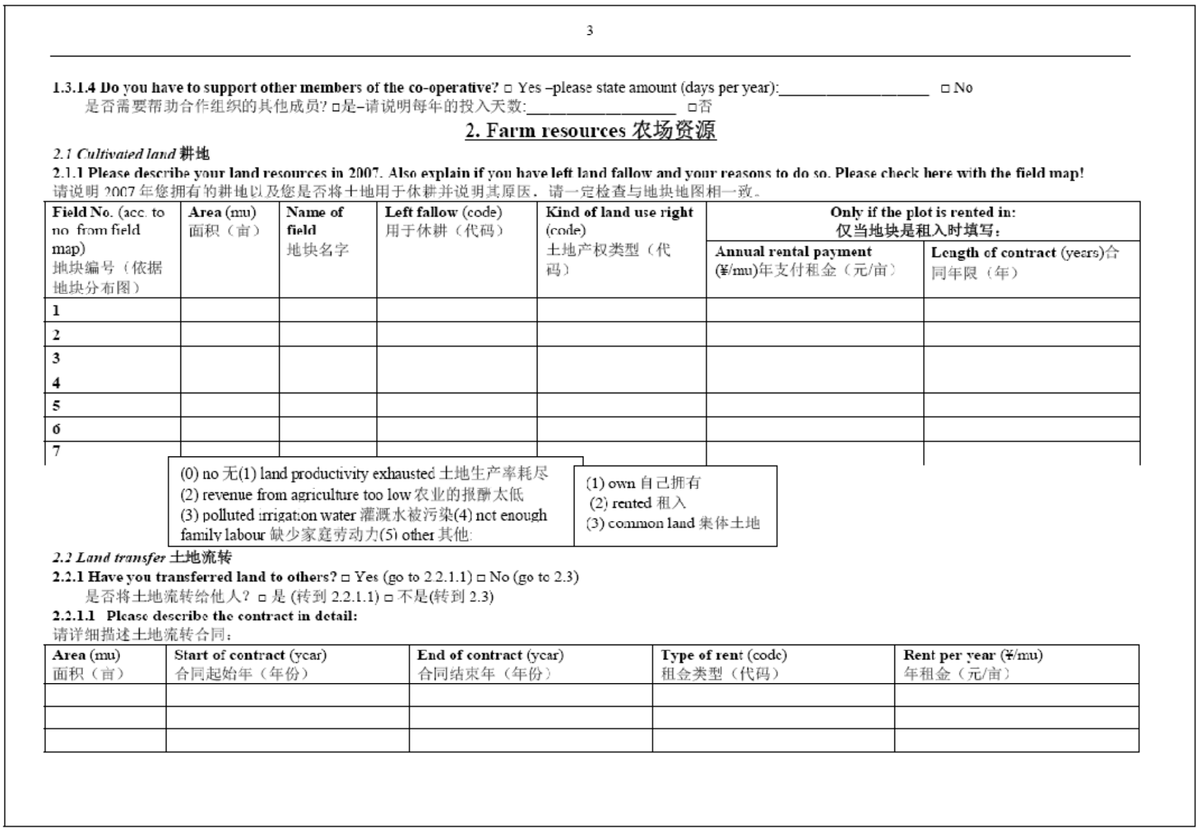
1.3 Co-operative 合作组织

1.3.1 Is your farm-household part of a co-operative? □ Yes (go to 1.3.1.1) □ No (go to 2)
是否是合作组织的成员？ □ 是(转到 1.3.1.1) □ 不是(转到 2)

1.3.1.1 Please state the name of the co-operative ____
请说明此合作组织的名称: ____

1.3.1.2 Please state why you are part of a co-operative: □ it is obligatory □ all my friends/neighbours are part of it □ I benefit from the services □ I get help from others □ I enjoy working with others □ Other: _________________
请说明加入合作组织的原因: □ 强制性的□所有的朋友和邻居都是合作组织的成员 □可以得到合作组织提供的服务 □可以得到他人的帮助 □喜欢与他人合作 □ 其他. _________________

1.3.1.3 Do you have to pay for being part of the co-operative? □ Yes –please state amount (¥ per year):_________________ □ No
加入合作组织是否需要交纳费用？ □是–说明每年的金额(元):_________________ □否



1.3.1.4 Do you have to support other members of the co-operative? □ Yes –please state amount (days per year):___________________ □ No
是否需要帮助合作组织的其他成员? □是–请说明每年的投入天数:___________________ □否

2. Farm resources 农场资源

2.1 Cultivated land 耕地

2.1.1 Please describe your land resources in 2007. Also explain if you have left land fallow and your reasons to do so. Please check here with the field map!
请说明 2007 年您拥有的耕地以及您是否将土地用于休耕并说明其原因，请一定检查与地块地图相一致。

Field No. (acc. to no. from field map) 地块编号（依据地块分布图）	**Area** (mu) 面积（亩）	**Name of field** 地块名字	**Left fallow** (code) 用于休耕（代码）	**Kind of land use right** (code) 土地产权类型（代码）	**Only if the plot is rented in: 仅当地块是租入时填写：**	
					Annual rental payment (¥/mu)年支付租金（元/亩）	**Length of contract** (years)合同年限（年）
1						
2						
3 4						
5						
6						
7						

(0) no 无(1) land productivity exhausted 土地生产率耗尽
(2) revenue from agriculture too low 农业的报酬太低
(3) polluted irrigation water 灌溉水被污染(4) not enough family labour 缺少家庭劳动力(5) other 其他:

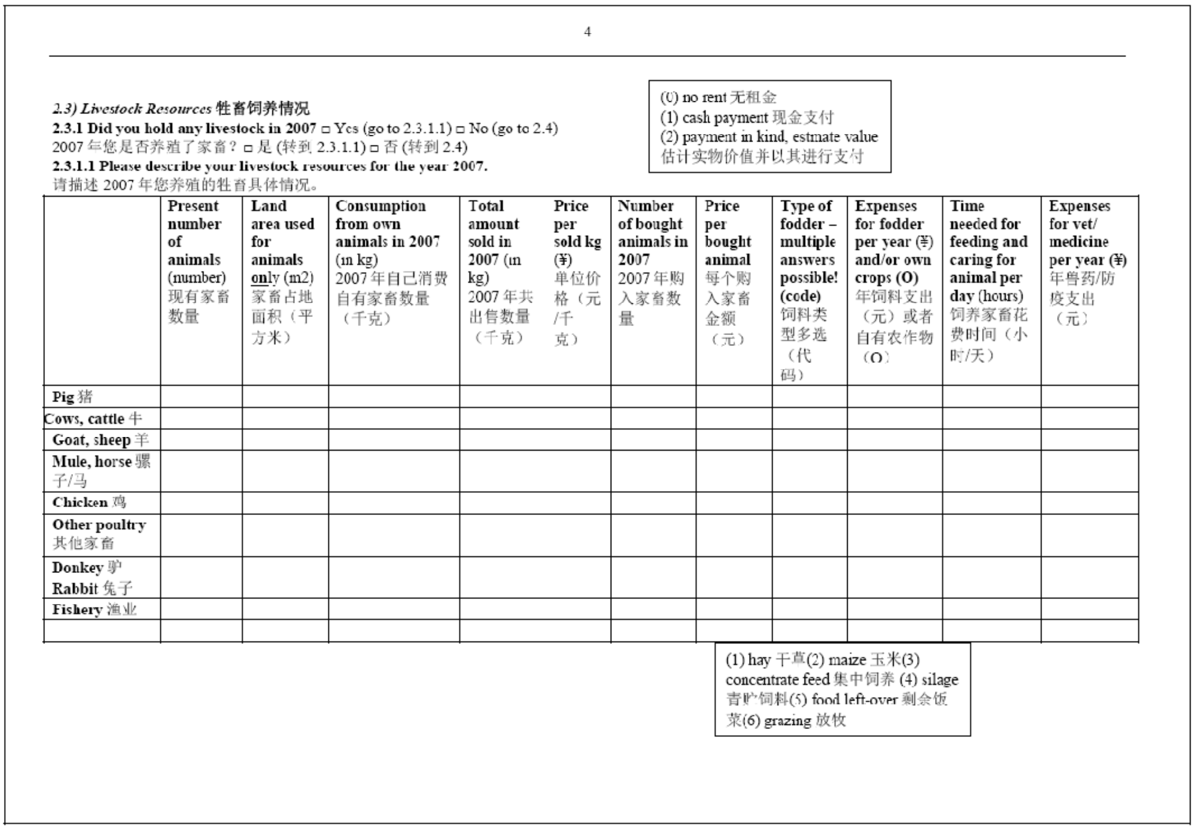
(1) own 自己拥有
(2) rented 租入
(3) common land 集体土地

2.2 Land transfer 土地流转

2.2.1 Have you transferred land to others? □ Yes (go to 2.2.1.1) □ No (go to 2.3)
是否将土地流转给他人? □ 是 (转到 2.2.1.1) □ 不是(转到 2.3)

2.2.1.1 Please describe the contract in detail:
请详细描述土地流转合同：

Area (mu) 面积（亩）	**Start of contract** (year) 合同起始年（年份）	**End of contract** (year) 合同结束年（年份）	**Type of rent** (code) 租金类型（代码）	**Rent per year** (¥/mu) 年租金（元/亩）



(0) no rent 无租金
(1) cash payment 现金支付
(2) payment in kind, estmate value 估计实物价值并以其进行支付

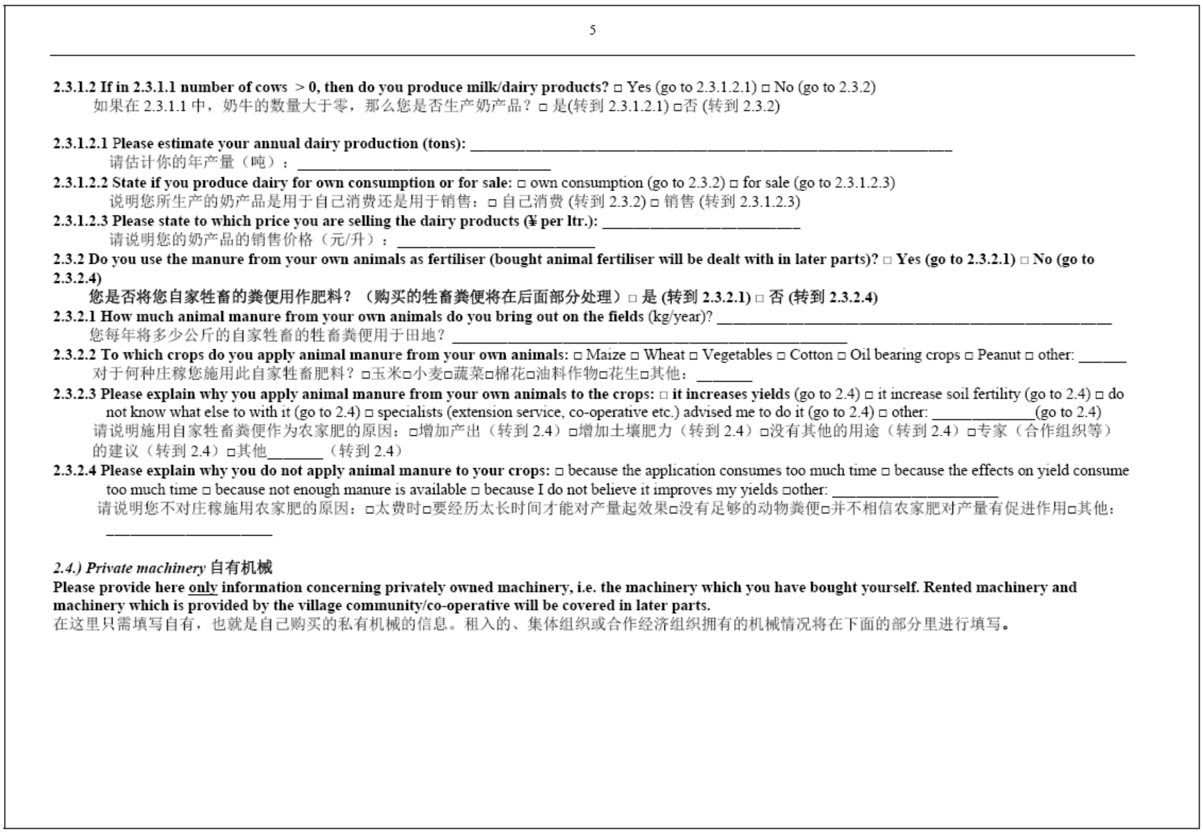
2.3) Livestock Resources 牲畜饲养情况

2.3.1 Did you hold any livestock in 2007 □ Yes (go to 2.3.1.1) □ No (go to 2.4)
2007 年您是否养殖了家畜？ □ 是 (转到 2.3.1.1) □ 否 (转到 2.4)

2.3.1.1 Please describe your livestock resources for the year 2007.
请描述 2007 年您养殖的牲畜具体情况。

	Present number of animals (number) 现有家畜数量	**Land area used for animals only** (m2) 家畜占地面积（平方米）	**Consumption from own animals in 2007** (in kg) 2007 年自己消费自有家畜数量（千克）	**Total amount sold in 2007** (in kg) 2007 年共出售数量（千克）	**Price per sold kg (¥)** 单位价格（元/千克）	**Number of bought animals in 2007** 2007 年购入家畜数量	**Price per bought animal** 每个购入家畜金额（元）	**Type of fodder – multiple answers possible! (code)** 饲料类型多选（代码）	**Expenses for fodder per year (¥) and/or own crops (O)** 年饲料支出（元）或者自有农作物（O）	**Time needed for feeding and caring for animal per day** (hours) 饲养家畜花费时间（小时/天）	**Expenses for vet/ medicine per year (¥)** 年兽药/防疫支出（元）
Pig 猪											
Cows, cattle 牛											
Goat, sheep 羊											
Mule, horse 骡子/马											
Chicken 鸡											
Other poultry 其他家畜											
Donkey 驴 **Rabbit** 兔子											
Fishery 渔业											

(1) hay 干草(2) maize 玉米(3) concentrate feed 集中饲养 (4) silage 青贮饲料(5) food left-over 剩余饭菜(6) grazing 放牧



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2.3.1.2 If in 2.3.1.1 number of cows > 0, then do you produce milk/dairy products? □ Yes (go to 2.3.1.2.1) □ No (go to 2.3.2)
如果在 2.3.1.1 中，奶牛的数量大于零，那么您是否生产奶产品？ □ 是(转到 2.3.1.2.1) □否 (转到 2.3.2)

2.3.1.2.1 Please estimate your annual dairy production (tons): ____
请估计你的年产量（吨）： ______________________________

2.3.1.2.2 State if you produce dairy for own consumption or for sale: □ own consumption (go to 2.3.2) □ for sale (go to 2.3.1.2.3)
说明您所生产的奶产品是用于自己消费还是用于销售：□ 自己消费 (转到 2.3.2) □ 销售 (转到 2.3.1.2.3)

2.3.1.2.3 Please state to which price you are selling the dairy products (¥ per ltr.): ______________________
请说明您的奶产品的销售价格（元/升）： ______________________

2.3.2 Do you use the manure from your own animals as fertiliser (bought animal fertiliser will be dealt with in later parts)? □ Yes (go to 2.3.2.1) □ No (go to 2.3.2.4)
您是否将您自家牲畜的粪便用作肥料？（购买的牲畜粪便将在后面部分处理）□ 是 (转到 2.3.2.1) □ 否 (转到 2.3.2.4)

2.3.2.1 How much animal manure from your own animals do you bring out on the fields (kg/year)? ____
您每年将多少公斤的自家牲畜的牲畜粪便用于田地？ ____

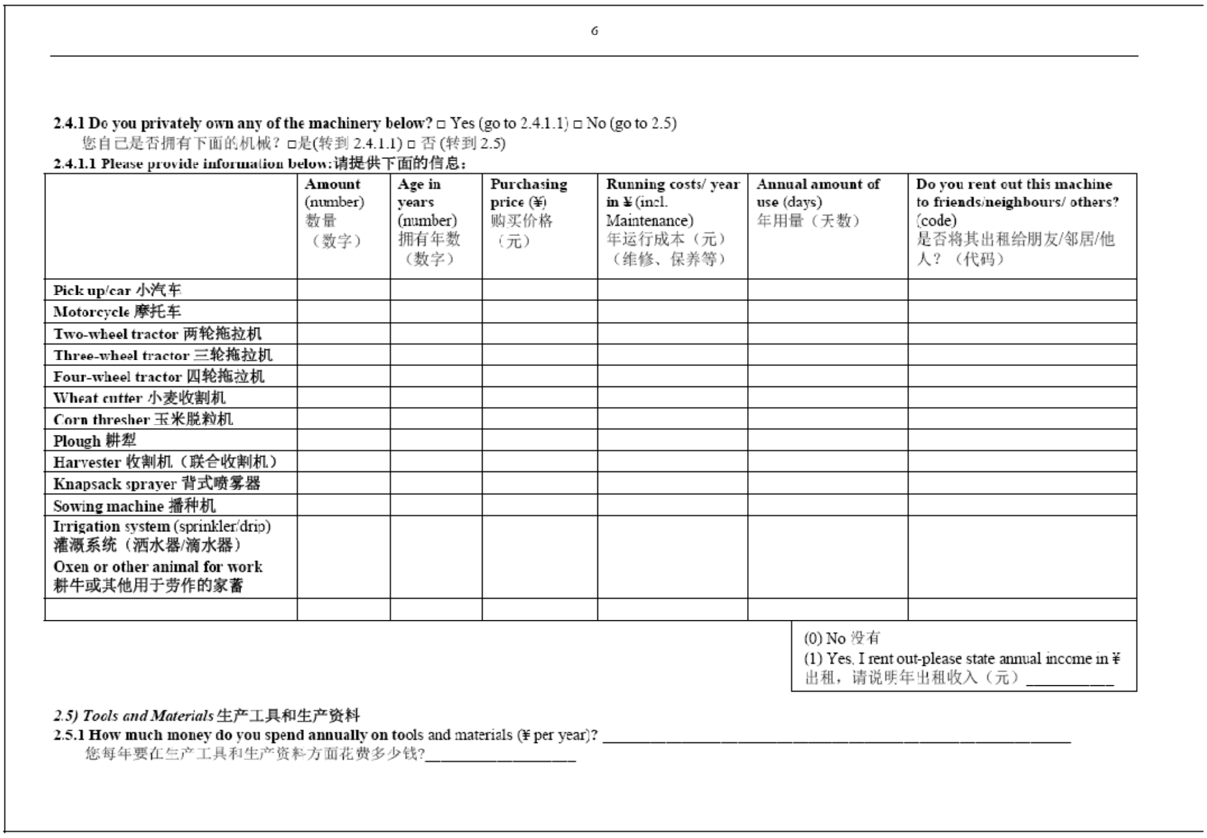
2.3.2.2 To which crops do you apply animal manure from your own animals: □ Maize □ Wheat □ Vegetables □ Cotton □ Oil bearing crops □ Peanut □ other: ______
对于何种庄稼您施用此自家牲畜肥料？ □玉米□小麦□蔬菜□棉花□油料作物□花生□其他： _______

2.3.2.3 Please explain why you apply animal manure from your own animals to the crops: □ it increases yields (go to 2.4) □ it increase soil fertility (go to 2.4) □ do not know what else to with it (go to 2.4) □ specialists (extension service, co-operative etc.) advised me to do it (go to 2.4) □ other: ____________(go to 2.4)
请说明施用自家牲畜粪便作为农家肥的原因：□增加产出（转到 2.4）□增加土壤肥力（转到 2.4）□没有其他的用途（转到 2.4）□专家（合作组织等）的建议（转到 2.4）□其他_______（转到 2.4）

2.3.2.4 Please explain why you do not apply animal manure to your crops: □ because the application consumes too much time □ because the effects on yield consume too much time □ because not enough manure is available □ because I do not believe it improves my yields □other: ____________________
请说明您不对庄稼施用农家肥的原因：□太费时□要经历太长时间才能对产量起效果□没有足够的动物粪便□并不相信农家肥对产量有促进作用□其他：
____

2.4.) Private machinery 自有机械

Please provide here only information concerning privately owned machinery, i.e. the machinery which you have bought yourself. Rented machinery and machinery which is provided by the village community/co-operative will be covered in later parts.
在这里只需填写自有，也就是自己购买的私有机械的信息。租入的、集体组织或合作经济组织拥有的机械情况将在下面的部分里进行填写。



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2.4.1 Do you privately own any of the machinery below? □ Yes (go to 2.4.1.1) □ No (go to 2.5)
您自己是否拥有下面的机械？ □是(转到 2.4.1.1) □ 否 (转到 2.5)

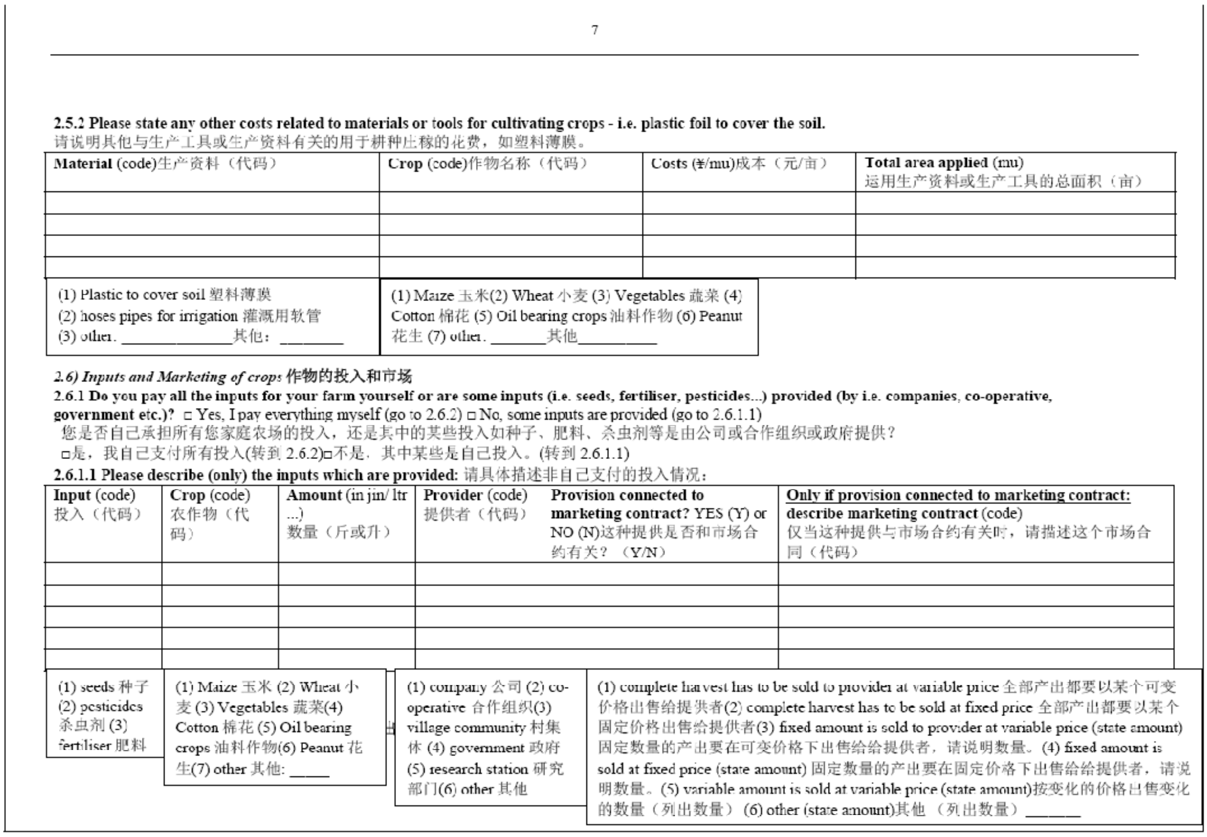
2.4.1.1 Please provide information below:请提供下面的信息：

	Amount (number) 数量（数字）	**Age in years** (number) 拥有年数（数字）	**Purchasing price** (¥) 购买价格（元）	**Running costs/ year in ¥** (incl. Maintenance) 年运行成本（元）（维修、保养等）	**Annual amount of use** (days) 年用量（天数）	**Do you rent out this machine to friends/neighbours/ others?** (code) 是否将其出租给朋友/邻居/他人？（代码）
Pick up/car 小汽车						
Motorcycle 摩托车						
Two-wheel tractor 两轮拖拉机						
Three-wheel tractor 三轮拖拉机						
Four-wheel tractor 四轮拖拉机						
Wheat cutter 小麦收割机						
Corn thresher 玉米脱粒机						
Plough 耕犁						
Harvester 收割机（联合收割机）						
Knapsack sprayer 背式喷雾器						
Sowing machine 播种机						
Irrigation system (sprinkler/drip) **灌溉系统（洒水器/滴水器）** **Oxen or other animal for work 耕牛或其他用于劳作的家畜**						

(0) No 没有
(1) Yes, I rent out-please state annual income in ¥
出租，请说明年出租收入（元） __________

2.5) Tools and Materials 生产工具和生产资料

2.5.1 How much money do you spend annually on tools and materials (¥ per year)? ____
您每年要在生产工具和生产资料方面花费多少钱?__________________



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2.5.2 Please state any other costs related to materials or tools for cultivating crops - i.e. plastic foil to cover the soil.
请说明其他与生产工具或生产资料有关的用于耕种庄稼的花费，如塑料薄膜。

Material (code)生产资料（代码）	**Crop** (code)作物名称（代码）	Costs (¥/mu)成本（元/亩）	**Total area applied** (mu) 运用生产资料或生产工具的总面积（亩）

(1) Plastic to cover soil 塑料薄膜
(2) hoses pipes for irrigation 灌溉用软管
(3) other. ______________其他：________

(1) Maize 玉米(2) Wheat 小麦 (3) Vegetables 蔬菜 (4) Cotton 棉花 (5) Oil bearing crops 油料作物 (6) Peanut 花生 (7) other. _______其他__________

***2.6) Inputs and Marketing of crops* 作物的投入和市场**

2.6.1 Do you pay all the inputs for your farm yourself or are some inputs (i.e. seeds, fertiliser, pesticides...) provided (by i.e. companies, co-operative, government etc.)? □ Yes, I pay everything myself (go to 2.6.2) □ No, some inputs are provided (go to 2.6.1.1)
您是否自己承担所有您家庭农场的投入，还是其中的某些投入如种子、肥料、杀虫剂等是由公司或合作组织或政府提供？
□是，我自己支付所有投入(转到 2.6.2)□不是，其中某些是自己投入。(转到 2.6.1.1)

2.6.1.1 Please describe (only) the inputs which are provided: 请具体描述非自己支付的投入情况：

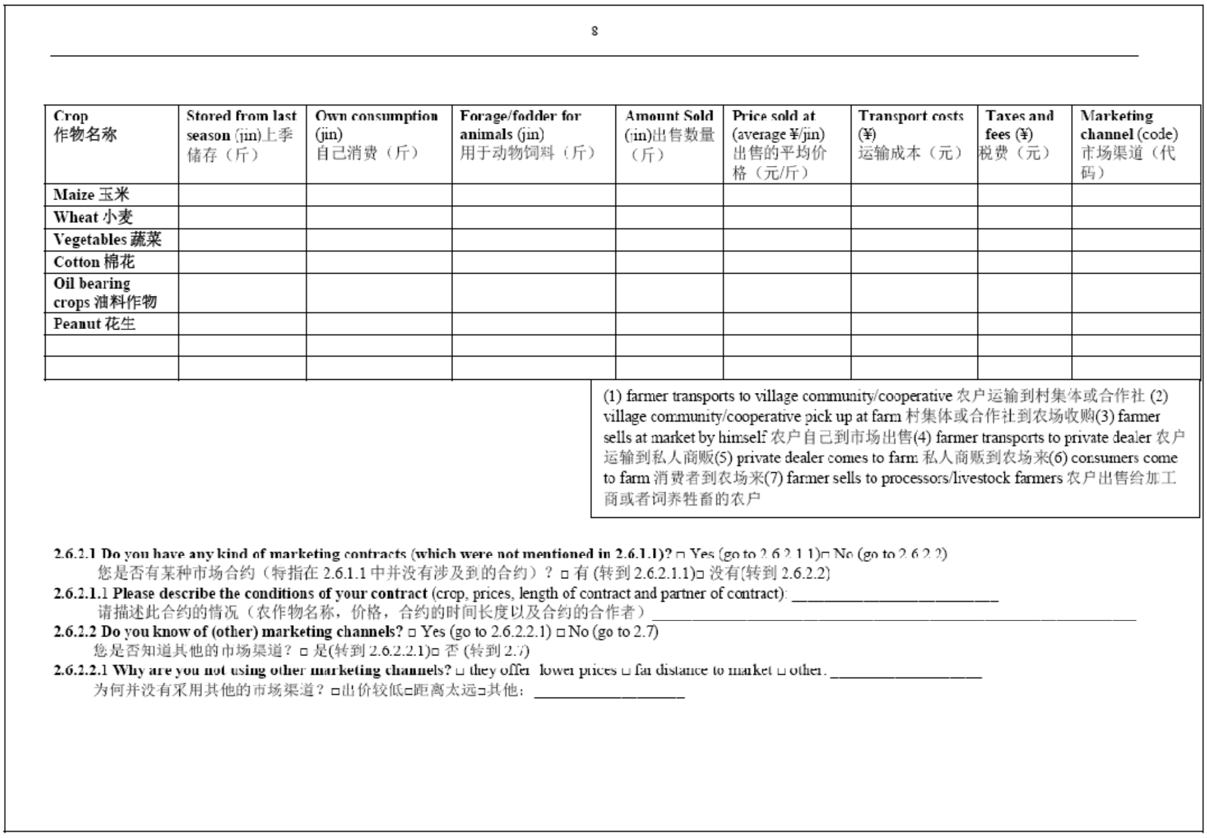
Input (code) 投入（代码）	**Crop** (code) 农作物（代码）	**Amount** (in jin/ ltr ...) 数量（斤或升）	**Provider** (code) 提供者（代码）	**Provision connected to marketing contract?** YES (Y) or NO (N)这种提供是否和市场合约有关？（Y/N）	**Only if provision connected to marketing contract: describe marketing contract** (code) 仅当这种提供与市场合约有关时，请描述这个市场合同（代码）

(1) seeds 种子 (2) pesticides 杀虫剂 (3) fertiliser 肥料

(1) Maize 玉米 (2) Wheat 小麦 (3) Vegetables 蔬菜(4) Cotton 棉花 (5) Oil bearing crops 油料作物(6) Peanut 花生(7) other 其他: _____

(1) company 公司 (2) co-operative 合作组织(3) village community 村集体 (4) government 政府 (5) research station 研究部门(6) other 其他

(1) complete harvest has to be sold to provider at variable price 全部产出都要以某个可变价格出售给提供者(2) complete harvest has to be sold at fixed price 全部产出都要以某个固定价格出售给提供者(3) fixed amount is sold to provider at variable price (state amount) 固定数量的产出要在可变价格下出售给给提供者，请说明数量。(4) fixed amount is sold at fixed price (state amount) 固定数量的产出要在固定价格下出售给给提供者，请说明数量。(5) variable amount is sold at variable price (state amount)按变化的价格出售变化的数量（列出数量）(6) other (state amount)其他（列出数量）_______



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Crop **作物名称**	**Stored from last season** (jin)上季储存（斤）	**Own consumption** (jin) 自己消费（斤）	**Forage/fodder for animals** (jin) 用于动物饲料（斤）	**Amount Sold** (jin)出售数量（斤）	**Price sold at** (average ¥/jin) 出售的平均价格（元/斤）	**Transport costs** (¥) 运输成本（元）	**Taxes and fees** (¥) 税费（元）	**Marketing channel** (code) 市场渠道（代码）
Maize 玉米								
Wheat 小麦								
Vegetables 蔬菜								
Cotton 棉花								
Oil bearing crops 油料作物								
Peanut 花生								

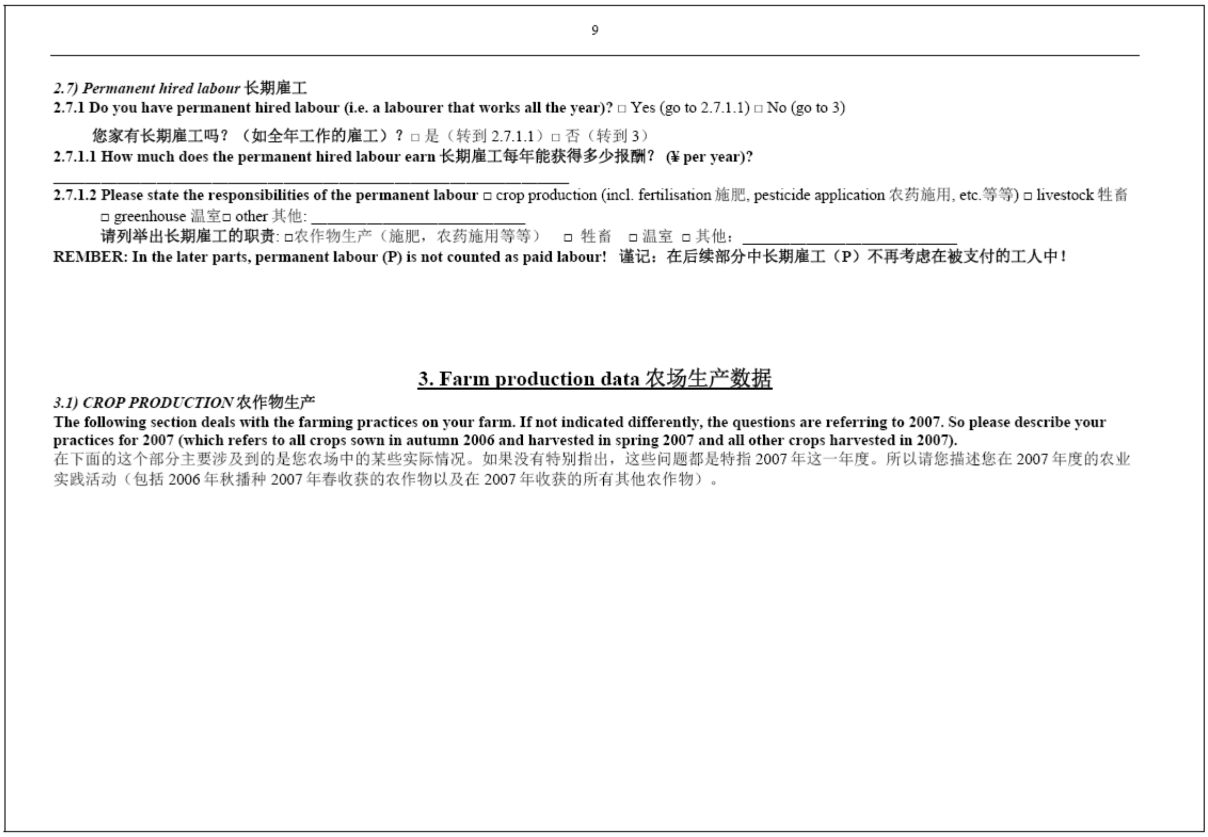
(1) farmer transports to village community/cooperative 农户运输到村集体或合作社 (2) village community/cooperative pick up at farm 村集体或合作社到农场收购(3) farmer sells at market by himself 农户自己到市场出售(4) farmer transports to private dealer 农户运输到私人商贩(5) private dealer comes to farm 私人商贩到农场来(6) consumers come to farm 消费者到农场来(7) farmer sells to processors/livestock farmers 农户出售给加工商或者饲养牲畜的农户

2.6.2.1 Do you have any kind of marketing contracts (which were not mentioned in 2.6.1.1)? □ Yes (go to 2.6.2.1.1)□ No (go to 2.6.2.2)
您是否有某种市场合约（特指在 2.6.1.1 中并没有涉及到的合约）？ □ 有 (转到 2.6.2.1.1)□ 没有(转到 2.6.2.2)

2.6.2.1.1 Please describe the conditions of your contract (crop, prices, length of contract and partner of contract): ___________________________
请描述此合约的情况（农作物名称，价格，合约的时间长度以及合约的合作者）____

2.6.2.2 Do you know of (other) marketing channels? □ Yes (go to 2.6.2.2.1) □ No (go to 2.7)
您是否知道其他的市场渠道？ □ 是(转到 2.6.2.2.1)□ 否 (转到 2.7)

2.6.2.2.1 Why are you not using other marketing channels? □ they offer lower prices □ far distance to market □ other. ____________________
为何并没有采用其他的市场渠道？ □出价较低□距离太远□其他：____________________



2.7) Permanent hired labour 长期雇工

2.7.1 Do you have permanent hired labour (i.e. a labourer that works all the year)? □ Yes (go to 2.7.1.1) □ No (go to 3)

您家有长期雇工吗？（如全年工作的雇工）？ □ 是（转到 2.7.1.1）□ 否（转到 3）

2.7.1.1 How much does the permanent hired labour earn 长期雇工每年能获得多少报酬？ (¥ per year)?

____

2.7.1.2 Please state the responsibilities of the permanent labour □ crop production (incl. fertilisation 施肥, pesticide application 农药施用, etc.等等) □ livestock 牲畜 □ greenhouse 温室□ other 其他: ________________________

请列举出长期雇工的职责: □农作物生产（施肥，农药施用等等） □ 牲畜 □ 温室 □ 其他：________________________

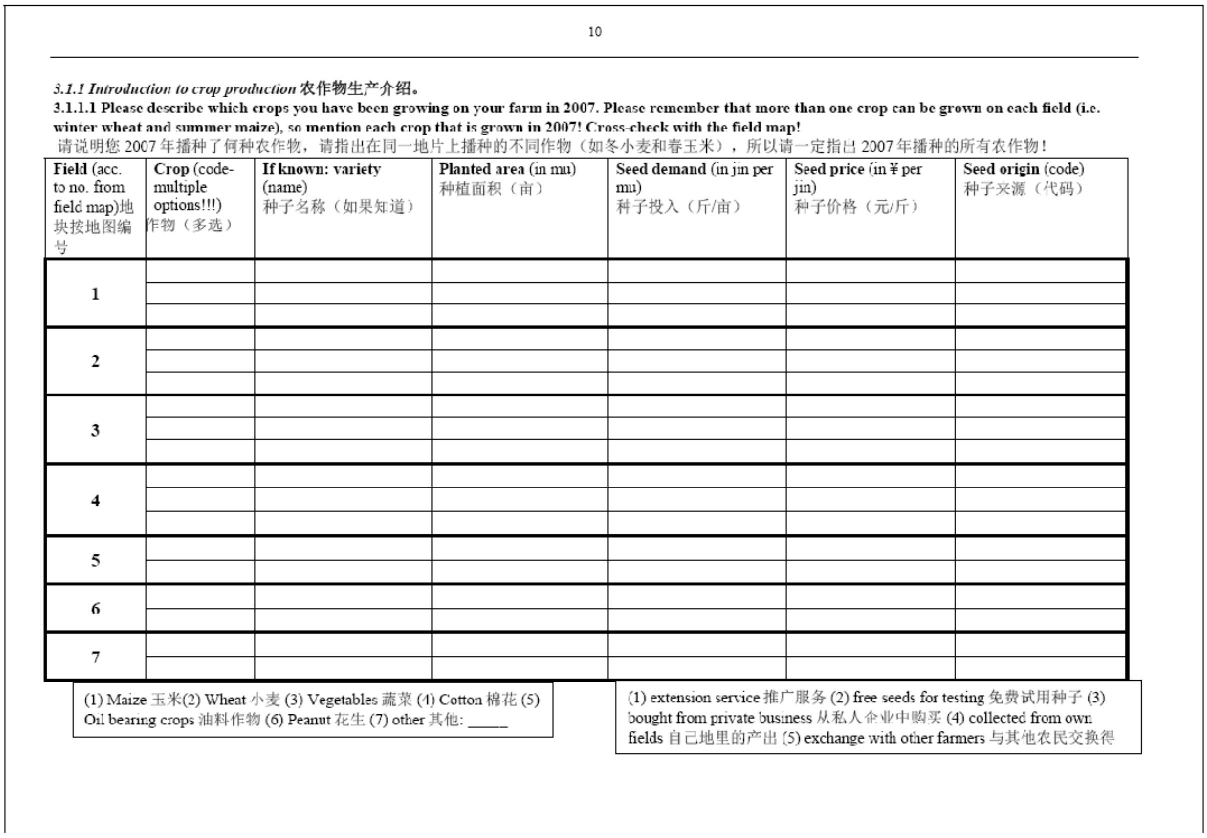
REMBER: In the later parts, permanent labour (P) is not counted as paid labour! 谨记：在后续部分中长期雇工（P）不再考虑在被支付的工人中！

3. Farm production data 农场生产数据

3.1) CROP PRODUCTION 农作物生产

The following section deals with the farming practices on your farm. If not indicated differently, the questions are referring to 2007. So please describe your practices for 2007 (which refers to all crops sown in autumn 2006 and harvested in spring 2007 and all other crops harvested in 2007).

在下面的这个部分主要涉及到的是您农场中的某些实际情况。如果没有特别指出，这些问题都是特指 2007 年这一年度。所以请您描述您在 2007 年度的农业实践活动（包括 2006 年秋播种 2007 年春收获的农作物以及在 2007 年收获的所有其他农作物）。



3.1.1 Introduction to crop production 农作物生产介绍。

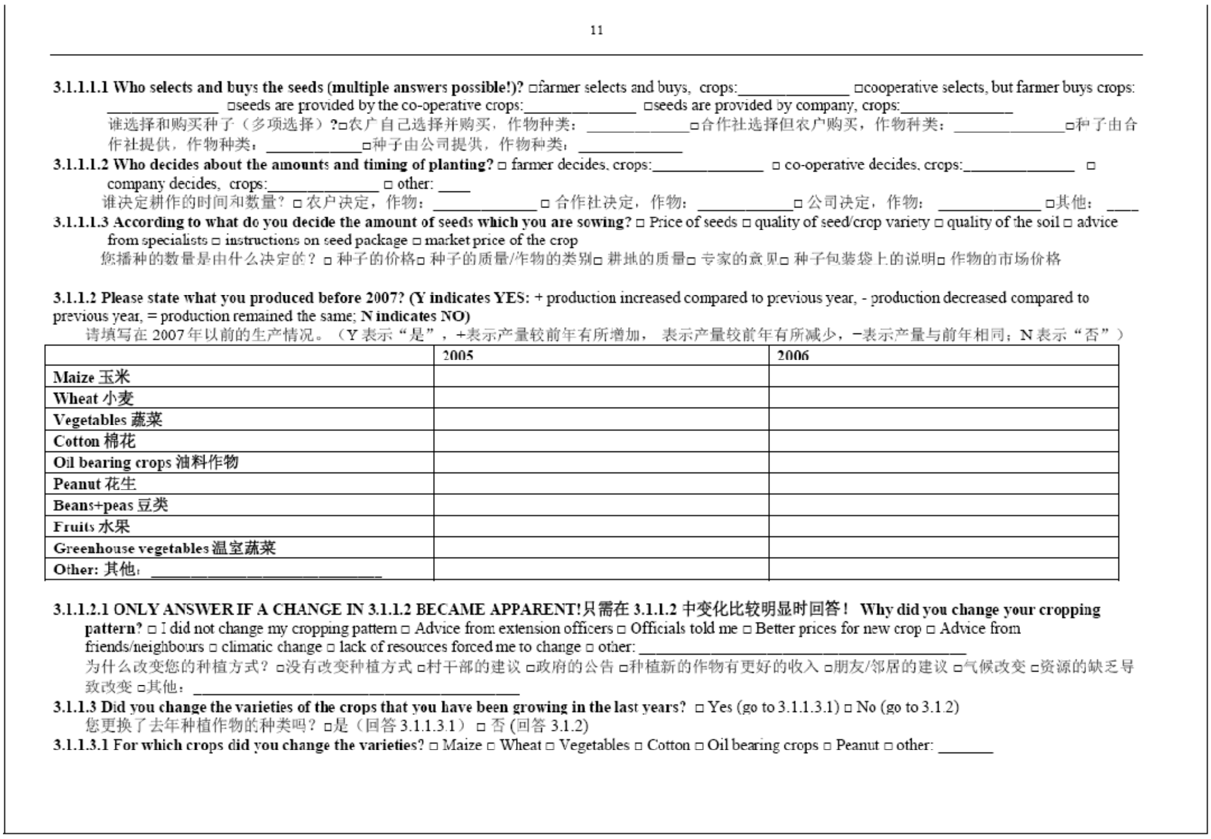
3.1.1.1 Please describe which crops you have been growing on your farm in 2007. Please remember that more than one crop can be grown on each field (i.e. winter wheat and summer maize), so mention each crop that is grown in 2007! Cross-check with the field map!

请说明您 2007 年播种了何种农作物，请指出在同一地片上播种的不同作物（如冬小麦和春玉米），所以请一定指出 2007 年播种的所有农作物！

Field (acc. to no. from field map)地块按地图编号	**Crop** (code-multiple options!!!) 作物（多选）	**If known: variety** (name) 种子名称（如果知道）	**Planted area** (in mu) 种植面积（亩）	**Seed demand** (in jin per mu) 种子投入（斤/亩）	**Seed price** (in ¥ per jin) 种子价格（元/斤）	**Seed origin** (code) 种子来源（代码）
1						
2						
3						
4						
5						
6						
7						

(1) Maize 玉米(2) Wheat 小麦 (3) Vegetables 蔬菜 (4) Cotton 棉花 (5) Oil bearing crops 油料作物 (6) Peanut 花生 (7) other 其他: _____

(1) extension service 推广服务 (2) free seeds for testing 免费试用种子 (3) bought from private business 从私人企业中购买 (4) collected from own fields 自己地里的产出 (5) exchange with other farmers 与其他农民交换得



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3.1.1.1.1 Who selects and buys the seeds (multiple answers possible!)? □farmer selects and buys, crops:_____________ □cooperative selects, but farmer buys crops: _____________ □seeds are provided by the co-operative crops:_____________ □seeds are provided by company, crops:_____________
谁选择和购买种子（多项选择）?□农户自己选择并购买，作物种类：____________□合作社选择但农户购买，作物种类：_____________□种子由合作社提供，作物种类：___________□种子由公司提供，作物种类：____________

3.1.1.1.2 Who decides about the amounts and timing of planting? □ farmer decides, crops:_____________ □ co-operative decides, crops:_____________ □ company decides, crops:_____________ □ other: ____
谁决定耕作的时间和数量？□ 农户决定，作物：____________□ 合作社决定，作物：___________□ 公司决定，作物：____________ □其他：____

3.1.1.1.3 According to what do you decide the amount of seeds which you are sowing? □ Price of seeds □ quality of seed/crop variety □ quality of the soil □ advice from specialists □ instructions on seed package □ market price of the crop
您播种的数量是由什么决定的？□ 种子的价格□ 种子的质量/作物的类别□ 耕地的质量□ 专家的意见□ 种子包装袋上的说明□ 作物的市场价格

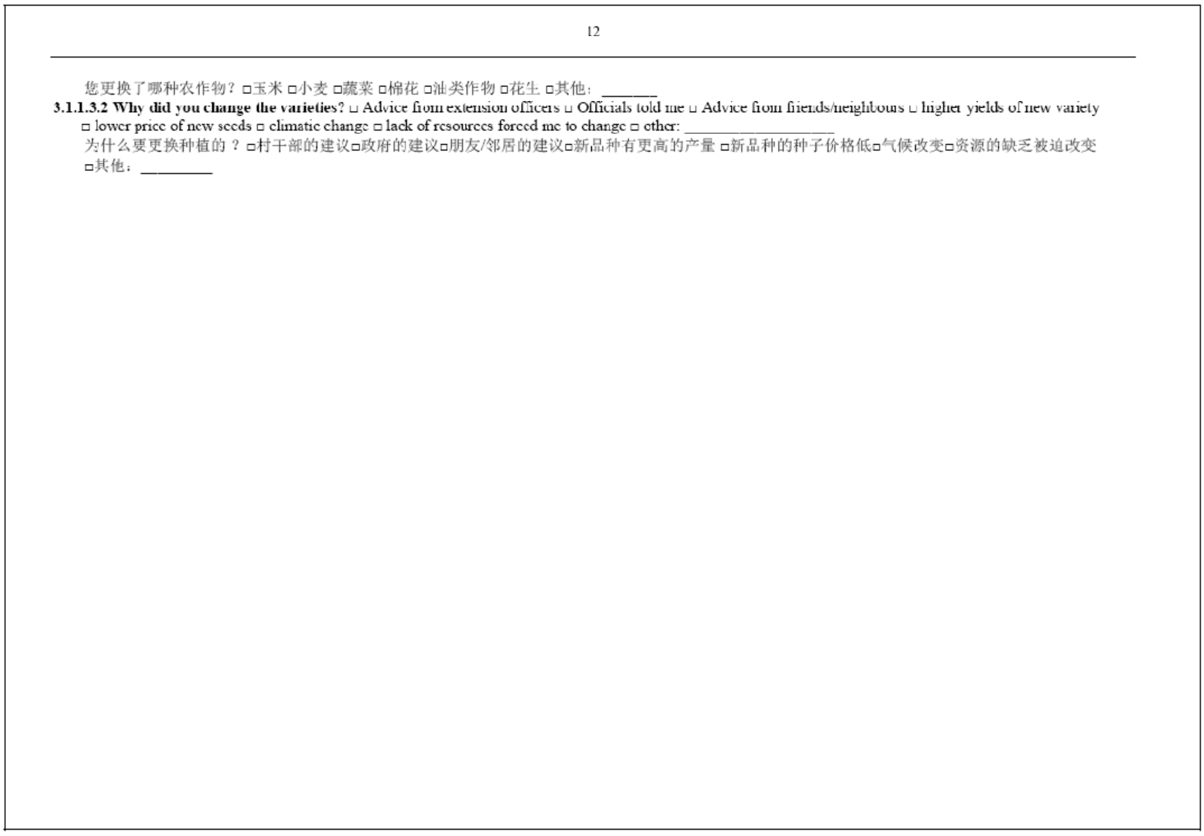
3.1.1.2 Please state what you produced before 2007? (Y indicates YES: + production increased compared to previous year, - production decreased compared to previous year, = production remained the same; **N indicates NO)**
请填写在 2007 年以前的生产情况。（Y 表示“是”，+表示产量较前年有所增加， 表示产量较前年有所减少，−表示产量与前年相同；N 表示“否”）

	2005	2006
Maize 玉米		
Wheat 小麦		
Vegetables 蔬菜		
Cotton 棉花		
Oil bearing crops 油料作物		
Peanut 花生		
Beans+peas 豆类		
Fruits 水果		
Greenhouse vegetables 温室蔬菜		
Other: 其他： __________________________		

3.1.1.2.1 ONLY ANSWER IF A CHANGE IN 3.1.1.2 BECAME APPARENT!只需在 3.1.1.2 中变化比较明显时回答！ Why did you change your cropping pattern? □ I did not change my cropping pattern □ Advice from extension officers □ Officials told me □ Better prices for new crop □ Advice from friends/neighbours □ climatic change □ lack of resources forced me to change □ other: ____________________________________
为什么改变您的种植方式？□没有改变种植方式 □村干部的建议 □政府的公告 □种植新的作物有更好的收入 □朋友/邻居的建议 □气候改变 □资源的缺乏导致改变 □其他：____________________________________

3.1.1.3 Did you change the varieties of the crops that you have been growing in the last years? □ Yes (go to 3.1.1.3.1) □ No (go to 3.1.2)
您更换了去年种植作物的种类吗？□是（回答 3.1.1.3.1） □ 否 (回答 3.1.2)

3.1.1.3.1 For which crops did you change the varieties? □ Maize □ Wheat □ Vegetables □ Cotton □ Oil bearing crops □ Peanut □ other: _______



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您更换了哪种农作物？□玉米 □小麦 □蔬菜 □棉花 □油类作物 □花生 □其他：_______

3.1.1.3.2 Why did you change the varieties? □ Advice from extension officers □ Officials told me □ Advice from friends/neighbours □ higher yields of new variety □ lower price of new seeds □ climatic change □ lack of resources forced me to change □ other: __________________
为什么要更换种植的 ？□村干部的建议□政府的建议□朋友/邻居的建议□新品种有更高的产量 □新品种的种子价格低□气候改变□资源的缺乏被迫改变 □其他：________

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3.1.2 Field Preparation and Planting **耕地规划和种植情况**

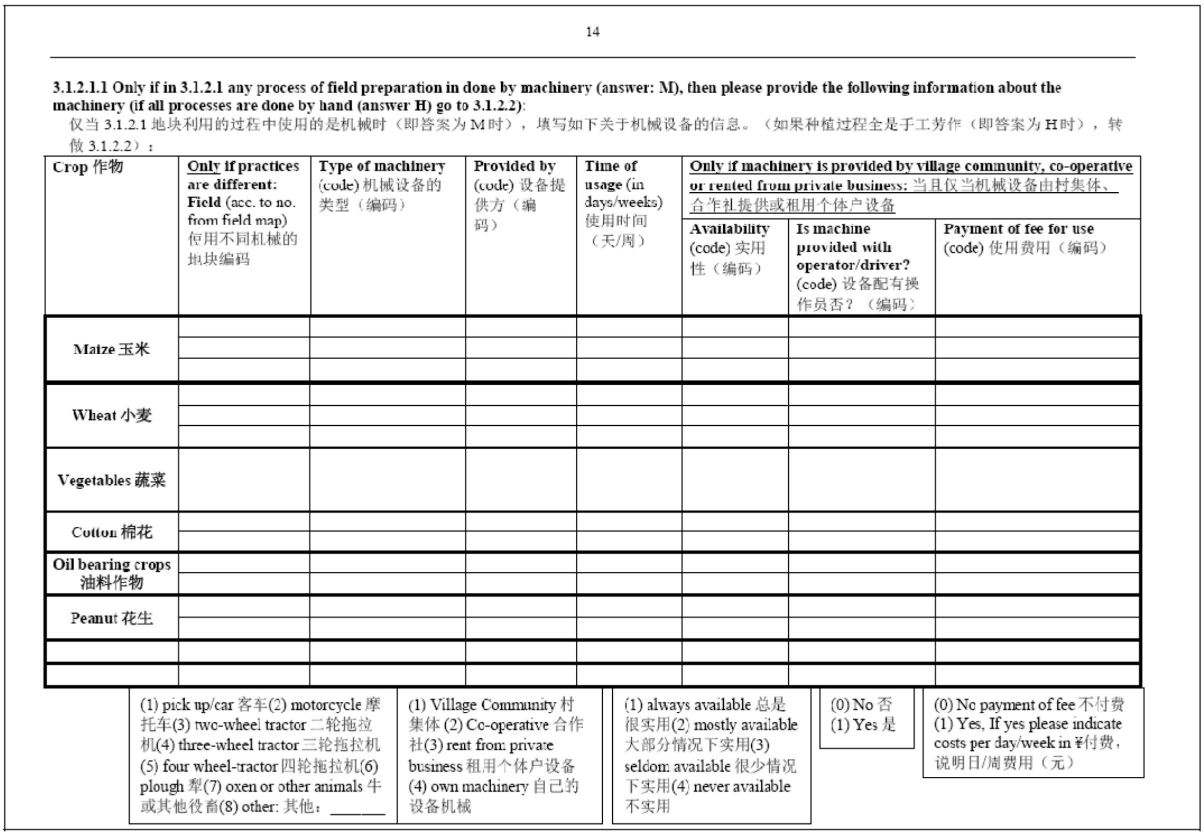
3.1.2.1 Please describe the processes of field preparation before planting the crops. If you apply different practices for the same crop on different fields, then please state separately for each field. If practices are the same on all fields: just state once per crop. Only answer for those crops where field preparation is done – so no answer means no field preparation is done for the respective crop.

请您说明在种植作物以前对于耕地的利用规划：如果您尝试把相同的作物种植在不同的地块上，请分别说明；如果各个地块的种植情况相同，请分作物说明。本题只对已经做好土地规划的农作物做出回答，对于个别没有做用地规划的作物不做回答。

Crop 作物	**Only if practices are different:** Field (acc. to no. from field map) 采用不同种植方式的地块编码	**Process of field preparation** (code)地块利用的过程（编码）	**By hand** (H) **or with machine** (M) 人工（H），机械操作（M）	**Month** (code) 月份（编码）	**Number of workers, separate between family (F), permanent (P) hired (H) and cooperative (C)** (number)劳作者的代码：家庭成员(F),长期(P),雇工(H)，合作(C)				**Salary/fee per paid worker** (¥/day) 人均雇工费用（元/天）	**Duration of preparation in total (T) OR per mu (M)** (hours) 花费时间：总共花费(T)或每亩花费(M)（单位：小时）		**Other preparation costs** (name+¥)其他准备工作的花费（名称+费用）
					F	**P**	**H**	**C**		**T**	**M**	
Maize 玉米												
Wheat 小麦												
Vegetables 蔬菜												
Cotton 棉花												
Oil bearing crops 油料作物												
Peanut 花生												

(1) plowing 犁(2) harrowing 耙 (3) turning of soil 施肥 (4) other 其他: _____

(1) Jan1 月(2)Feb2 月(3)Mar3 月(4)Apr4 月(5)May5 月(6)Jun6 月(7)Jul7 月(8)Aug8 月(9)Sep9 月(10)Oct10 月(11)Nov11 月(12)Dec12 月



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3.1.2.1.1 Only if in 3.1.2.1 any process of field preparation in done by machinery (answer: M), then please provide the following information about the machinery (if all processes are done by hand (answer H) go to 3.1.2.2):

仅当 3.1.2.1 地块利用的过程中使用的是机械时（即答案为 M 时），填写如下关于机械设备的信息。（如果种植过程全是手工劳作（即答案为 H 时），转做 3.1.2.2）：

Crop 作物	**Only if practices are different: Field** (acc. to no. from field map) 使用不同机械的地块编码	**Type of machinery** (code) 机械设备的类型（编码）	**Provided by** (code) 设备提供方（编码）	**Time of usage** (in days/weeks) 使用时间（天/周）	**Only if machinery is provided by village community, co-operative or rented from private business:** 当且仅当机械设备由村集体、合作社提供或租用个体户设备		
					Availability (code) 实用性（编码）	**Is machine provided with operator/driver?** (code) 设备配有操作员否？（编码）	**Payment of fee for use** (code) 使用费用（编码）
Maize 玉米							
Wheat 小麦							
Vegetables 蔬菜							
Cotton 棉花							
Oil bearing crops 油料作物							
Peanut 花生							

(1) pick up/car 客车(2) motorcycle 摩托车(3) two-wheel tractor 二轮拖拉机(4) three-wheel tractor 三轮拖拉机(5) four wheel-tractor 四轮拖拉机(6) plough 犁(7) oxen or other animals 牛或其他役畜(8) other: 其他：______

(1) Village Community 村集体 (2) Co-operative 合作社(3) rent from private business 租用个体户设备(4) own machinery 自己的设备机械

(1) always available 总是很实用(2) mostly available 大部分情况下实用(3) seldom available 很少情况下实用(4) never available 不实用

(0) No 否
(1) Yes 是

(0) No payment of fee 不付费
(1) Yes, If yes please indicate costs per day/week in ¥付费，说明日/周费用（元）

3.1.2.2 Please describe the processes of planting the crops. If you apply different practices for the same crop on different fields, then please state separately for each field. If practices are the same on all fields: just state once per crop.
请说明种植作物的过程，如果您尝试着将同一作物种植在不同的地块上，请分别说明；如果各个地块的种植情况相同，请分作物说明。

Crop 作物	**Only if practices are different: Field** (acc. to no. from field map) 不同地块上的种植情况（根据地块编码填写）	**By hand** (H) **or with machine** (M) 人工（H），机械操作（M）	**Month** (code) 月份（编码）	**Number of workers, separate family (F), permanent (P) hired (H) and co-operative (C)** (number)劳作者的代码：单独劳作(F), 长期(P),合作(C)，雇工(H)				**Salary/fee per paid worker** (¥/day)人均工资/费用（元/天）	**Duration of planting in total (T) OR per mu (M)** (hours) 花费时间：总共花费(T)或每亩花费(M)（单位：小时）		**Other planting costs** (name+¥)其他花费（名称+费用）
				F	**P**	**H**	**C**		**T**	**M**	
Maize 玉米											
Wheat 小麦											
Vegetables 蔬菜											
Cotton 棉花											
Oil bearing crops 油料作物											
Peanut 花生											

(1) Jan1 月 (2)Feb2 月(3)Mar3 月(4)Apr4 月(5)May5 月 (6)Jun6 月(7)Jul7 月(8)Aug8 月(9)Sep9 月(10)Oct10 月 (11)Nov11 月(12)Dec12 月

3.1.2.2.1 Only if in 3.1.2.2 any process of planting the crops is done by machinery (answer: M), then please provide the following information about the machinery (if all processes are done by hand (answer H) go to 3.1.2.3):
当 3.1.2.2 中种植作物使用的是机械时（即答案为 M 时），填写如下关于机械设备的信息；（如果种植过程全是手工劳作（即答案为 H 时），转做 3.1.2.3）：

Crop 作物	**Only if practices are different: Field** (acc. to no. from field map)使用不同机械时的地块编码	**Type of machinery** (code) 机械设备的类型（编码）	**Provided by** (code) 设备提供方（编码）	**Time of usage** (in days/weeks) 使用时间（天/周）	**Only if machinery is provided by village community, co-operative or rented from private business:** 当且仅当机械设备由村集体、合作社提供或租用个体户设备		
					Availability (code) 实用性（编码）	**Is machine provided with operator/driver?** (code) 设备配有操作员否？（编码）	**Payment of fee for use** (code) 使用费用（编码）
Maize 玉米							
Wheat 小麦							
Vegetables 蔬菜							
Cotton 棉花							
Oil bearing crops 油料作物							
Peanut 花生							

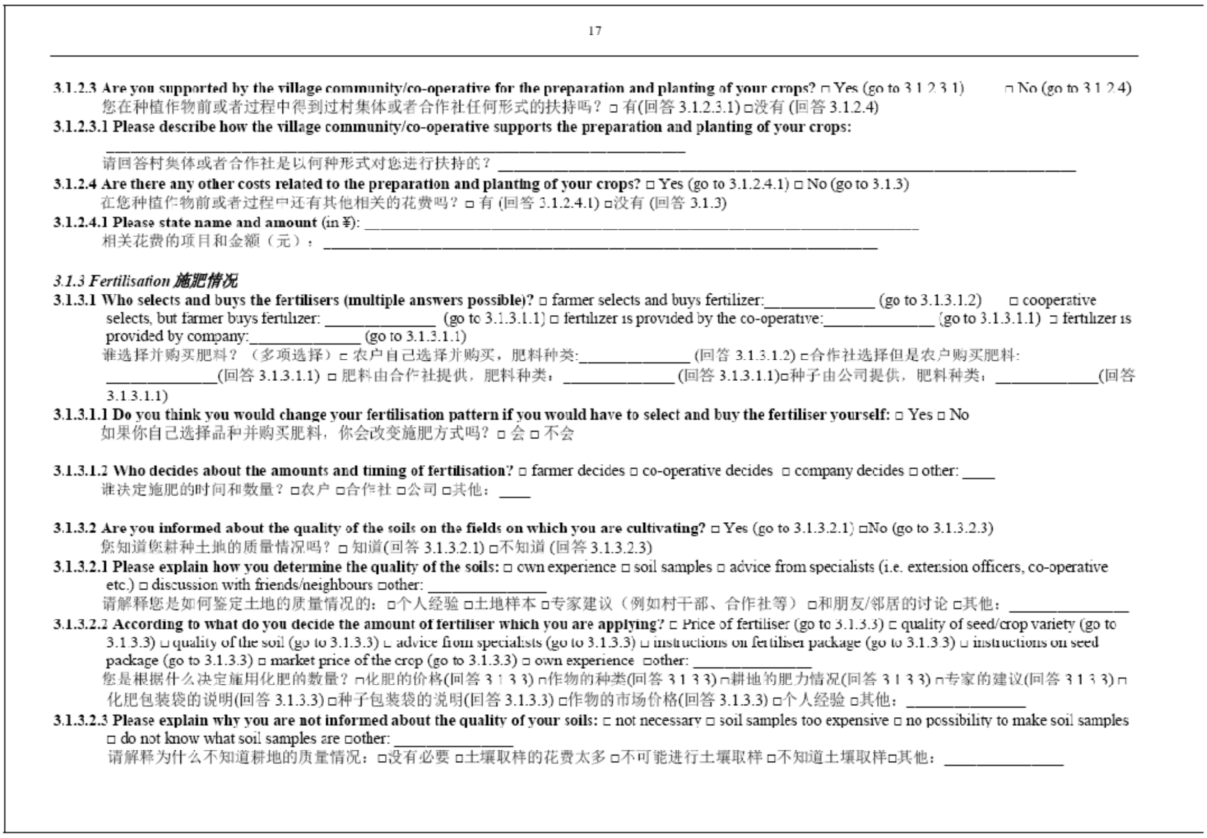
(1) pick up/car 客车 (2) motorcycle 摩托车 (3)two-wheel tractor 两轮拖拉机 (4) three-wheel tractor 三轮拖拉机(5)four wheel-tractor 四轮拖拉机(6) sowing machine 播种机(7) oxen or other animals 牛或其他役畜 (8) other: 其他：__________

(1) Village Community 村集体(2) Co-operative 合作社(3) rent from private business 租用个体户设备 (4) own machinery 自己的设备机械

(1) always available 总是很实用(2) mostly available 大部分情况下实用(3) seldom available 很少情况下实用(4) never available 不实用

(0) No 否
(1) Yes 是

(0) No payment of fee 不付费
(1) Yes, If yes please indicate costs per day/week in ¥付费，说明日/周费用（元）



3.1.2.3 Are you supported by the village community/co-operative for the preparation and planting of your crops? □ Yes (go to 3.1.2.3.1) □ No (go to 3.1.2.4)
您在种植作物前或者过程中得到过村集体或者合作社任何形式的扶持吗？□ 有(回答 3.1.2.3.1) □没有 (回答 3.1.2.4)

3.1.2.3.1 Please describe how the village community/co-operative supports the preparation and planting of your crops: ____________________________________
请回答村集体或者合作社是以何种形式对您进行扶持的？ ____________________________________

3.1.2.4 Are there any other costs related to the preparation and planting of your crops? □ Yes (go to 3.1.2.4.1) □ No (go to 3.1.3)
在您种植作物前或者过程中还有其他相关的花费吗？□ 有 (回答 3.1.2.4.1) □没有 (回答 3.1.3)

3.1.2.4.1 Please state name and amount (in ¥): ____________________________________
相关花费的项目和金额（元）： ____________________________________

3.1.3 Fertilisation 施肥情况

3.1.3.1 Who selects and buys the fertilisers (multiple answers possible)? □ farmer selects and buys fertilizer:______________ (go to 3.1.3.1.2) □ cooperative selects, but farmer buys fertilizer: ______________ (go to 3.1.3.1.1) □ fertilizer is provided by the co-operative:______________ (go to 3.1.3.1.1) □ fertilizer is provided by company:______________ (go to 3.1.3.1.1)
谁选择并购买肥料？（多项选择）□ 农户自己选择并购买，肥料种类:______________ (回答 3.1.3.1.2) □合作社选择但是农户购买肥料: ______________(回答 3.1.3.1.1) □ 肥料由合作社提供，肥料种类：______________(回答 3.1.3.1.1)□种子由公司提供，肥料种类：______________(回答 3.1.3.1.1)

3.1.3.1.1 Do you think you would change your fertilisation pattern if you would have to select and buy the fertiliser yourself: □ Yes □ No
如果你自己选择品和并购买肥料，你会改变施肥方式吗？□ 会 □ 不会

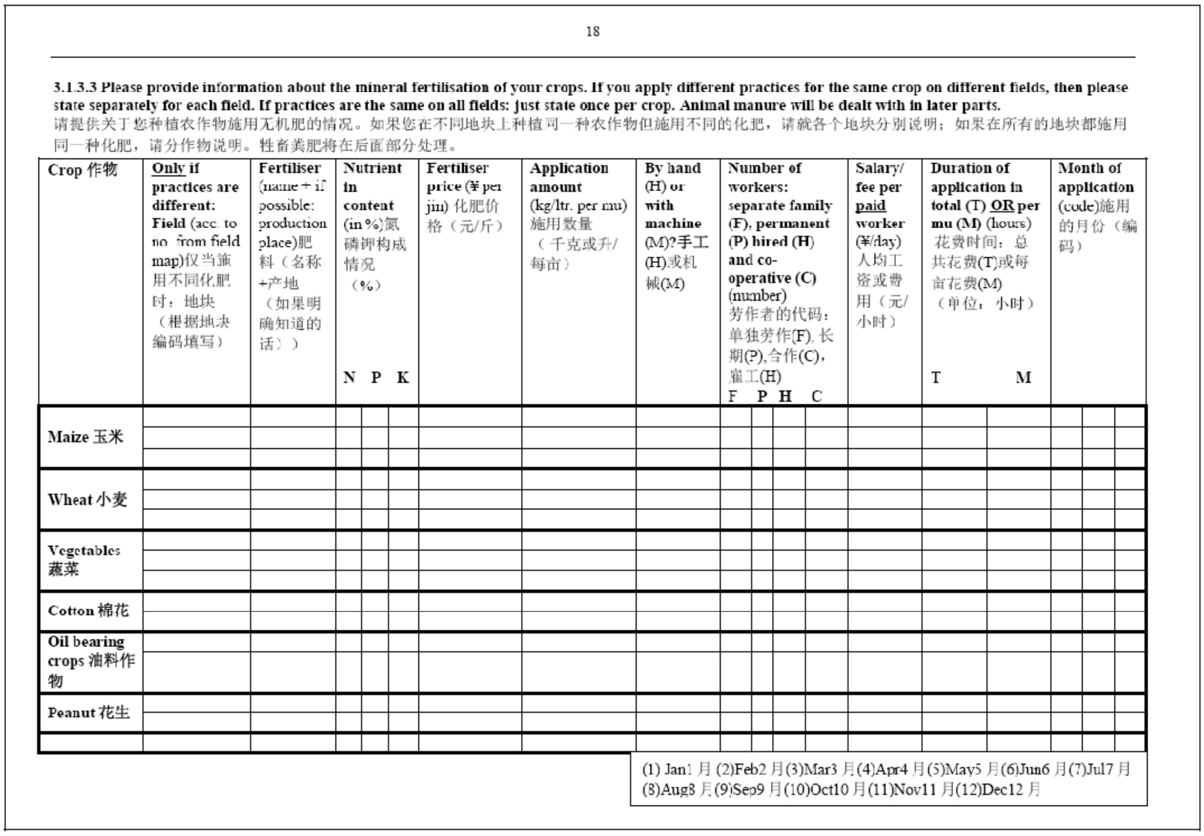
3.1.3.1.2 Who decides about the amounts and timing of fertilisation? □ farmer decides □ co-operative decides □ company decides □ other: ____
谁决定施肥的时间和数量？□农户 □合作社 □公司 □其他： ____

3.1.3.2 Are you informed about the quality of the soils on the fields on which you are cultivating? □ Yes (go to 3.1.3.2.1) □No (go to 3.1.3.2.3)
您知道您耕种土地的质量情况吗？□ 知道(回答 3.1.3.2.1) □不知道 (回答 3.1.3.2.3)

3.1.3.2.1 Please explain how you determine the quality of the soils: □ own experience □ soil samples □ advice from specialists (i.e. extension officers, co-operative etc.) □ discussion with friends/neighbours □other: ______________
请解释您是如何鉴定土地的质量情况的：□个人经验 □土地样本 □专家建议（例如村干部、合作社等）□和朋友/邻居的讨论 □其他：______________

3.1.3.2.2 According to what do you decide the amount of fertiliser which you are applying? □ Price of fertiliser (go to 3.1.3.3) □ quality of seed/crop variety (go to 3.1.3.3) □ quality of the soil (go to 3.1.3.3) □ advice from specialists (go to 3.1.3.3) □ instructions on fertiliser package (go to 3.1.3.3) □ instructions on seed package (go to 3.1.3.3) □ market price of the crop (go to 3.1.3.3) □ own experience □other: ______________
您是根据什么决定施用化肥的数量？□化肥的价格(回答 3.1.3.3) □作物的种类(回答 3.1.3.3) □耕地的肥力情况(回答 3.1.3.3) □专家的建议(回答 3.1.3.3) □化肥包装袋的说明(回答 3.1.3.3) □种子包装袋的说明(回答 3.1.3.3) □作物的市场价格(回答 3.1.3.3) □个人经验 □其他：______________

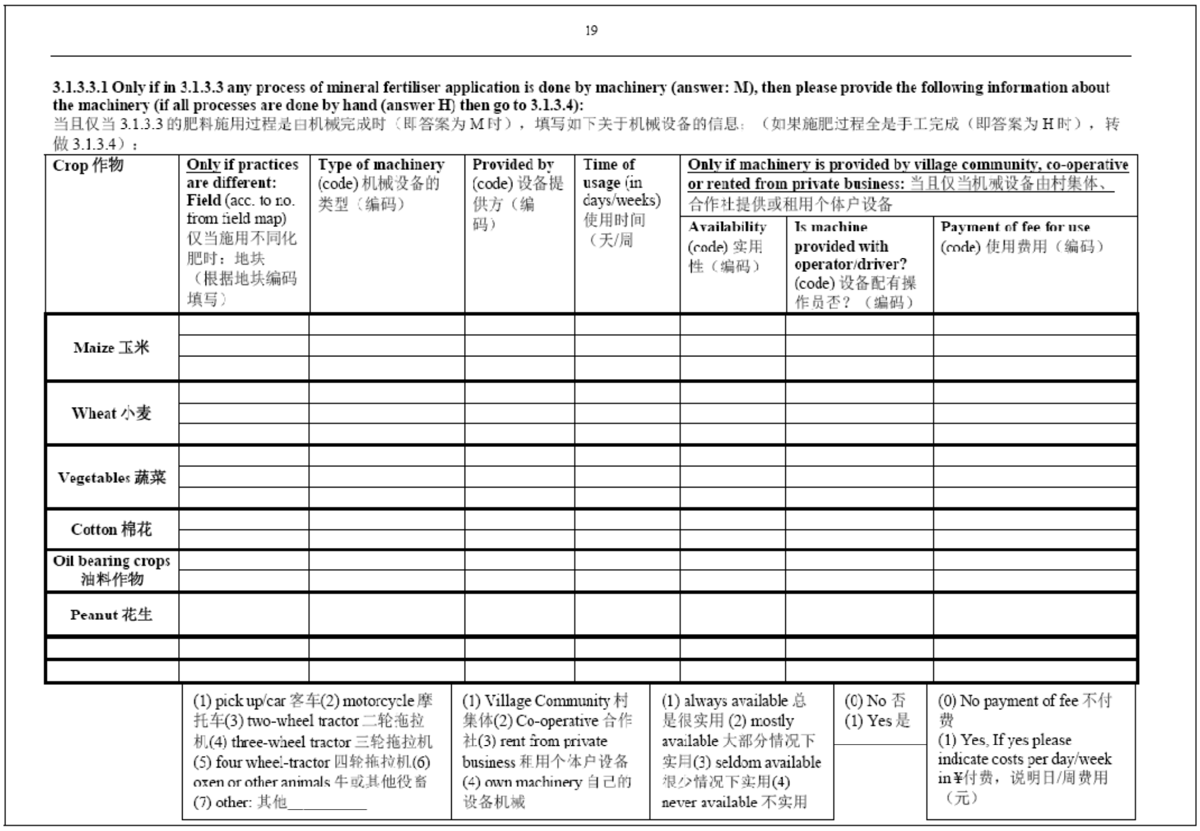
3.1.3.2.3 Please explain why you are not informed about the quality of your soils: □ not necessary □ soil samples too expensive □ no possibility to make soil samples □ do not know what soil samples are □other: ______________
请解释为什么不知道耕地的质量情况：□没有必要 □土壤取样的花费太多 □不可能进行土壤取样 □不知道土壤取样□其他：______________



3.1.3.3 Please provide information about the mineral fertilisation of your crops. If you apply different practices for the same crop on different fields, then please state separately for each field. If practices are the same on all fields: just state once per crop. Animal manure will be dealt with in later parts.
请提供关于您种植农作物施用无机肥的情况。如果您在不同地块上种植同一种农作物但施用不同的化肥，请就各个地块分别说明；如果在所有的地块都施用同一种化肥，请分作物说明。牲畜粪肥将在后面部分处理。

Crop 作物	**Only if** practices are different: Field (acc. to no. from field map)仅当施用不同化肥时：地块（根据地块编码填写）	Fertiliser (name + if possible: production place)肥料（名称+产地（如果明确知道的话））	Nutrient in content (in %)氮磷钾构成情况（%）			Fertiliser price (¥ per jin) 化肥价格（元/斤）	Application amount (kg/ltr. per mu) 施用数量（千克或升/每亩）	By hand (H) or with machine (M)?手工(H)或机械(M)	Number of workers: separate family (F), permanent (P) hired (H) and co-operative (C) (number) 劳作者的代码：单独劳作(F), 长期(P),合作(C), 雇工(H)				Salary/ fee per paid worker (¥/day) 人均工资或费用（元/小时）	Duration of application in total (T) OR per mu (M) (hours) 花费时间：总共花费(T)或每亩花费(M)（单位：小时）		Month of application (code)施用的月份（编码）		
			N	P	K				F	P	H	C		T	M			
Maize 玉米																		
Wheat 小麦																		
Vegetables 蔬菜																		
Cotton 棉花																		
Oil bearing crops 油料作物																		
Peanut 花生																		

(1) Jan1 月 (2)Feb2 月(3)Mar3 月(4)Apr4 月(5)May5 月(6)Jun6 月(7)Jul7 月(8)Aug8 月(9)Sep9 月(10)Oct10 月(11)Nov11 月(12)Dec12 月



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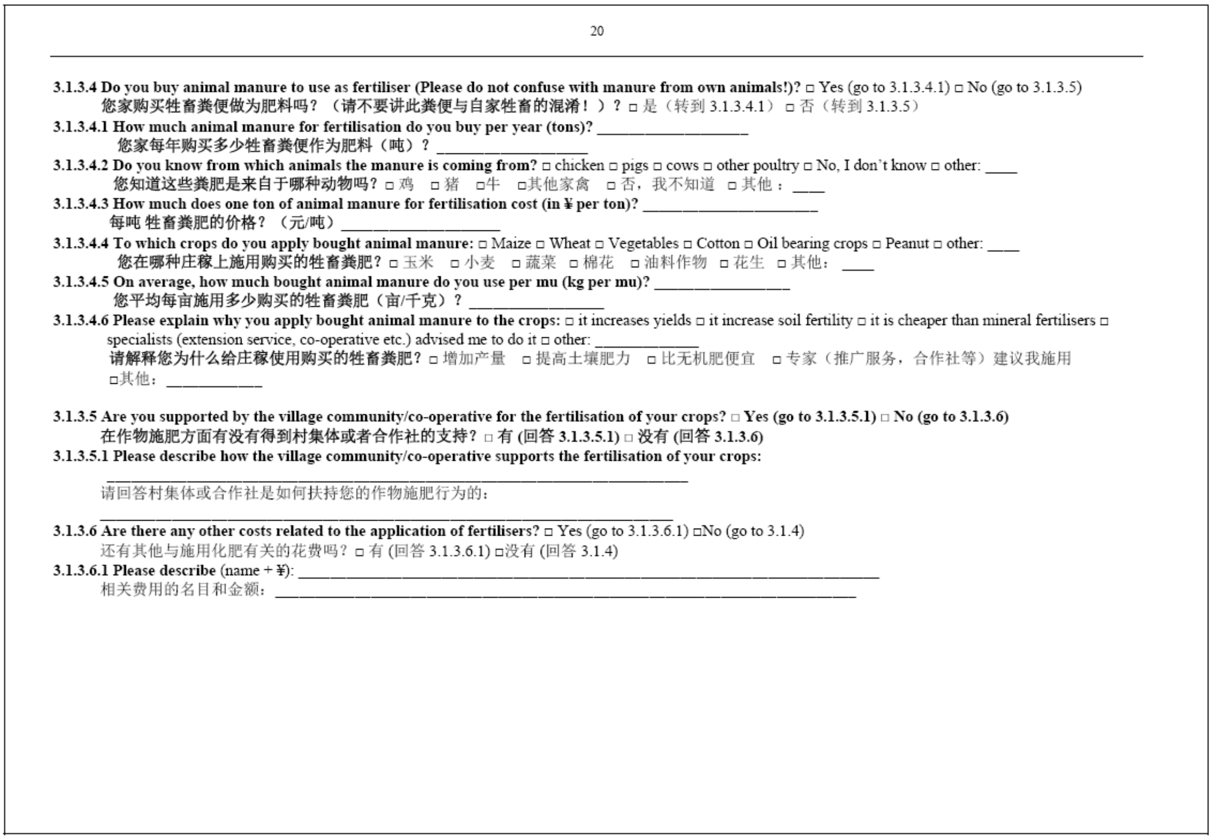
3.1.3.3.1 Only if in 3.1.3.3 any process of mineral fertiliser application is done by machinery (answer: M), then please provide the following information about the machinery (if all processes are done by hand (answer H) then go to 3.1.3.4):
当且仅当 3.1.3.3 的肥料施用过程是由机械完成时（即答案为 M 时），填写如下关于机械设备的信息：（如果施肥过程全是手工完成（即答案为 H 时），转做 3.1.3.4）：

Crop 作物	**Only if practices are different: Field** (acc. to no. from field map) 仅当施用不同化肥时：地块（根据地块编码填写）	**Type of machinery** (code) 机械设备的类型（编码）	**Provided by** (code) 设备提供方（编码）	**Time of usage** (in days/weeks) 使用时间（天/周	**Only if machinery is provided by village community, co-operative or rented from private business:** 当且仅当机械设备由村集体、合作社提供或租用个体户设备		
					Availability (code) 实用性（编码）	**Is machine provided with operator/driver?** (code) 设备配有操作员否？（编码）	**Payment of fee for use** (code) 使用费用（编码）
Maize 玉米							
Wheat 小麦							
Vegetables 蔬菜							
Cotton 棉花							
Oil bearing crops 油料作物							
Peanut 花生							
		(1) pick up/car 客车(2) motorcycle 摩托车(3) two-wheel tractor 二轮拖拉机(4) three-wheel tractor 三轮拖拉机(5) four wheel-tractor 四轮拖拉机(6) oxen or other animals 牛或其他役畜(7) other: 其他__________	(1) Village Community 村集体(2) Co-operative 合作社(3) rent from private business 租用个体户设备(4) own machinery 自己的设备机械		(1) always available 总是很实用 (2) mostly available 大部分情况下实用(3) seldom available 很少情况下实用(4) never available 不实用	(0) No 否 (1) Yes 是	(0) No payment of fee 不付费 (1) Yes, If yes please indicate costs per day/week in ¥付费，说明日/周费用（元）



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3.1.3.4 Do you buy animal manure to use as fertiliser (Please do not confuse with manure from own animals!)? □ Yes (go to 3.1.3.4.1) □ No (go to 3.1.3.5)
您家购买牲畜粪便做为肥料吗？（请不要讲此粪便与自家牲畜的混淆！）？ □ 是（转到 3.1.3.4.1） □ 否（转到 3.1.3.5）

3.1.3.4.1 How much animal manure for fertilisation do you buy per year (tons)? __________________
您家每年购买多少牲畜粪便作为肥料（吨）？ __________________

3.1.3.4.2 Do you know from which animals the manure is coming from? □ chicken □ pigs □ cows □ other poultry □ No, I don't know □ other: ____
您知道这些粪肥是来自于哪种动物吗？ □ 鸡 □ 猪 □牛 □其他家禽 □ 否，我不知道 □ 其他：____

3.1.3.4.3 How much does one ton of animal manure for fertilisation cost (in ¥ per ton)? ______________________
每吨 牲畜粪肥的价格？（元/吨） ____________________

3.1.3.4.4 To which crops do you apply bought animal manure: □ Maize □ Wheat □ Vegetables □ Cotton □ Oil bearing crops □ Peanut □ other: ____
您在哪种庄稼上施用购买的牲畜粪肥？ □ 玉米 □ 小麦 □ 蔬菜 □ 棉花 □ 油料作物 □ 花生 □ 其他：____

3.1.3.4.5 On average, how much bought animal manure do you use per mu (kg per mu)? _________________
您平均每亩施用多少购买的牲畜粪肥（亩/千克）？ _________________

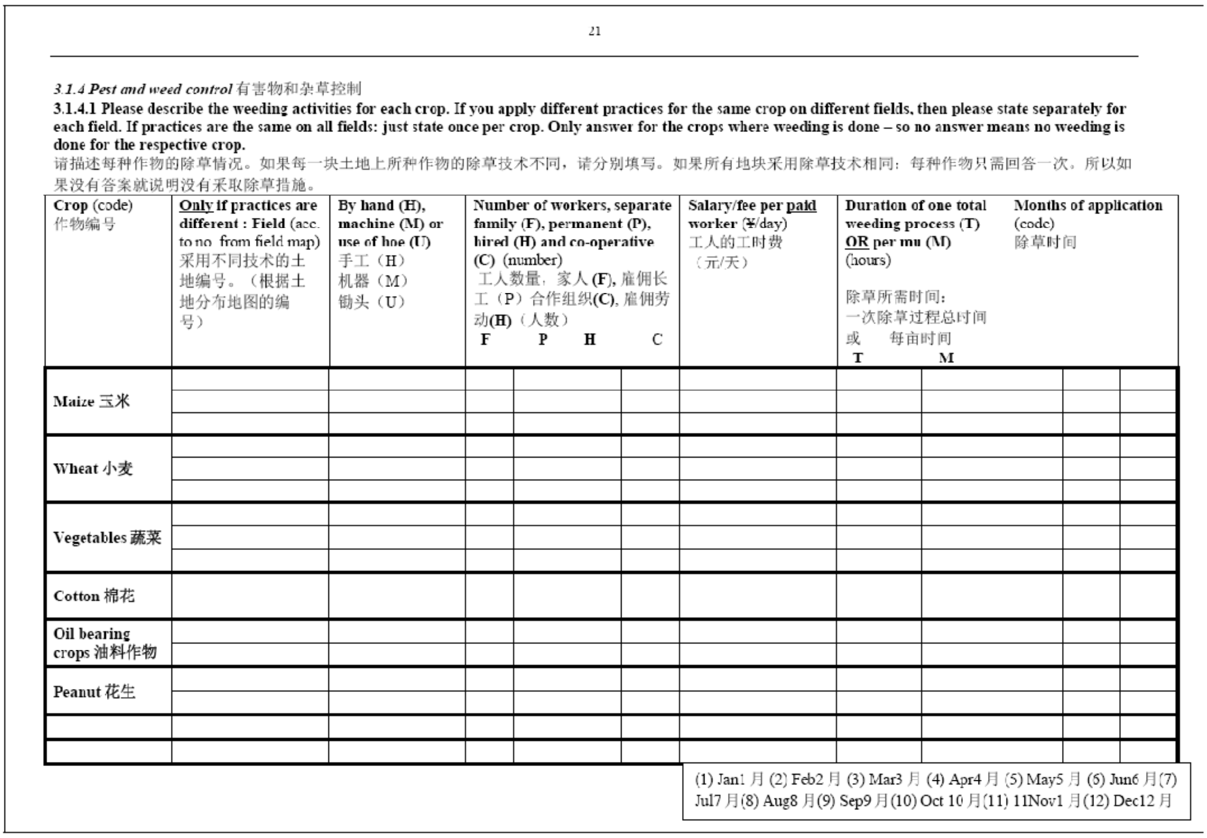
3.1.3.4.6 Please explain why you apply bought animal manure to the crops: □ it increases yields □ it increase soil fertility □ it is cheaper than mineral fertilisers □ specialists (extension service, co-operative etc.) advised me to do it □ other: _____________
请解释您为什么给庄稼使用购买的牲畜粪肥？ □ 增加产量 □ 提高土壤肥力 □ 比无机肥便宜 □ 专家（推广服务，合作社等）建议我施用 □其他：____________

3.1.3.5 Are you supported by the village community/co-operative for the fertilisation of your crops? □ Yes (go to 3.1.3.5.1) □ No (go to 3.1.3.6)
在作物施肥方面有没有得到村集体或者合作社的支持？□ 有 (回答 3.1.3.5.1) □ 没有 (回答 3.1.3.6)

3.1.3.5.1 Please describe how the village community/co-operative supports the fertilisation of your crops:
____
请回答村集体或合作社是如何扶持您的作物施肥行为的：
____

3.1.3.6 Are there any other costs related to the application of fertilisers? □ Yes (go to 3.1.3.6.1) □No (go to 3.1.4)
还有其他与施用化肥有关的花费吗？□ 有 (回答 3.1.3.6.1) □没有 (回答 3.1.4)

3.1.3.6.1 Please describe (name + ¥): ____
相关费用的名目和金额：____



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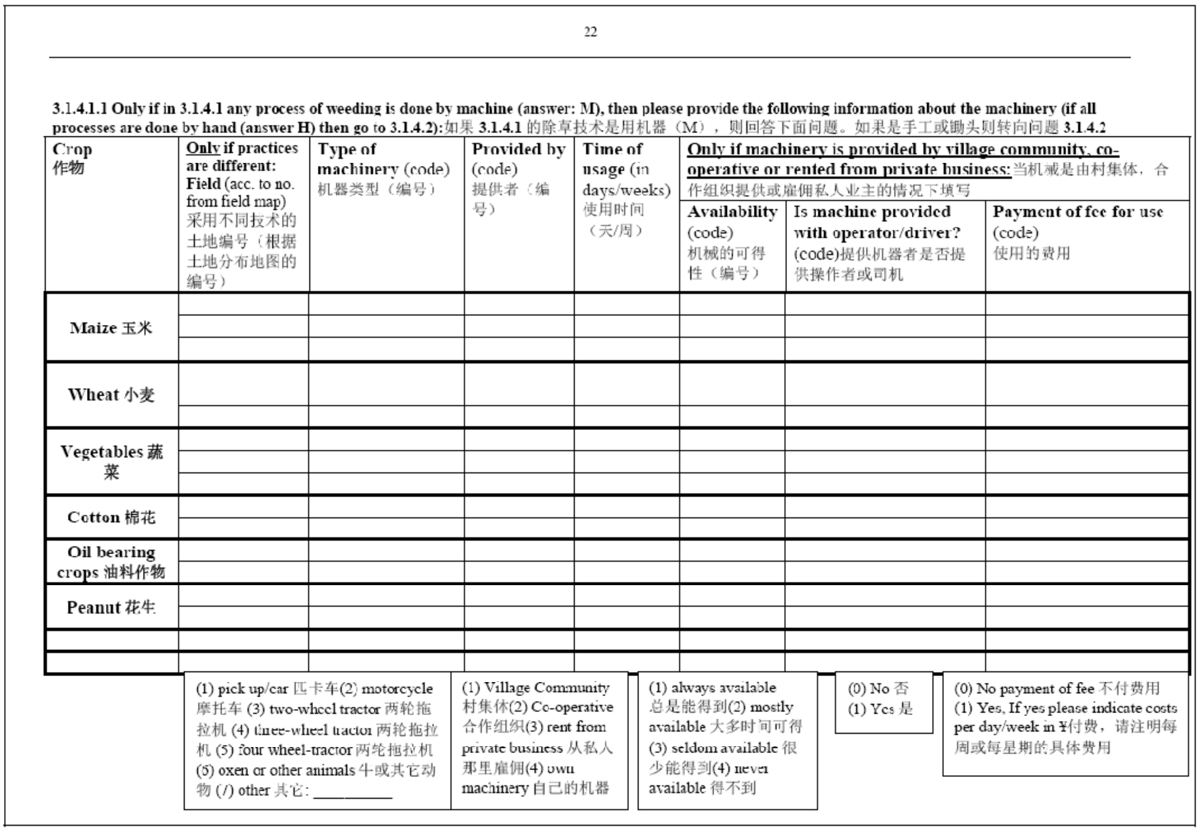
3.1.4 Pest and weed control 有害物和杂草控制

3.1.4.1 Please describe the weeding activities for each crop. If you apply different practices for the same crop on different fields, then please state separately for each field. If practices are the same on all fields: just state once per crop. Only answer for the crops where weeding is done – so no answer means no weeding is done for the respective crop.

请描述每种作物的除草情况。如果每一块土地上所种作物的除草技术不同，请分别填写。如果所有地块采用除草技术相同：每种作物只需回答一次。所以如果没有答案就说明没有采取除草措施。

Crop (code) 作物编号	**Only if practices are different : Field** (acc. to no. from field map) 采用不同技术的土地编号。（根据土地分布地图的编号）	**By hand (H), machine (M) or use of hoe (U)** 手工（H）机器（M）锄头（U）	**Number of workers, separate family (F), permanent (P), hired (H) and co-operative (C)** (number) 工人数量，家人 **(F)**, 雇佣长工（P）合作组织**(C)**, 雇佣劳动**(H)**（人数）				**Salary/fee per paid worker** (¥/day) 工人的工时费（元/天）	**Duration of one total weeding process (T) OR per mu (M)** (hours) 除草所需时间：一次除草过程总时间 或 每亩时间		**Months of application** (code) 除草时间	
			F	**P**	**H**	C		**T**	**M**		
Maize 玉米											
Wheat 小麦											
Vegetables 蔬菜											
Cotton 棉花											
Oil bearing crops 油料作物											
Peanut 花生											

(1) Jan1 月 (2) Feb2 月 (3) Mar3 月 (4) Apr4 月 (5) May5 月 (6) Jun6 月(7) Jul7 月(8) Aug8 月(9) Sep9 月(10) Oct 10 月(11) 11Nov1 月(12) Dec12 月



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3.1.4.1.1 Only if in 3.1.4.1 any process of weeding is done by machine (answer: M), then please provide the following information about the machinery (if all processes are done by hand (answer H) then go to 3.1.4.2):如果 **3.1.4.1** 的除草技术是用机器（M），则回答下面问题。如果是手工或锄头则转向问题 **3.1.4.2**

Crop 作物	**Only if practices are different: Field** (acc. to no. from field map) 采用不同技术的土地编号（根据土地分布地图的编号）	**Type of machinery** (code) 机器类型（编号）	**Provided by** (code) 提供者（编号）	**Time of usage** (in days/weeks) 使用时间（天/周）	**Only if machinery is provided by village community, co-operative or rented from private business:** 当机械是由村集体，合作组织提供或雇佣私人业主的情况下填写		
					Availability (code) 机械的可得性（编号）	**Is machine provided with operator/driver?** (code)提供机器者是否提供操作者或司机	**Payment of fee for use** (code) 使用的费用
Maize 玉米							
Wheat 小麦							
Vegetables 蔬菜							
Cotton 棉花							
Oil bearing crops 油料作物							
Peanut 花生							

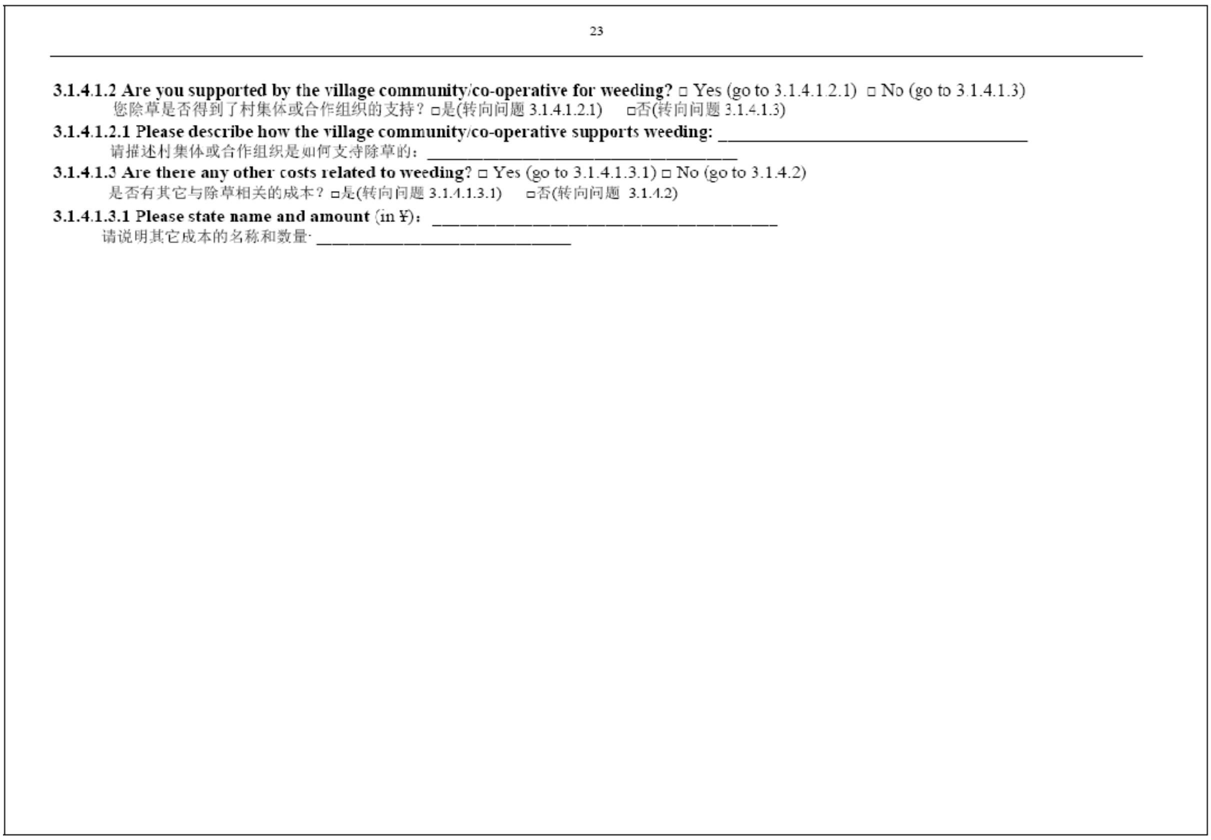
(1) pick up/car 匹卡车(2) motorcycle 摩托车 (3) two-wheel tractor 两轮拖拉机 (4) three-wheel tractor 两轮拖拉机 (5) four wheel-tractor 两轮拖拉机 (5) oxen or other animals 牛或其它动物 (/) other 其它: __________

(1) Village Community 村集体(2) Co-operative 合作组织(3) rent from private business 从私人那里雇佣(4) own machinery 自己的机器

(1) always available 总是能得到(2) mostly available 大多时间可得 (3) seldom available 很少能得到(4) never available 得不到

(0) No 否
(1) Yes 是

(0) No payment of fee 不付费用
(1) Yes, If yes please indicate costs per day/week in ¥付费，请注明每周或每星期的具体费用

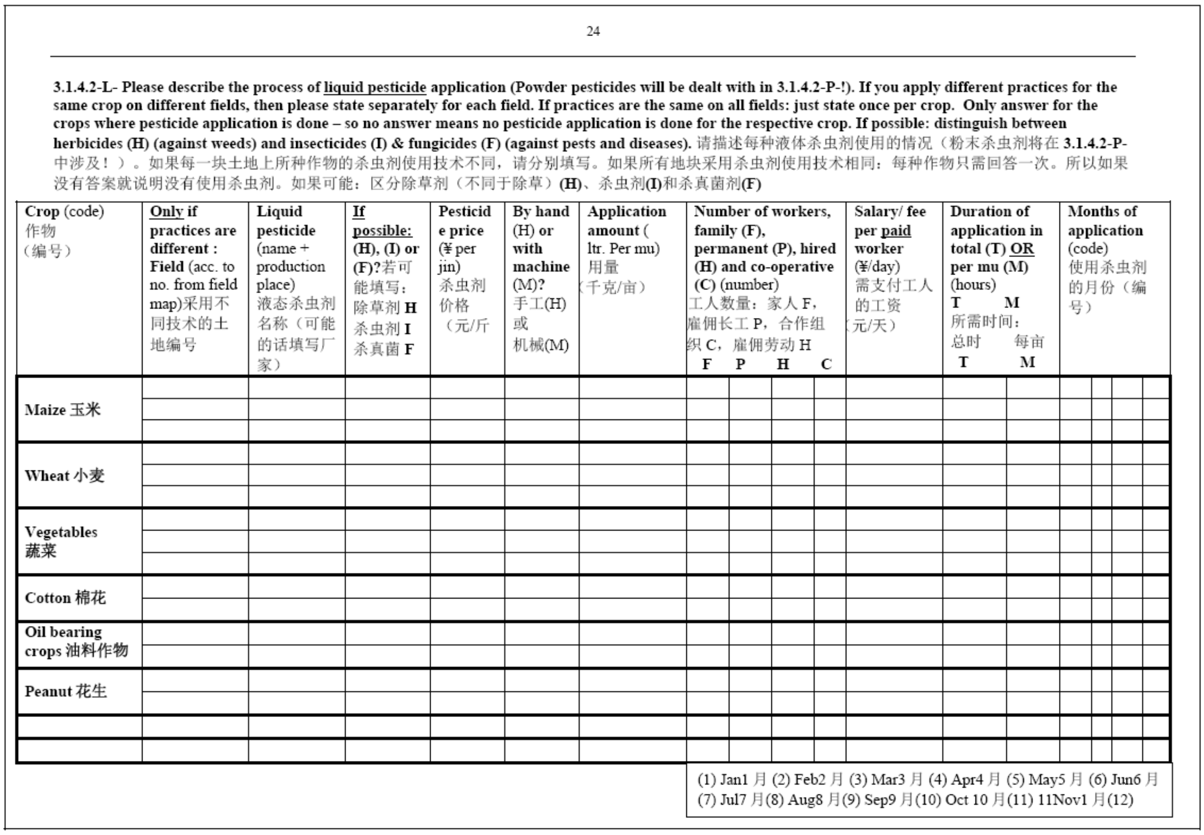


3.1.4.1.2 Are you supported by the village community/co-operative for weeding? □ Yes (go to 3.1.4.1.2.1) □ No (go to 3.1.4.1.3)
您除草是否得到了村集体或合作组织的支持？□是(转向问题 3.1.4.1.2.1) □否(转向问题 3.1.4.1.3)

3.1.4.1.2.1 Please describe how the village community/co-operative supports weeding: ___________________________________
请描述村集体或合作组织是如何支持除草的：___________________________________

3.1.4.1.3 Are there any other costs related to weeding? □ Yes (go to 3.1.4.1.3.1) □ No (go to 3.1.4.2)
是否有其它与除草相关的成本？□是(转向问题 3.1.4.1.3.1) □否(转向问题 3.1.4.2)

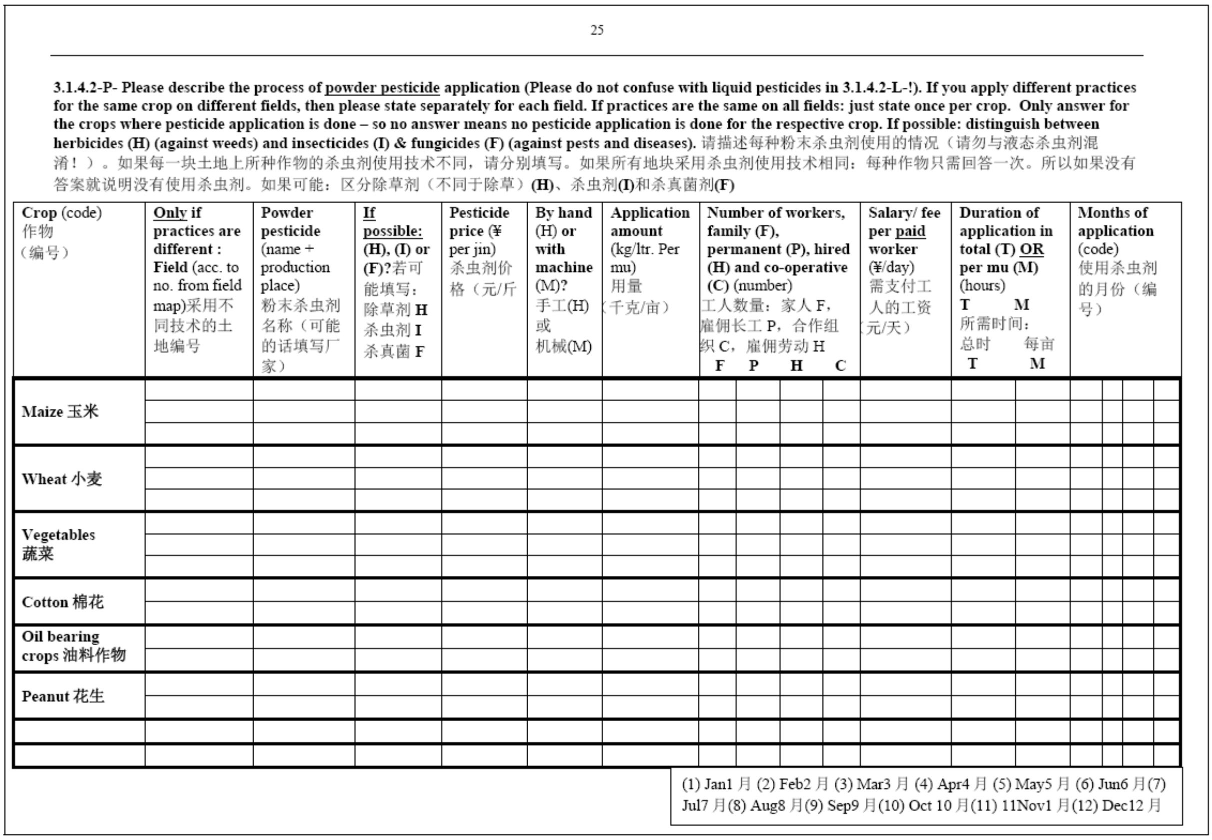
3.1.4.1.3.1 Please state name and amount (in ¥)：_______________________________________
请说明其它成本的名称和数量· _____________________________



3.1.4.2-L- Please describe the process of <u>liquid pesticide</u> application (Powder pesticides will be dealt with in 3.1.4.2-P-!). If you apply different practices for the same crop on different fields, then please state separately for each field. If practices are the same on all fields: just state once per crop. Only answer for the crops where pesticide application is done – so no answer means no pesticide application is done for the respective crop. If possible: distinguish between herbicides (H) (against weeds) and insecticides (I) & fungicides (F) (against pests and diseases). 请描述每种液体杀虫剂使用的情况（粉末杀虫剂将在 **3.1.4.2-P-** 中涉及！）。如果每一块土地上所种作物的杀虫剂使用技术不同，请分别填写。如果所有地块采用杀虫剂使用技术相同：每种作物只需回答一次。所以如果没有答案就说明没有使用杀虫剂。如果可能：区分除草剂（不同于除草）**(H)**、杀虫剂**(I)**和杀真菌剂**(F)**

Crop (code) 作物 （编号）	**<u>Only</u> if practices are different : Field** (acc. to no. from field map)采用不同技术的土地编号	**Liquid pesticide** (name + production place) 液态杀虫剂名称（可能的话填写厂家）	**<u>If possible:</u> (H), (I) or (F)?**若可能填写：除草剂 **H** 杀虫剂 **I** 杀真菌 **F**	**Pesticide price** (¥ per jin) 杀虫剂价格 （元/斤	**By hand** (H) or **with machine** (M)? 手工(H) 或 机械(M)	**Application amount (** ltr. Per mu) 用量 （千克/亩）	**Number of workers, family (F), permanent (P), hired (H) and co-operative (C)** (number) 工人数量：家人 F，雇佣长工 P，合作组织 C，雇佣劳动 H				**Salary/ fee per <u>paid</u> worker** (¥/day) 需支付工人的工资 （元/天）	**Duration of application in total (T) <u>OR</u> per mu (M)** (hours) **T M** 所需时间：总时 每亩		**Months of application** (code) 使用杀虫剂的月份（编号）			
							F	**P**	**H**	**C**		**T**	**M**				
Maize 玉米																	
Wheat 小麦																	
Vegetables 蔬菜																	
Cotton 棉花																	
Oil bearing crops 油料作物																	
Peanut 花生																	

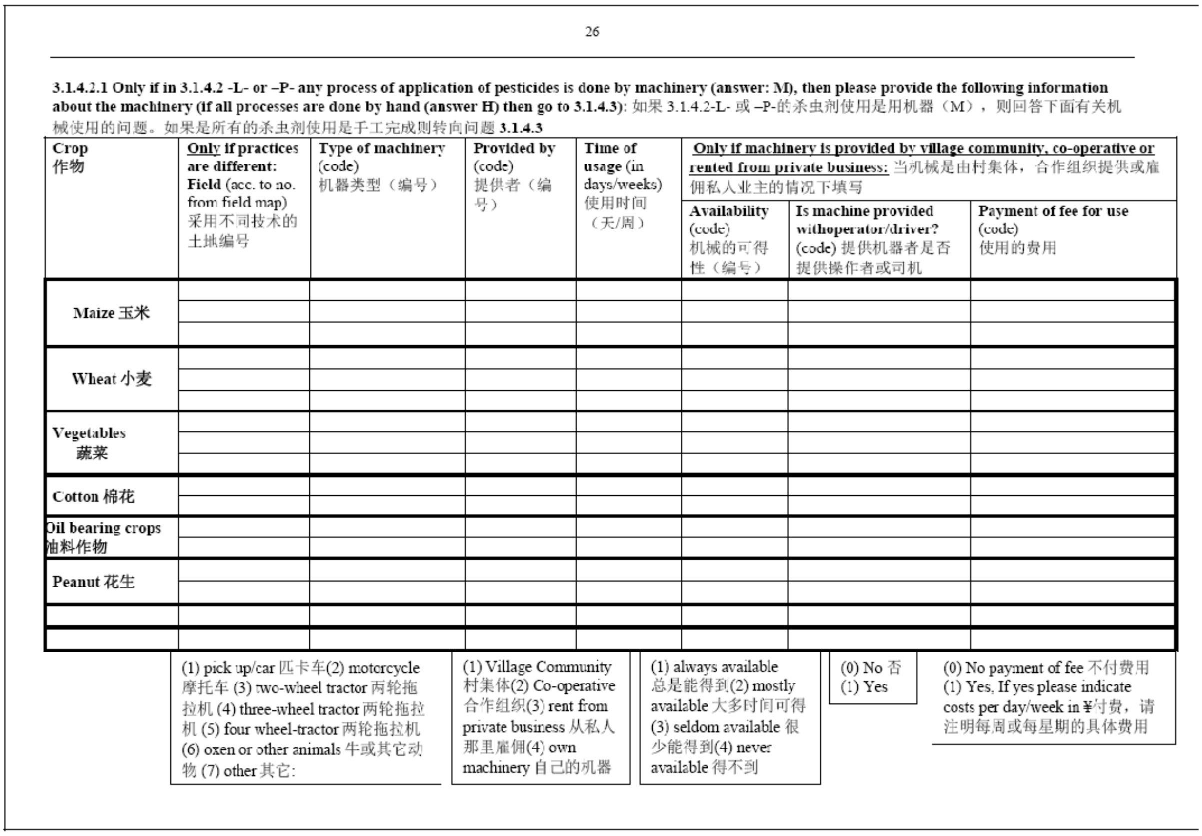
(1) Jan1 月 (2) Feb2 月 (3) Mar3 月 (4) Apr4 月 (5) May5 月 (6) Jun6 月
(7) Jul7 月(8) Aug8 月(9) Sep9 月(10) Oct 10 月(11) 11Nov1 月(12)



3.1.4.2-P- Please describe the process of powder pesticide application (Please do not confuse with liquid pesticides in 3.1.4.2-L-!). If you apply different practices for the same crop on different fields, then please state separately for each field. If practices are the same on all fields: just state once per crop. Only answer for the crops where pesticide application is done – so no answer means no pesticide application is done for the respective crop. If possible: distinguish between herbicides (H) (against weeds) and insecticides (I) & fungicides (F) (against pests and diseases). 请描述每种粉末杀虫剂使用的情况（请勿与液态杀虫剂混淆！）。如果每一块土地上所种作物的杀虫剂使用技术不同，请分别填写。如果所有地块采用杀虫剂使用技术相同：每种作物只需回答一次。所以如果没有答案就说明没有使用杀虫剂。如果可能：区分除草剂（不同于除草）**(H)**、杀虫剂**(I)**和杀真菌剂**(F)**

Crop (code) 作物（编号）	**Only if practices are different : Field** (acc. to no. from field map)采用不同技术的土地编号	**Powder pesticide** (name + production place) 粉末杀虫剂名称（可能的话填写厂家）	**If possible: (H), (I) or (F)?**若可能填写：除草剂 **H** 杀虫剂 **I** 杀真菌 **F**	**Pesticide price (¥** per jin) 杀虫剂价格（元/斤	**By hand** (H) or **with machine** (M)? 手工(H) 或 机械(M)	**Application amount** (kg/ltr. Per mu) 用量（千克/亩）	**Number of workers, family (F), permanent (P), hired (H) and co-operative (C)** (number) 工人数量：家人 F，雇佣长工 P，合作组织 C，雇佣劳动 H				**Salary/ fee per paid worker** (¥/day) 需支付工人的工资（元/天）	**Duration of application in total (T) OR per mu (M)** (hours) 所需时间：总时 每亩		**Months of application** (code) 使用杀虫剂的月份（编号）
							F	**P**	**H**	**C**		**T**	**M**	
Maize 玉米														
Wheat 小麦														
Vegetables 蔬菜														
Cotton 棉花														
Oil bearing crops 油料作物														
Peanut 花生														

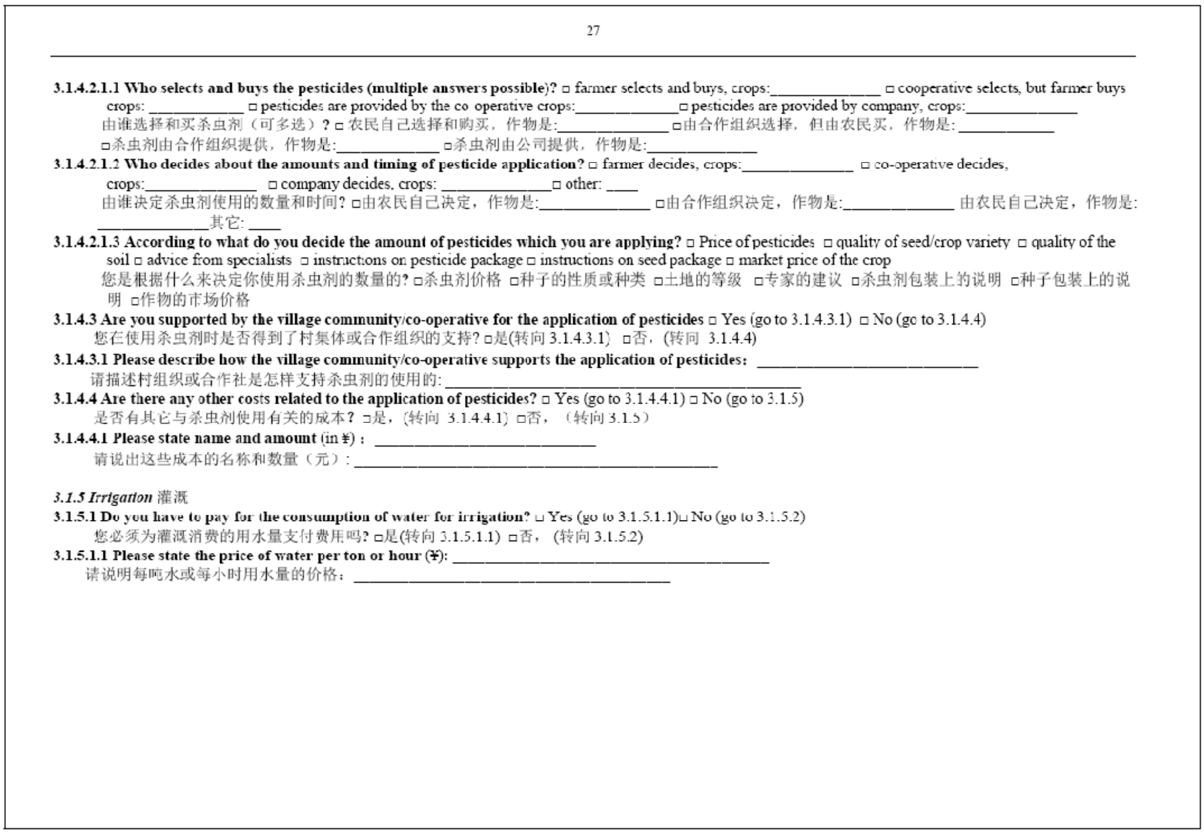
(1) Jan1 月 (2) Feb2 月 (3) Mar3 月 (4) Apr4 月 (5) May5 月 (6) Jun6 月 (7) Jul7 月(8) Aug8 月(9) Sep9 月(10) Oct 10 月(11) 11Nov1 月(12) Dec12 月



3.1.4.2.1 Only if in 3.1.4.2 -L- or –P- any process of application of pesticides is done by machinery (answer: M), then please provide the following information about the machinery (if all processes are done by hand (answer H) then go to 3.1.4.3): 如果 3.1.4.2-L- 或 –P-的杀虫剂使用是用机器（M），则回答下面有关机械使用的问题。如果是所有的杀虫剂使用是手工完成则转向问题 **3.1.4.3**

Crop 作物	**Only if practices are different: Field** (acc. to no. from field map) 采用不同技术的土地编号	**Type of machinery** (code) 机器类型（编号）	**Provided by** (code) 提供者（编号）	**Time of usage** (in days/weeks) 使用时间（天/周）	**Only if machinery is provided by village community, co-operative or rented from private business:** 当机械是由村集体，合作组织提供或雇佣私人业主的情况下填写		
					Availability (code) 机械的可得性（编号）	**Is machine provided withoperator/driver?** (code) 提供机器者是否提供操作者或司机	**Payment of fee for use** (code) 使用的费用
Maize 玉米							
Wheat 小麦							
Vegetables 蔬菜							
Cotton 棉花							
Oil bearing crops 油料作物							
Peanut 花生							

(1) pick up/car 匹卡车(2) motorcycle 摩托车 (3) two-wheel tractor 两轮拖拉机 (4) three-wheel tractor 两轮拖拉机 (5) four wheel-tractor 两轮拖拉机 (6) oxen or other animals 牛或其它动物 (7) other 其它:	(1) Village Community 村集体(2) Co-operative 合作组织(3) rent from private business 从私人那里雇佣(4) own machinery 自己的机器	(1) always available 总是能得到(2) mostly available 大多时间可得 (3) seldom available 很少能得到(4) never available 得不到	(0) No 否 (1) Yes	(0) No payment of fee 不付费用 (1) Yes, If yes please indicate costs per day/week in ¥付费，请注明每周或每星期的具体费用



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3.1.4.2.1.1 Who selects and buys the pesticides (multiple answers possible)? □ farmer selects and buys, crops:______________ □ cooperative selects, but farmer buys crops: ____________ □ pesticides are provided by the co operative crops:_____________□ pesticides are provided by company, crops:______________

由谁选择和买杀虫剂（可多选）? □ 农民自己选择和购买，作物是:_____________□由合作组织选择，但由农民买，作物是: ____________ □杀虫剂由合作组织提供，作物是:____________ □杀虫剂由公司提供，作物是:______________

3.1.4.2.1.2 Who decides about the amounts and timing of pesticide application? □ farmer decides, crops:______________ □ co-operative decides, crops:______________ □ company decides, crops: ______________□ other: ____

由谁决定杀虫剂使用的数量和时间? □由农民自己决定，作物是:_____________ □由合作组织决定，作物是:_____________ 由农民自己决定，作物是: _____________其它: ____

3.1.4.2.1.3 According to what do you decide the amount of pesticides which you are applying? □ Price of pesticides □ quality of seed/crop variety □ quality of the soil □ advice from specialists □ instructions on pesticide package □ instructions on seed package □ market price of the crop

您是根据什么来决定你使用杀虫剂的数量的? □杀虫剂价格 □种子的性质或种类 □土地的等级 □专家的建议 □杀虫剂包装上的说明 □种子包装上的说明 □作物的市场价格

3.1.4.3 Are you supported by the village community/co-operative for the application of pesticides □ Yes (go to 3.1.4.3.1) □ No (go to 3.1.4.4)

您在使用杀虫剂时是否得到了村集体或合作组织的支持? □是(转向 3.1.4.3.1) □否，(转向 3.1.4.4)

3.1.4.3.1 Please describe how the village community/co-operative supports the application of pesticides： ___________________________

请描述村组织或合作社是怎样支持杀虫剂的使用的: ____

3.1.4.4 Are there any other costs related to the application of pesticides? □ Yes (go to 3.1.4.4.1) □ No (go to 3.1.5)

是否有其它与杀虫剂使用有关的成本? □是，(转向 3.1.4.4.1) □否，（转向 3.1.5）

3.1.4.4.1 Please state name and amount (in ¥)： ___________________________

请说出这些成本的名称和数量（元）: ____

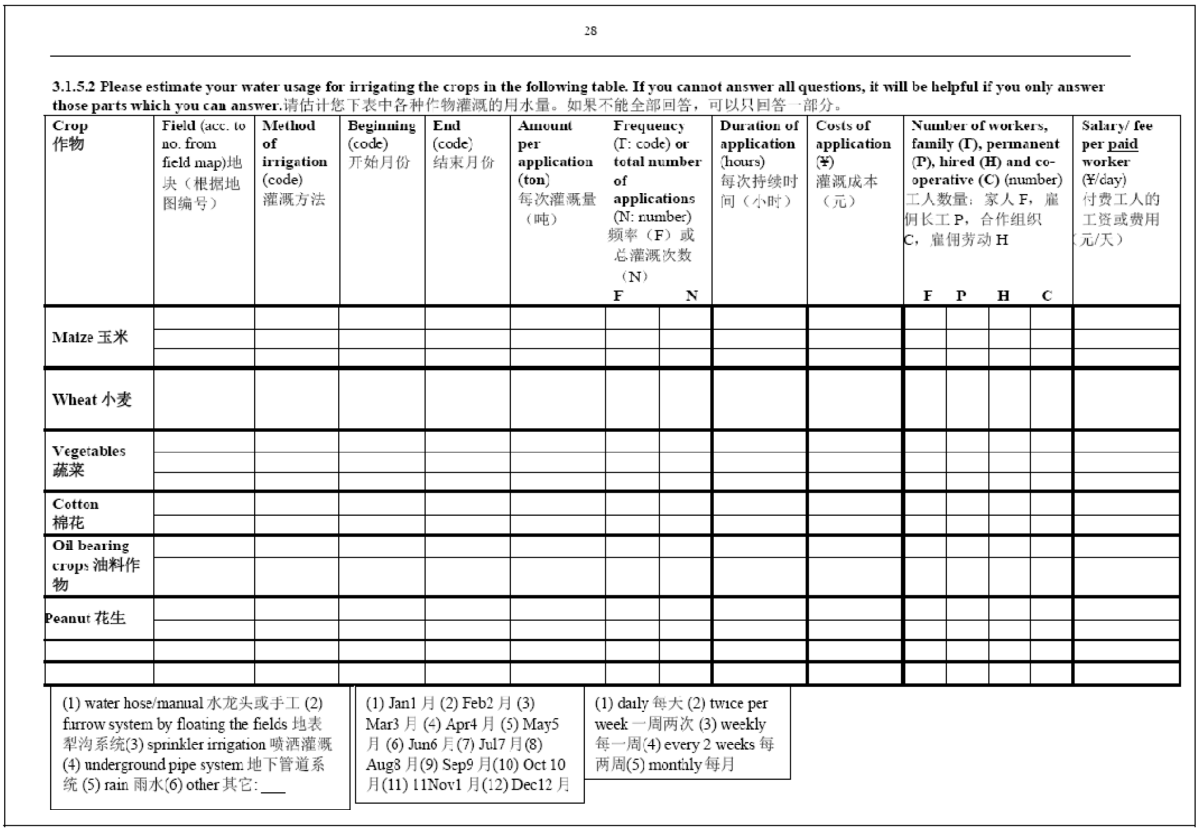
3.1.5 Irrigation 灌溉

3.1.5.1 Do you have to pay for the consumption of water for irrigation? □ Yes (go to 3.1.5.1.1)□ No (go to 3.1.5.2)

您必须为灌溉消费的用水量支付费用吗? □是(转向 3.1.5.1.1) □否，(转向 3.1.5.2)

3.1.5.1.1 Please state the price of water per ton or hour (¥): _______________________________________

请说明每吨水或每小时用水量的价格：_______________________________________



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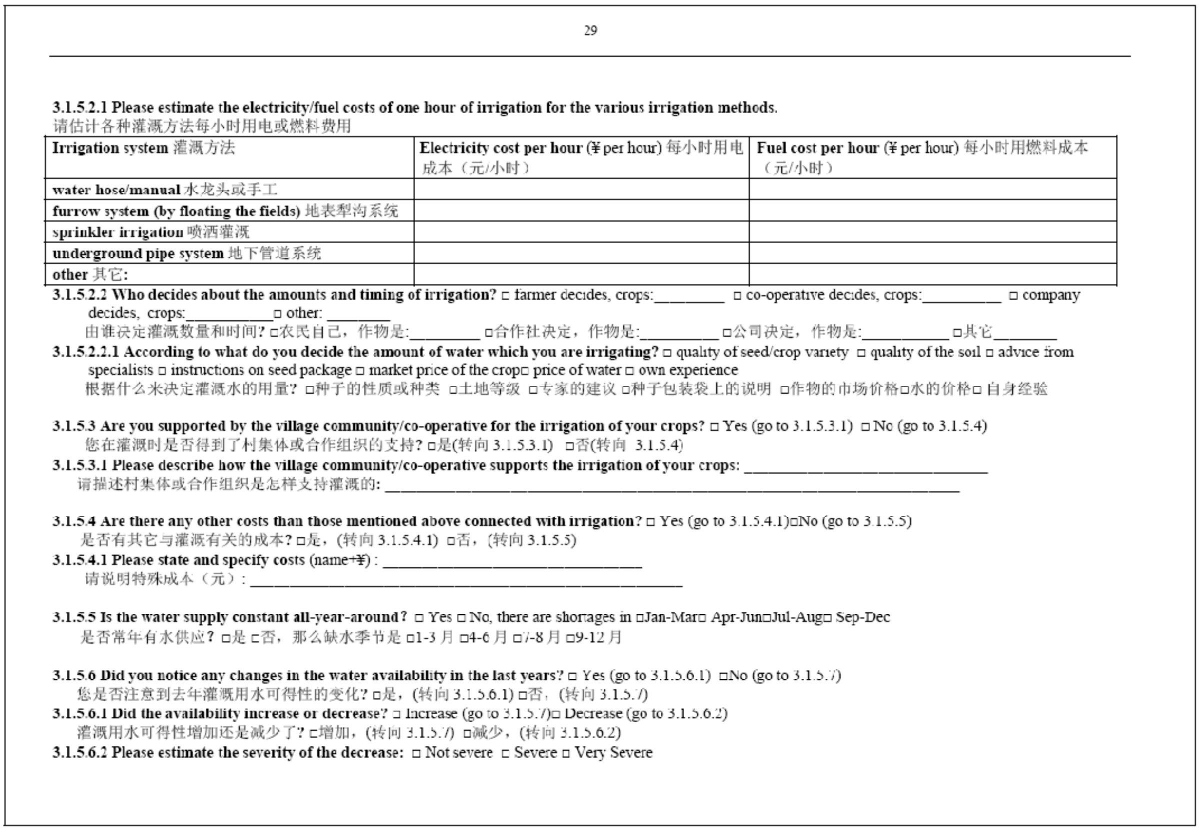
3.1.5.2 Please estimate your water usage for irrigating the crops in the following table. If you cannot answer all questions, it will be helpful if you only answer those parts which you can answer. 请估计您下表中各种作物灌溉的用水量。如果不能全部回答，可以只回答一部分。

Crop 作物	Field (acc. to no. from field map)地块（根据地图编号）	**Method of irrigation** (code) 灌溉方法	**Beginning** (code) 开始月份	**End** (code) 结束月份	**Amount per application (ton)** 每次灌溉量（吨）	**Frequency** (F: code) or **total number of applications** (N: number) 频率（F）或总灌溉次数（N）		**Duration of application** (hours) 每次持续时间（小时）	**Costs of application** (¥) 灌溉成本（元）	**Number of workers, family (F), permanent (P), hired (H) and co-operative (C) (number)** 工人数量：家人 F，雇佣长工 P，合作组织 C，雇佣劳动 H				**Salary/ fee per paid worker** (¥/day) 付费工人的工资或费用（元/天）
						F	**N**			**F**	**P**	**H**	**C**	
Maize 玉米														
Wheat 小麦														
Vegetables 蔬菜														
Cotton 棉花														
Oil bearing crops 油料作物														
Peanut 花生														

(1) water hose/manual 水龙头或手工 (2) furrow system by floating the fields 地表犁沟系统(3) sprinkler irrigation 喷洒灌溉 (4) underground pipe system 地下管道系统 (5) rain 雨水(6) other 其它: ___

(1) Jan1 月 (2) Feb2 月 (3) Mar3 月 (4) Apr4 月 (5) May5 月 (6) Jun6 月 (7) Jul7 月 (8) Aug8 月 (9) Sep9 月 (10) Oct 10 月 (11) 11Nov1 月 (12) Dec12 月

(1) daily 每天 (2) twice per week 一周两次 (3) weekly 每一周 (4) every 2 weeks 每两周 (5) monthly 每月



3.1.5.2.1 Please estimate the electricity/fuel costs of one hour of irrigation for the various irrigation methods.
请估计各种灌溉方法每小时用电或燃料费用

Irrigation system 灌溉方法	**Electricity cost per hour** (¥ per hour) 每小时用电成本（元/小时）	**Fuel cost per hour** (¥ per hour) 每小时用燃料成本（元/小时）
water hose/manual 水龙头或手工		
furrow system (by floating the fields) 地表犁沟系统		
sprinkler irrigation 喷洒灌溉		
underground pipe system 地下管道系统		
other 其它:		

3.1.5.2.2 Who decides about the amounts and timing of irrigation? □ farmer decides, crops:_________ □ co-operative decides, crops:__________ □ company decides, crops:___________□ other: ________
由谁决定灌溉数量和时间? □农民自己，作物是:_________ □合作社决定，作物是:__________ □公司决定，作物是:___________ □其它________

3.1.5.2.2.1 According to what do you decide the amount of water which you are irrigating? □ quality of seed/crop variety □ quality of the soil □ advice from specialists □ instructions on seed package □ market price of the crop□ price of water □ own experience
根据什么来决定灌溉水的用量? □种子的性质或种类 □土地等级 □专家的建议 □种子包装袋上的说明 □作物的市场价格□水的价格□ 自身经验

3.1.5.3 Are you supported by the village community/co-operative for the irrigation of your crops? □ Yes (go to 3.1.5.3.1) □ No (go to 3.1.5.4)
您在灌溉时是否得到了村集体或合作组织的支持? □是(转向 3.1.5.3.1) □否(转向 3.1.5.4)

3.1.5.3.1 Please describe how the village community/co-operative supports the irrigation of your crops: _______________________________
请描述村集体或合作组织是怎样支持灌溉的: ____

3.1.5.4 Are there any other costs than those mentioned above connected with irrigation? □ Yes (go to 3.1.5.4.1)□No (go to 3.1.5.5)
是否有其它与灌溉有关的成本? □是，(转向 3.1.5.4.1) □否，(转向 3.1.5.5)

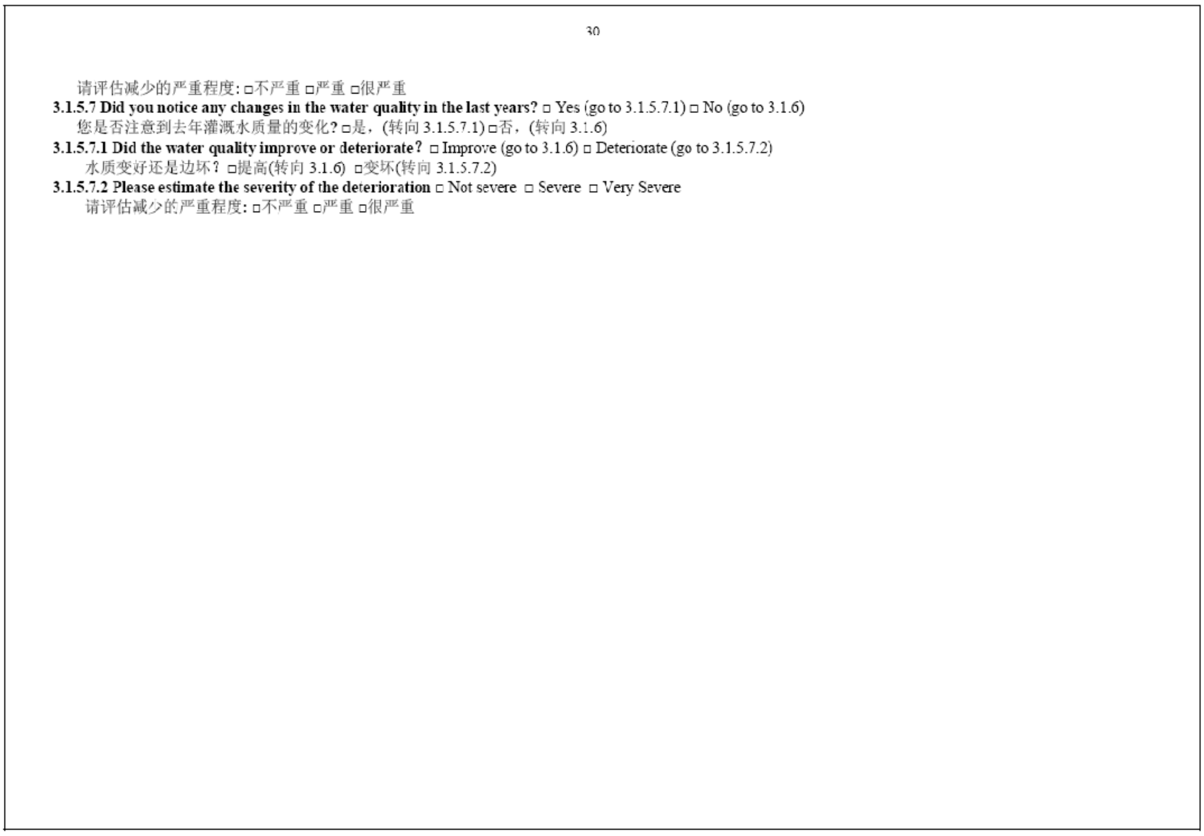
3.1.5.4.1 Please state and specify costs (name+¥) : _________________________________
请说明特殊成本（元）: ____

3.1.5.5 Is the water supply constant all-year-around? □ Yes □ No, there are shortages in □Jan-Mar□ Apr-Jun□Jul-Aug□ Sep-Dec
是否常年有水供应? □是 □否，那么缺水季节是 □1-3 月 □4-6 月 □7-8 月 □9-12 月

3.1.5.6 Did you notice any changes in the water availability in the last years? □ Yes (go to 3.1.5.6.1) □No (go to 3.1.5.7)
您是否注意到去年灌溉用水可得性的变化? □是，(转向 3.1.5.6.1) □否，(转向 3.1.5.7)

3.1.5.6.1 Did the availability increase or decrease? □ Increase (go to 3.1.5.7)□ Decrease (go to 3.1.5.6.2)
灌溉用水可得性增加还是减少了? □增加，(转向 3.1.5.7) □减少，(转向 3.1.5.6.2)

3.1.5.6.2 Please estimate the severity of the decrease: □ Not severe □ Severe □ Very Severe

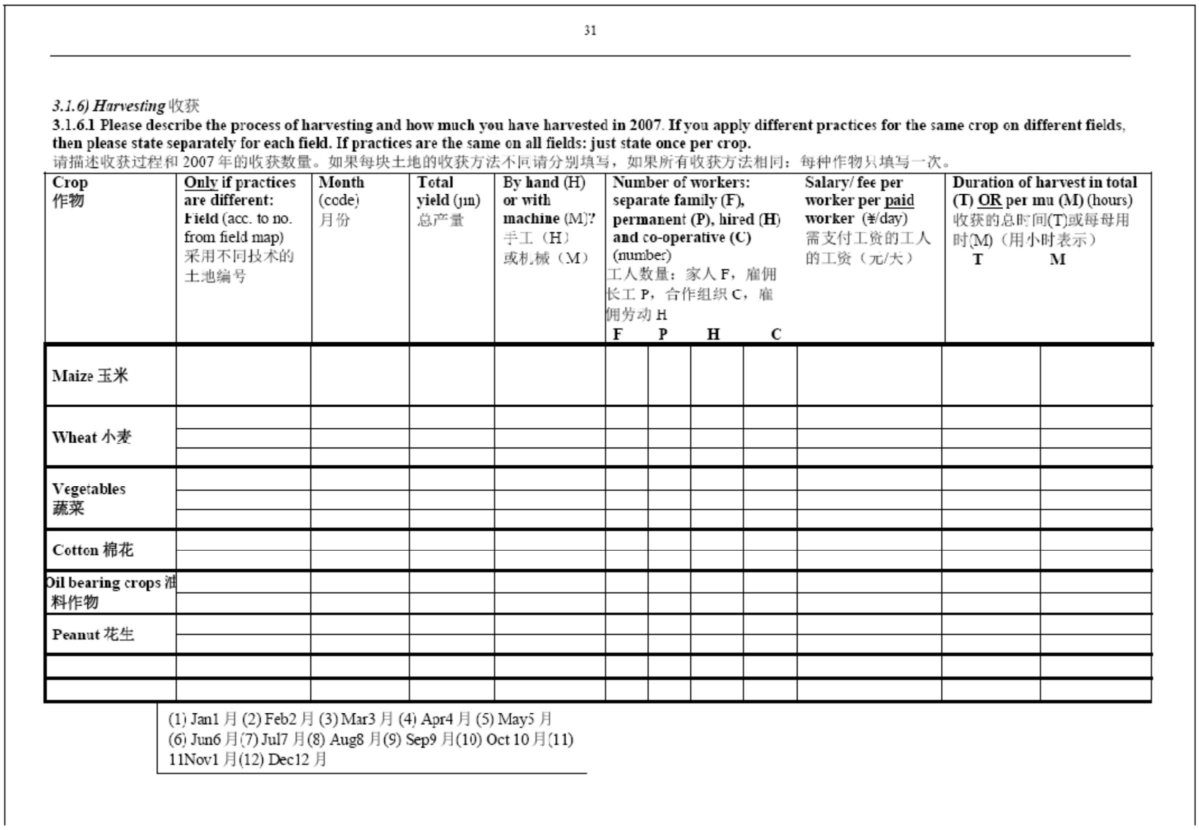


请评估减少的严重程度: □不严重 □严重 □很严重

3.1.5.7 Did you notice any changes in the water quality in the last years? □ Yes (go to 3.1.5.7.1) □ No (go to 3.1.6)
您是否注意到去年灌溉水质量的变化? □是，(转向 3.1.5.7.1) □否，(转向 3.1.6)

3.1.5.7.1 Did the water quality improve or deteriorate? □ Improve (go to 3.1.6) □ Deteriorate (go to 3.1.5.7.2)
水质变好还是边坏? □提高(转向 3.1.6) □变坏(转向 3.1.5.7.2)

3.1.5.7.2 Please estimate the severity of the deterioration □ Not severe □ Severe □ Very Severe
请评估减少的严重程度: □不严重 □严重 □很严重

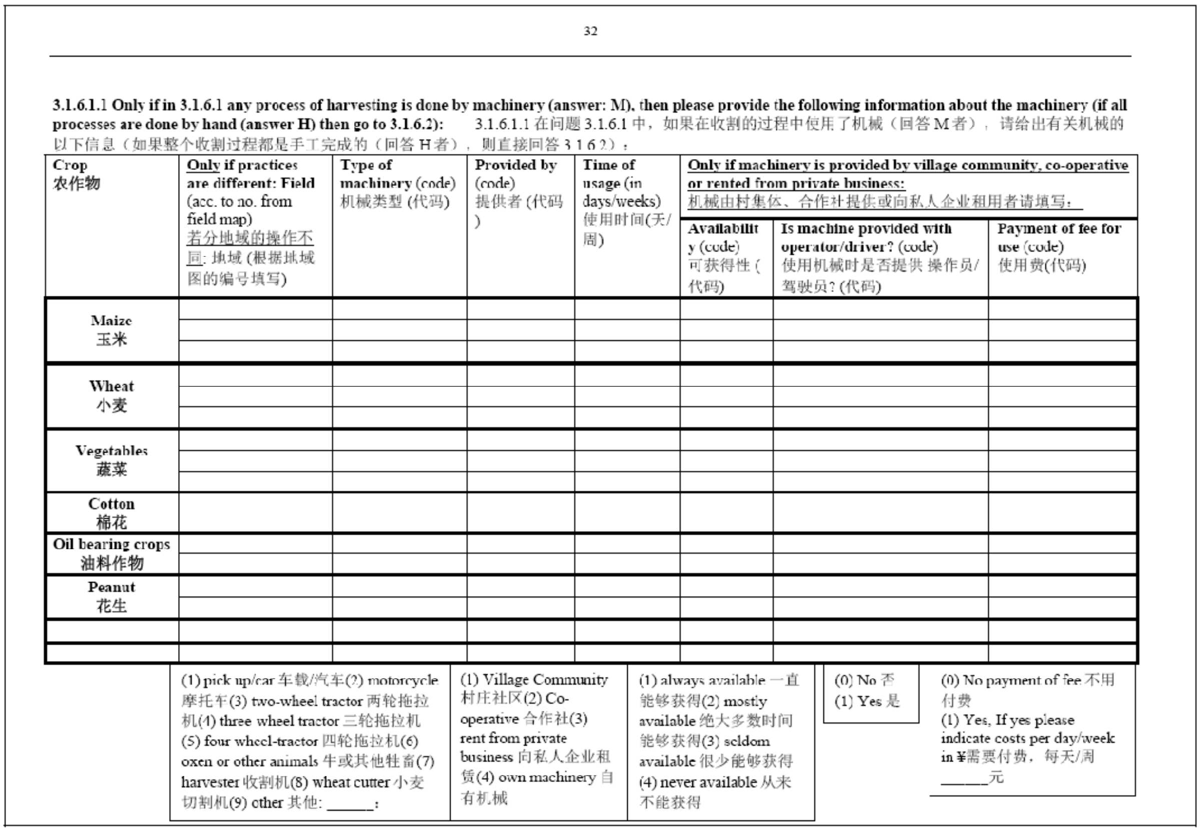


3.1.6) Harvesting 收获

3.1.6.1 Please describe the process of harvesting and how much you have harvested in 2007. If you apply different practices for the same crop on different fields, then please state separately for each field. If practices are the same on all fields: just state once per crop.
请描述收获过程和 2007 年的收获数量。如果每块土地的收获方法不同请分别填写，如果所有收获方法相同：每种作物只填写一次。

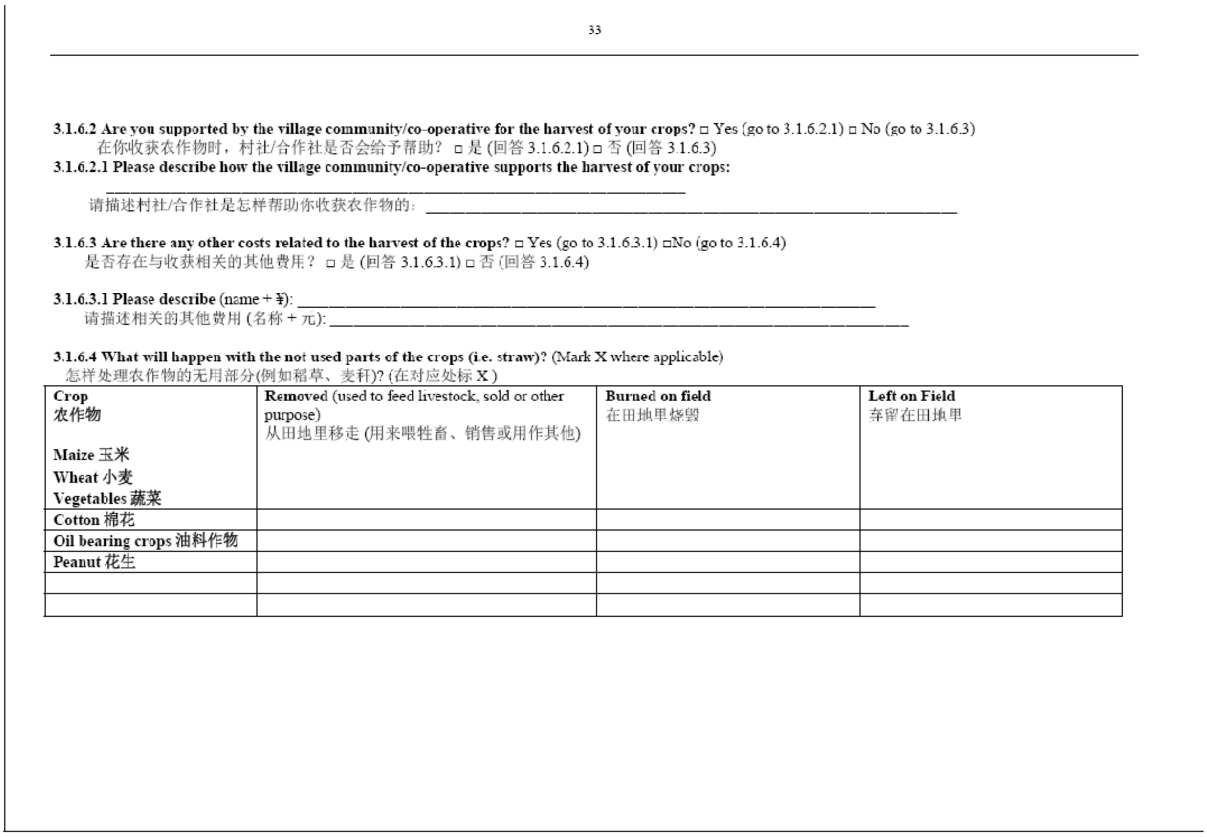
Crop 作物	**Only if practices are different: Field** (acc. to no. from field map) 采用不同技术的土地编号	**Month** (code) 月份	**Total yield** (jin) 总产量	**By hand (H) or with machine** (M)? 手工（H）或机械（M）	**Number of workers: separate family (F), permanent (P), hired (H) and co-operative (C)** (number) 工人数量：家人 F，雇佣长工 P，合作组织 C，雇佣劳动 H				**Salary/ fee per worker per paid worker** (¥/day) 需支付工资的工人的工资（元/天）	**Duration of harvest in total (T) OR per mu (M) (hours)** 收获的总时间(T)或每亩用时(M)（用小时表示）	
					F	**P**	**H**	**C**		**T**	**M**
Maize 玉米											
Wheat 小麦											
Vegetables 蔬菜											
Cotton 棉花											
Oil bearing crops 油料作物											
Peanut 花生											

(1) Jan1 月 (2) Feb2 月 (3) Mar3 月 (4) Apr4 月 (5) May5 月 (6) Jun6 月(7) Jul7 月(8) Aug8 月(9) Sep9 月(10) Oct 10 月(11) 11Nov1 月(12) Dec12 月



3.1.6.1.1 Only if in 3.1.6.1 any process of harvesting is done by machinery (answer: M), then please provide the following information about the machinery (if all processes are done by hand (answer H) then go to 3.1.6.2): 3.1.6.1.1 在问题 3.1.6.1 中，如果在收割的过程中使用了机械（回答 M 者），请给出有关机械的以下信息（如果整个收割过程都是手工完成的（回答 H 者），则直接回答 3.1.6.2）：

Crop 农作物	**Only if practices are different: Field** (acc. to no. from field map) 若分地域的操作不同: 地域 (根据地域图的编号填写)	**Type of machinery** (code) 机械类型 (代码)	**Provided by** (code) 提供者 (代码)	**Time of usage** (in days/weeks) 使用时间(天/周)	**Only if machinery is provided by village community, co-operative or rented from private business:** 机械由村集体、合作社提供或向私人企业租用者请填写：		
					Availability (code) 可获得性 (代码)	**Is machine provided with operator/driver?** (code) 使用机械时是否提供 操作员/驾驶员? (代码)	**Payment of fee for use** (code) 使用费(代码)
Maize 玉米							
Wheat 小麦							
Vegetables 蔬菜							
Cotton 棉花							
Oil bearing crops 油料作物							
Peanut 花生							
		(1) pick up/car 车载/汽车(2) motorcycle 摩托车(3) two-wheel tractor 两轮拖拉机(4) three wheel tractor 三轮拖拉机(5) four wheel-tractor 四轮拖拉机(6) oxen or other animals 牛或其他牲畜(7) harvester 收割机(8) wheat cutter 小麦切割机(9) other 其他: ______:	(1) Village Community 村庄社区(2) Co-operative 合作社(3) rent from private business 向私人企业租赁(4) own machinery 自有机械		(1) always available 一直能够获得(2) mostly available 绝大多数时间能够获得(3) seldom available 很少能够获得(4) never available 从来不能获得	(0) No 否 (1) Yes 是	(0) No payment of fee 不用付费 (1) Yes, If yes please indicate costs per day/week in ¥需要付费，每天/周 ______元



3.1.6.2 Are you supported by the village community/co-operative for the harvest of your crops? □ Yes (go to 3.1.6.2.1) □ No (go to 3.1.6.3)
在你收获农作物时，村社/合作社是否会给予帮助？ □ 是 (回答 3.1.6.2.1) □ 否 (回答 3.1.6.3)

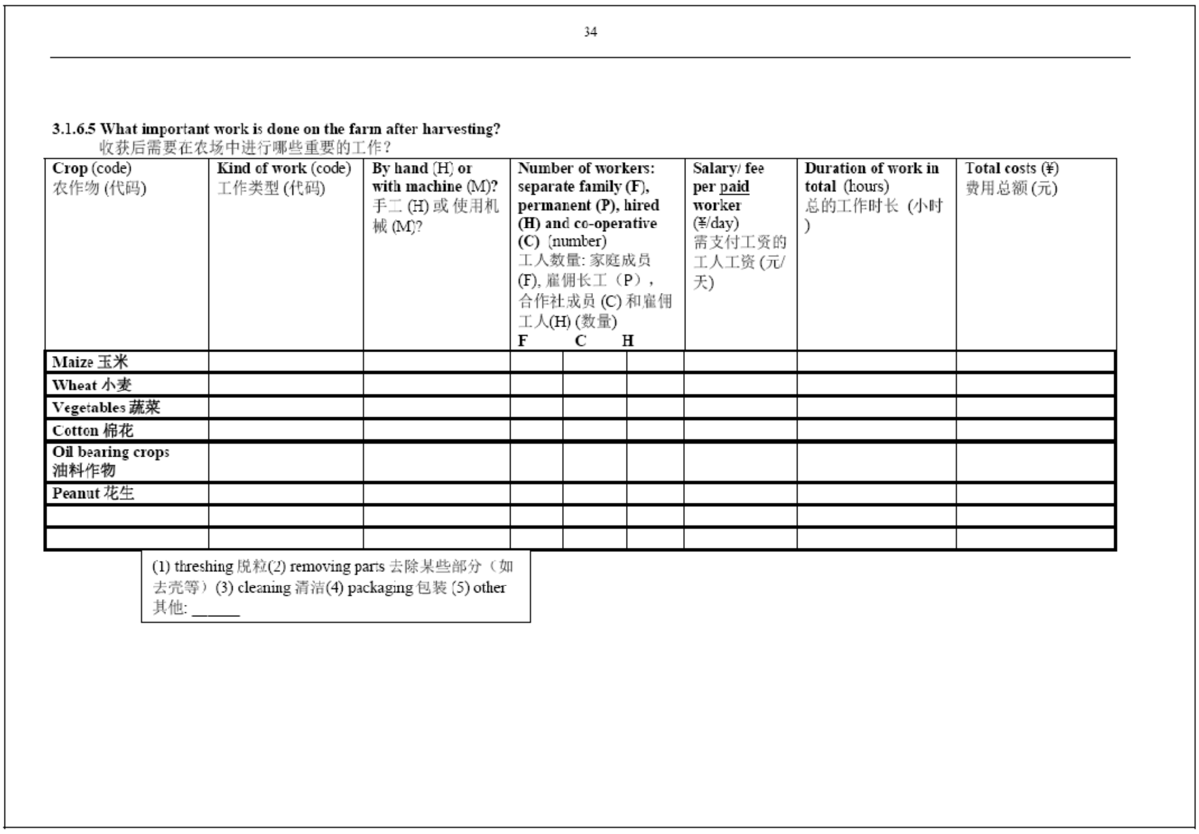
3.1.6.2.1 Please describe how the village community/co-operative supports the harvest of your crops:
____
请描述村社/合作社是怎样帮助你收获农作物的：____

3.1.6.3 Are there any other costs related to the harvest of the crops? □ Yes (go to 3.1.6.3.1) □No (go to 3.1.6.4)
是否存在与收获相关的其他费用？ □ 是 (回答 3.1.6.3.1) □ 否 (回答 3.1.6.4)

3.1.6.3.1 Please describe (name + ¥): ____
请描述相关的其他费用 (名称 + 元): ____

3.1.6.4 What will happen with the not used parts of the crops (i.e. straw)? (Mark X where applicable)
怎样处理农作物的无用部分(例如稻草、麦秆)? (在对应处标 X)

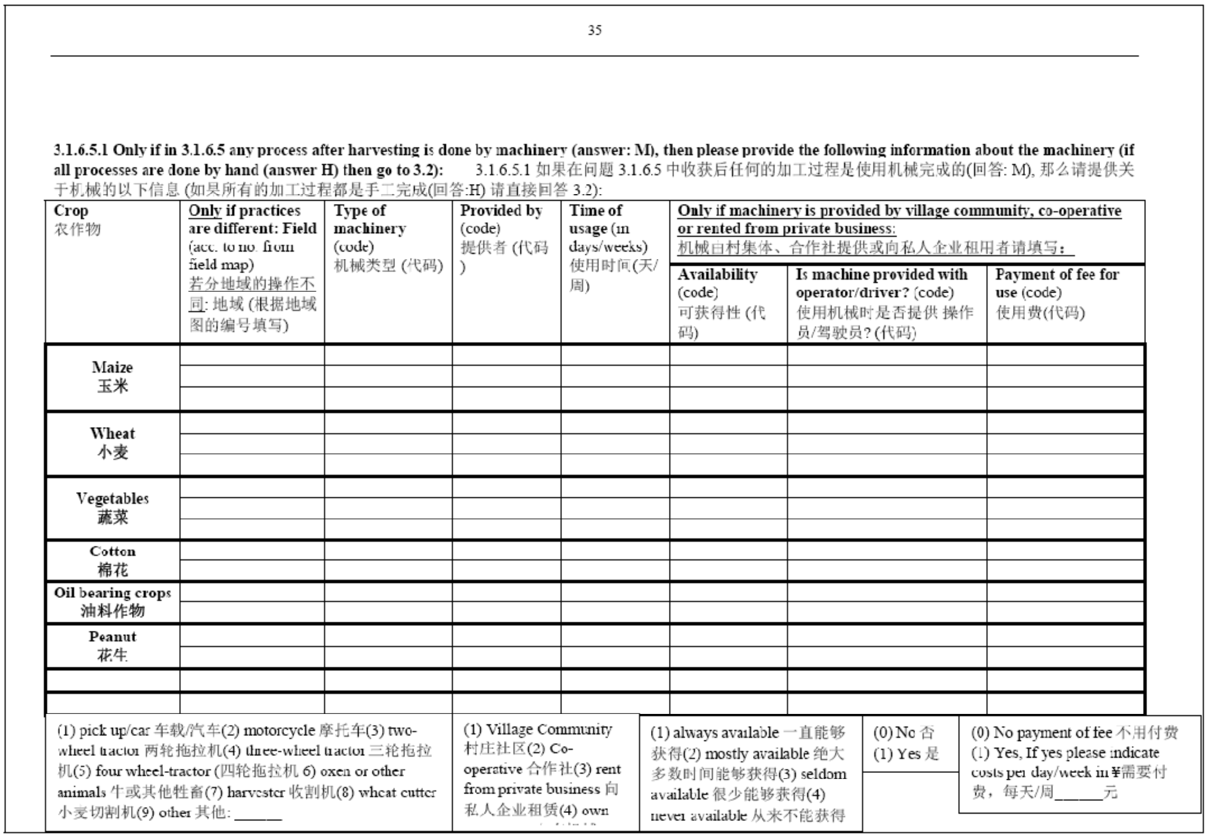
Crop **农作物**	**Removed** (used to feed livestock, sold or other purpose) 从田地里移走 (用来喂牲畜、销售或用作其他)	**Burned on field** 在田地里焚毁	**Left on Field** 弃留在田地里
Maize 玉米 **Wheat 小麦** **Vegetables 蔬菜**			
Cotton 棉花			
Oil bearing crops 油料作物			
Peanut 花生			



3.1.6.5 What important work is done on the farm after harvesting?
收获后需要在农场中进行哪些重要的工作？

Crop (code) 农作物 (代码)	**Kind of work** (code) 工作类型 (代码)	**By hand** (H) **or with machine** (M)? 手工 (H) 或 使用机械 (M)?	**Number of workers: separate family (F), permanent (P), hired (H) and co-operative (C)** (number) 工人数量: 家庭成员 (F), 雇佣长工（P），合作社成员 (C) 和雇佣工人(H) (数量)			**Salary/ fee per paid worker** (¥/day) 需支付工资的工人工资 (元/天)	**Duration of work in total** (hours) 总的工作时长 (小时)	Total costs (¥) 费用总额 (元)
			F	**C**	**H**			
Maize 玉米								
Wheat 小麦								
Vegetables 蔬菜								
Cotton 棉花								
Oil bearing crops 油料作物								
Peanut 花生								

(1) threshing 脱粒(2) removing parts 去除某些部分（如去壳等）(3) cleaning 清洁(4) packaging 包装 (5) other 其他: ______



3.1.6.5.1 Only if in 3.1.6.5 any process after harvesting is done by machinery (answer: M), then please provide the following information about the machinery (if all processes are done by hand (answer H) then go to 3.2): 3.1.6.5.1 如果在问题 3.1.6.5 中收获后任何的加工过程是使用机械完成的(回答: M), 那么请提供关于机械的以下信息 (如果所有的加工过程都是手工完成(回答:H) 请直接回答 3.2):

Crop 农作物	**Only if practices are different: Field** (acc. to no. from field map) 若分地域的操作不同: 地域 (根据地域图的编号填写)	**Type of machinery** (code) 机械类型 (代码)	**Provided by** (code) 提供者 (代码)	**Time of usage** (in days/weeks) 使用时间(天/周)	**Only if machinery is provided by village community, co-operative or rented from private business:** 机械由村集体、合作社提供或向私人企业租用者请填写：		
					Availability (code) 可获得性 (代码)	**Is machine provided with operator/driver?** (code) 使用机械时是否提供 操作员/驾驶员? (代码)	**Payment of fee for use** (code) 使用费(代码)
Maize **玉米**							
Wheat **小麦**							
Vegetables **蔬菜**							
Cotton **棉花**							
Oil bearing crops **油料作物**							
Peanut **花生**							

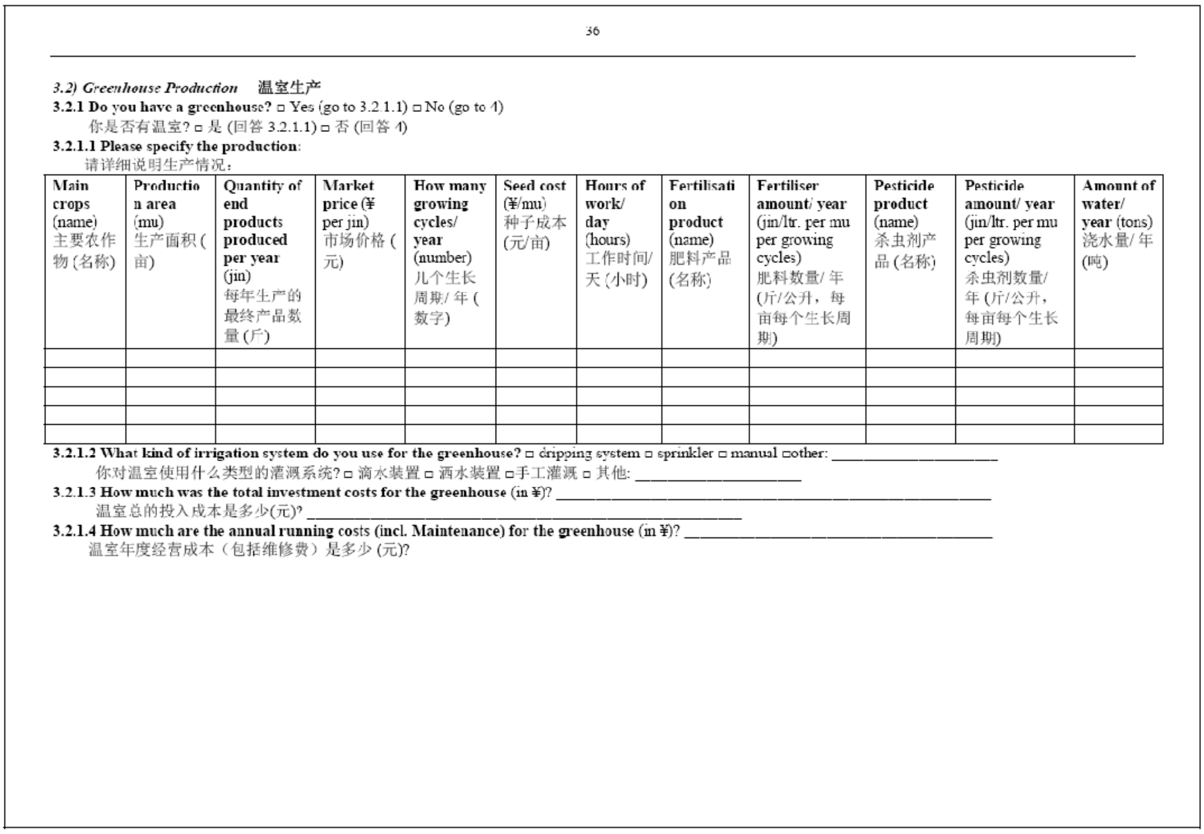
(1) pick up/car 车载/汽车(2) motorcycle 摩托车(3) two-wheel tractor 两轮拖拉机(4) three-wheel tractor 三轮拖拉机(5) four wheel-tractor (四轮拖拉机 6) oxen or other animals 牛或其他牲畜(7) harvester 收割机(8) wheat cutter 小麦切割机(9) other 其他: ______

(1) Village Community 村庄社区(2) Co-operative 合作社(3) rent from private business 向私人企业租赁(4) own

(1) always available 一直能够获得(2) mostly available 绝大多数时间能够获得(3) seldom available 很少能够获得(4) never available 从来不能获得

(0) No 否
(1) Yes 是

(0) No payment of fee 不用付费
(1) Yes, If yes please indicate costs per day/week in ¥需要付费，每天/周______元



3.2) Greenhouse Production 温室生产

3.2.1 Do you have a greenhouse? □ Yes (go to 3.2.1.1) □ No (go to 4)
你是否有温室? □ 是 (回答 3.2.1.1) □ 否 (回答 4)

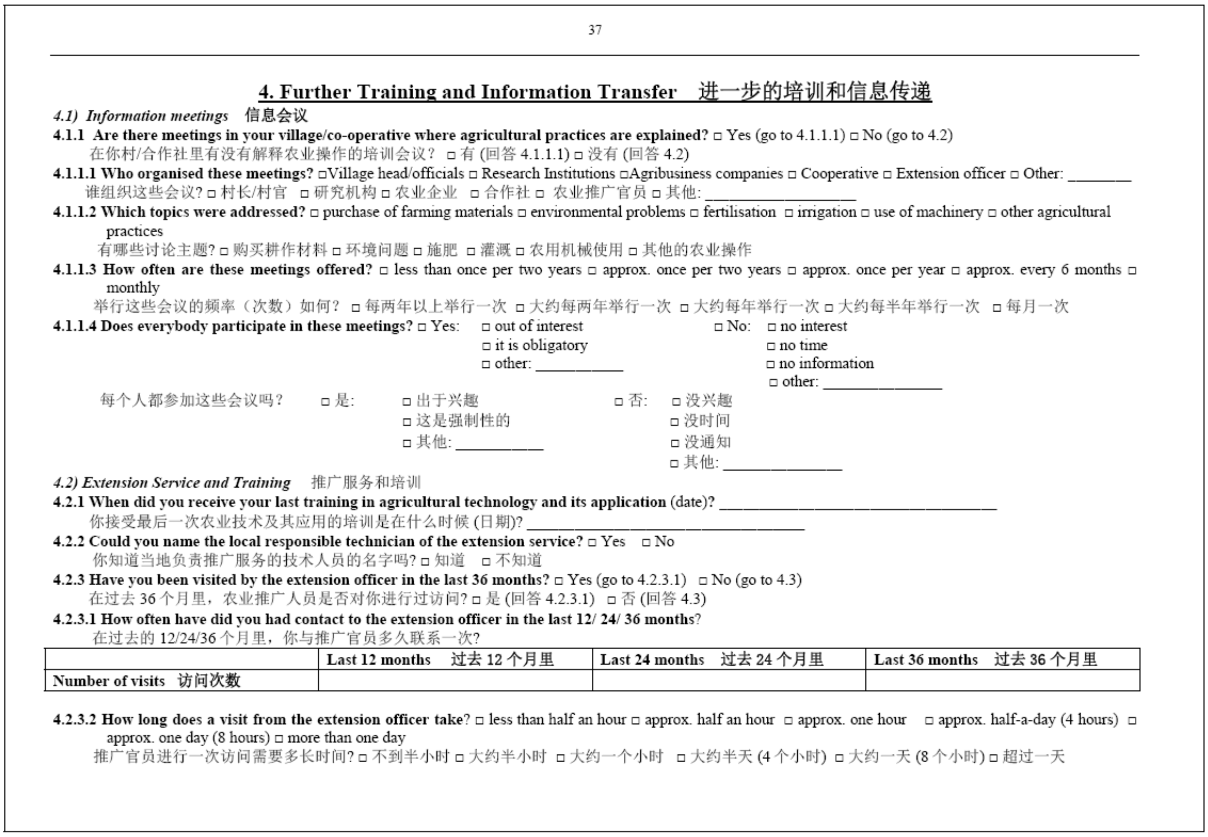
3.2.1.1 Please specify the production:
请详细说明生产情况：

Main crops (name) 主要农作物 (名称)	**Production area** (mu) 生产面积 (亩)	**Quantity of end products produced per year** (jin) 每年生产的最终产品数量 (斤)	**Market price (¥ per jin)** 市场价格 (元)	**How many growing cycles/ year** (number) 几个生长周期/ 年 (数字)	**Seed cost** (¥/mu) 种子成本 (元/亩)	**Hours of work/ day** (hours) 工作时间/天 (小时)	**Fertilisation product** (name) 肥料产品 (名称)	**Fertiliser amount/ year** (jin/ltr. per mu per growing cycles) 肥料数量/ 年 (斤/公升，每亩每个生长周期)	**Pesticide product** (name) 杀虫剂产品 (名称)	**Pesticide amount/ year** (jin/ltr. per mu per growing cycles) 杀虫剂数量/ 年 (斤/公升，每亩每个生长周期)	**Amount of water/ year** (tons) 浇水量/ 年 (吨)

3.2.1.2 What kind of irrigation system do you use for the greenhouse? □ dripping system □ sprinkler □ manual □other: ____________________
你对温室使用什么类型的灌溉系统? □ 滴水装置 □ 洒水装置 □手工灌溉 □ 其他: ____________________

3.2.1.3 How much was the total investment costs for the greenhouse (in ¥)? ____
温室总的投入成本是多少(元)? ____

3.2.1.4 How much are the annual running costs (incl. Maintenance) for the greenhouse (in ¥)? ____________________________________
温室年度经营成本（包括维修费）是多少 (元)?



4. Further Training and Information Transfer 进一步的培训和信息传递

4.1) Information meetings 信息会议

4.1.1 Are there meetings in your village/co-operative where agricultural practices are explained? □ Yes (go to 4.1.1.1) □ No (go to 4.2)
在你村/合作社里有没有解释农业操作的培训会议？ □ 有 (回答 4.1.1.1) □ 没有 (回答 4.2)

4.1.1.1 Who organised these meetings? □Village head/officials □ Research Institutions □Agribusiness companies □ Cooperative □ Extension officer □ Other: ________
谁组织这些会议? □ 村长/村官 □ 研究机构 □ 农业企业 □ 合作社 □ 农业推广官员 □ 其他: ____________________

4.1.1.2 Which topics were addressed? □ purchase of farming materials □ environmental problems □ fertilisation □ irrigation □ use of machinery □ other agricultural practices
有哪些讨论主题? □ 购买耕作材料 □ 环境问题 □ 施肥 □ 灌溉 □ 农用机械使用 □ 其他的农业操作

4.1.1.3 How often are these meetings offered? □ less than once per two years □ approx. once per two years □ approx. once per year □ approx. every 6 months □ monthly
举行这些会议的频率（次数）如何？ □ 每两年以上举行一次 □ 大约每两年举行一次 □ 大约每年举行一次 □ 大约每半年举行一次 □ 每月一次

4.1.1.4 Does everybody participate in these meetings? □ Yes: □ out of interest
□ it is obligatory
□ other: ___________
□ No: □ no interest
□ no time
□ no information
□ other: _______________

每个人都参加这些会议吗？ □ 是: □ 出于兴趣
□ 这是强制性的
□ 其他: ___________
□ 否: □ 没兴趣
□ 没时间
□ 没通知
□ 其他: _______________

4.2) Extension Service and Training 推广服务和培训

4.2.1 When did you receive your last training in agricultural technology and its application (date)? ____________________________________
你接受最后一次农业技术及其应用的培训是在什么时候 (日期)? ____________________________________

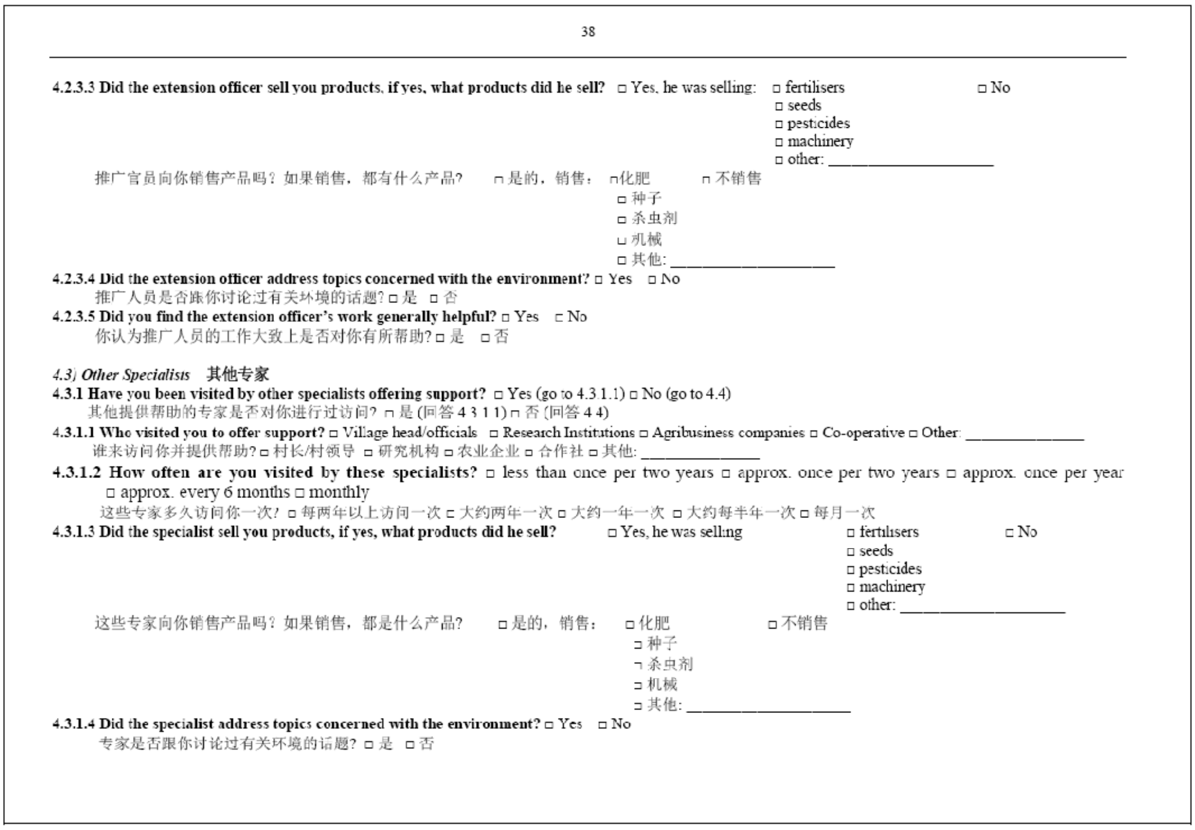
4.2.2 Could you name the local responsible technician of the extension service? □ Yes □ No
你知道当地负责推广服务的技术人员的名字吗? □ 知道 □ 不知道

4.2.3 Have you been visited by the extension officer in the last 36 months? □ Yes (go to 4.2.3.1) □ No (go to 4.3)
在过去 36 个月里，农业推广人员是否对你进行过访问? □ 是 (回答 4.2.3.1) □ 否 (回答 4.3)

4.2.3.1 How often have did you had contact to the extension officer in the last 12/ 24/ 36 months?
在过去的 12/24/36 个月里，你与推广官员多久联系一次?

	Last 12 months 过去 12 个月里	**Last 24 months 过去 24 个月里**	**Last 36 months 过去 36 个月里**
Number of visits 访问次数			

4.2.3.2 How long does a visit from the extension officer take? □ less than half an hour □ approx. half an hour □ approx. one hour □ approx. half-a-day (4 hours) □ approx. one day (8 hours) □ more than one day
推广官员进行一次访问需要多长时间? □ 不到半小时 □ 大约半小时 □ 大约一个小时 □ 大约半天 (4 个小时) □ 大约一天 (8 个小时) □ 超过一天



4.2.3.3 Did the extension officer sell you products, if yes, what products did he sell? □ Yes, he was selling: □ fertilisers
□ seeds
□ pesticides
□ machinery
□ other: ______________________
□ No

推广官员向你销售产品吗？如果销售，都有什么产品? □ 是的，销售： □化肥
□ 种子
□ 杀虫剂
□ 机械
□ 其他: ______________________
□ 不销售

4.2.3.4 Did the extension officer address topics concerned with the environment? □ Yes □ No
推广人员是否跟你讨论过有关环境的话题? □ 是 □ 否

4.2.3.5 Did you find the extension officer's work generally helpful? □ Yes □ No
你认为推广人员的工作大致上是否对你有所帮助? □ 是 □ 否

4.3) Other Specialists 其他专家

4.3.1 Have you been visited by other specialists offering support? □ Yes (go to 4.3.1.1) □ No (go to 4.4)
其他提供帮助的专家是否对你进行过访问? □ 是 (回答 4.3.1.1) □ 否 (回答 4.4)

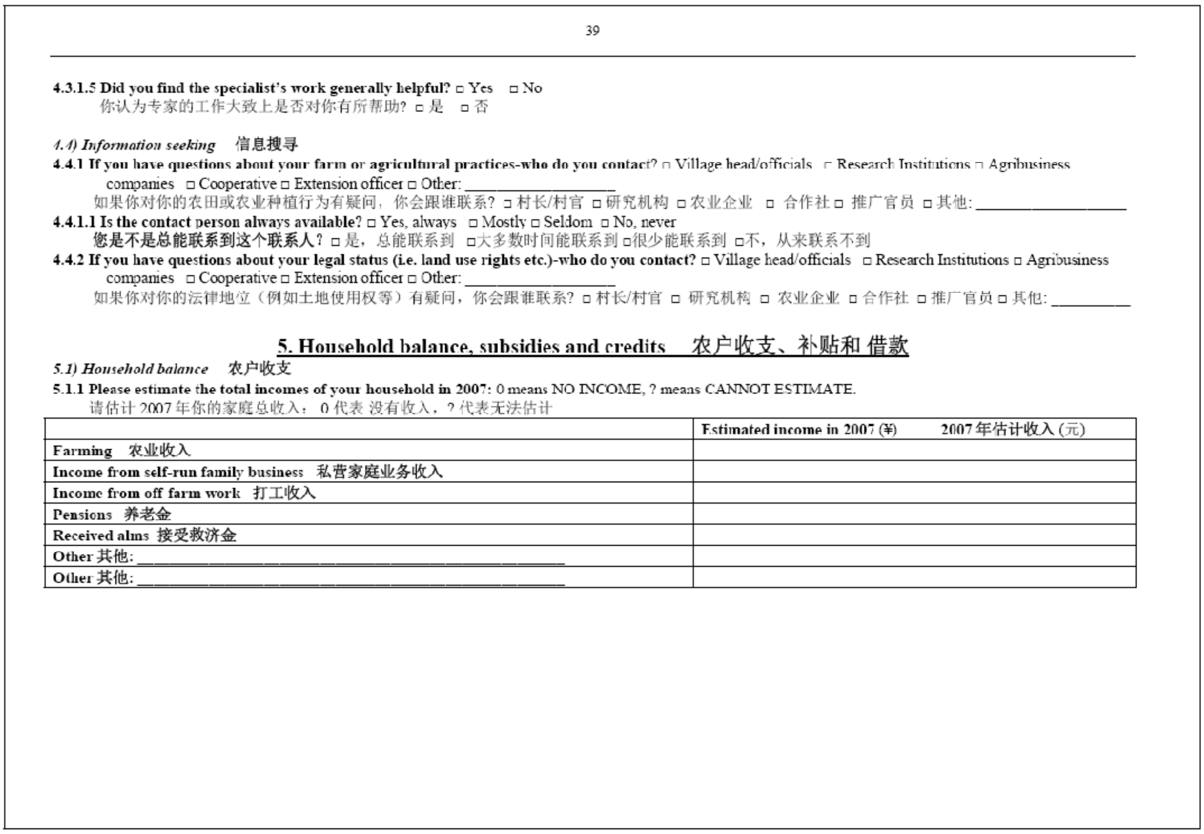
4.3.1.1 Who visited you to offer support? □ Village head/officials □ Research Institutions □ Agribusiness companies □ Co-operative □ Other: _______________
谁来访问你并提供帮助? □ 村长/村领导 □ 研究机构 □ 农业企业 □ 合作社 □ 其他: _______________

4.3.1.2 How often are you visited by these specialists? □ less than once per two years □ approx. once per two years □ approx. once per year □ approx. every 6 months □ monthly
这些专家多久访问你一次? □ 每两年以上访问一次 □ 大约两年一次 □ 大约一年一次 □ 大约每半年一次 □ 每月一次

4.3.1.3 Did the specialist sell you products, if yes, what products did he sell? □ Yes, he was selling □ fertilisers
□ seeds
□ pesticides
□ machinery
□ other: ______________________
□ No

这些专家向你销售产品吗？如果销售，都是什么产品? □ 是的，销售： □ 化肥
□ 种子
□ 杀虫剂
□ 机械
□ 其他: ______________________
□ 不销售

4.3.1.4 Did the specialist address topics concerned with the environment? □ Yes □ No
专家是否跟你讨论过有关环境的话题? □ 是 □ 否



4.3.1.5 Did you find the specialist's work generally helpful? □ Yes □ No
你认为专家的工作大致上是否对你有所帮助? □ 是 □ 否

4.4) Information seeking 信息搜寻

4.4.1 If you have questions about your farm or agricultural practices-who do you contact? □ Village head/officials □ Research Institutions □ Agribusiness companies □ Cooperative □ Extension officer □ Other: ____________________
如果你对你的农田或农业种植行为有疑问，你会跟谁联系? □ 村长/村官 □ 研究机构 □ 农业企业 □ 合作社 □ 推广官员 □ 其他: ____________________

4.4.1.1 Is the contact person always available? □ Yes, always □ Mostly □ Seldom □ No, never
您是不是总能联系到这个联系人? □ 是，总能联系到 □大多数时间能联系到 □很少能联系到 □不，从来联系不到

4.4.2 If you have questions about your legal status (i.e. land use rights etc.)-who do you contact? □ Village head/officials □ Research Institutions □ Agribusiness companies □ Cooperative □ Extension officer □ Other: ____________________
如果你对你的法律地位（例如土地使用权等）有疑问，你会跟谁联系? □ 村长/村官 □ 研究机构 □ 农业企业 □ 合作社 □ 推广官员 □ 其他: __________

5. Household balance, subsidies and credits 农户收支、补贴和 借款

5.1) Household balance 农户收支

5.1.1 Please estimate the total incomes of your household in 2007: 0 means NO INCOME, ? means CANNOT ESTIMATE.
请估计 2007 年你的家庭总收入： 0 代表 没有收入，? 代表无法估计

	Estimated income in 2007 (¥) 2007 年估计收入 (元)
Farming 农业收入	
Income from self-run family business 私营家庭业务收入	
Income from off farm work 打工收入	
Pensions 养老金	
Received alms 接受救济金	
Other 其他: ______________________________	
Other 其他: ______________________________	

5.1.2 Please estimate the total expenditures of your household in 2007: 0 means NO EXPENDITURE, ? means CANNOT ESTIMATE.
请估计 2007 年你的家庭总支出：0 代表没有支出，? 代表无法估计.

	Estimated expenditure in 2007 (¥) 2007 年估计支出 (元)
Farm production expenditures 农业生产支出	
Expenditure for self-run family business 私营家庭业务支出	
Fees for education 教育费用	
Medical expenditure 医疗费用	
Marriages and funerals 婚葬费用	
Food expenses (home and away) 食物开支 (在家吃与外出就餐)	
Transport and communication 交通与通讯费	
Other 其他: ______________________________	

5.2) Subsidies and Taxes 补贴和税收

5.2.1 Which taxes and fees did the household pay in 2007?
2007 年家庭交了哪几种税费?

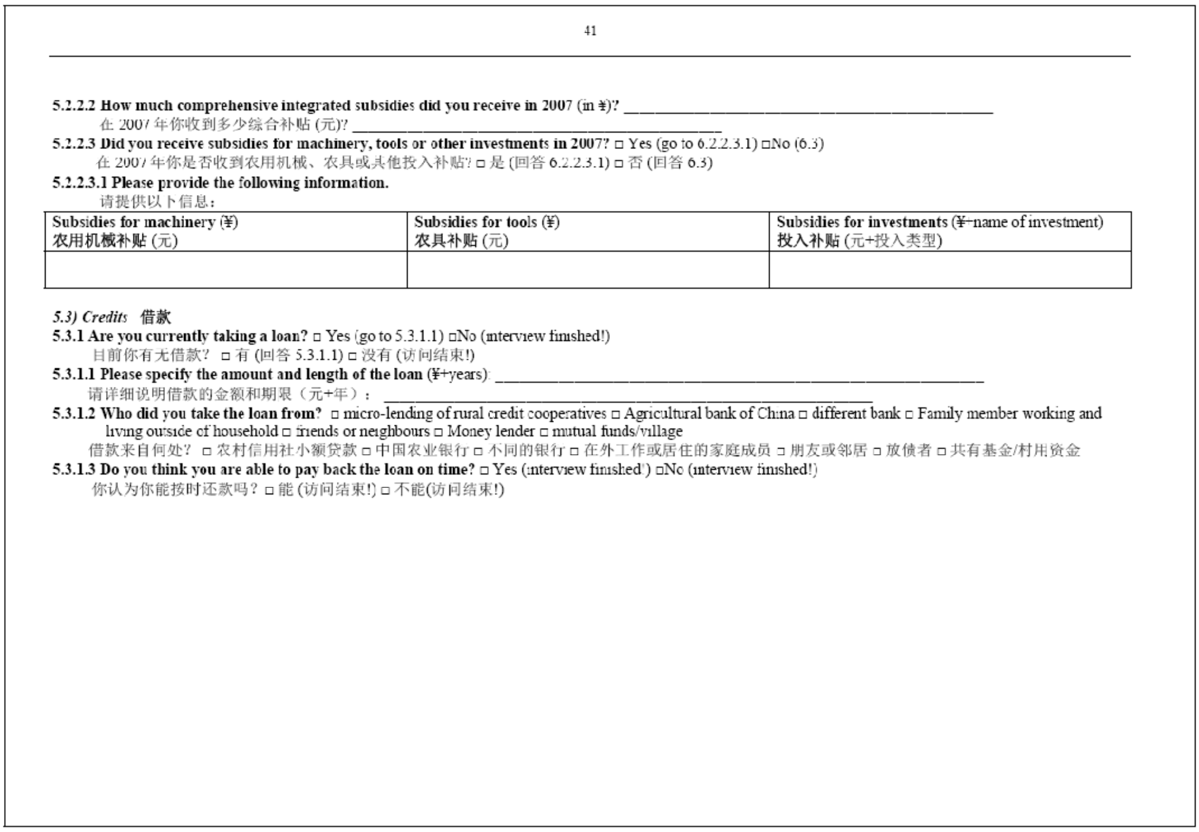
Agricultural tax (¥) **农业税** (元)	**Special product tax (¥)** **农业特产税** (元)	**Fees for collective purpose (¥)** **村集体费用（村提留）**(元)	**Community work** (total days for household) **社区劳动** (家庭总天数)

5.2.2 Did you receive subsidies in 2007? □ Yes (go to 5.2.2.1) □No (go to 5.3)
2007 年你是否得到过补贴? □ 是 (回答 5.2.2.1) □否 (回答 5.3)

5.2.2.1 Please provide the following information about direct subsidies for grains which you received in 2007.
请提供你在 2007 年收到的谷物直接补贴的以下信息：

Crop 农作物	**Area or amount** (mu or jin) 面积或数量(亩或斤)	**Amount** (¥) 金额(元)	**Time** (code) 时间 (代码)
Wheat 小麦			
Maize 玉米			
Rice 水稻			
Soy bean 大豆			
Cotton 棉花			
Other 其他			

(1) at harvesting 收获期 (2) at sowing 播种期 (3) other time 其他时间



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5.2.2.2 How much comprehensive integrated subsidies did you receive in 2007 (in ¥)? ____________________

在 2007 年你收到多少综合补贴 (元)? ____________________

5.2.2.3 Did you receive subsidies for machinery, tools or other investments in 2007? □ Yes (go to 6.2.2.3.1) □No (6.3)

在 2007 年你是否收到农用机械、农具或其他投入补贴? □ 是 (回答 6.2.2.3.1) □ 否 (回答 6.3)

5.2.2.3.1 Please provide the following information.

请提供以下信息：

Subsidies for machinery (¥) **农用机械补贴** (元)	**Subsidies for tools** (¥) **农具补贴** (元)	**Subsidies for investments** (¥+name of investment) **投入补贴** (元+投入类型)

***5.3) Credits* 借款**

5.3.1 Are you currently taking a loan? □ Yes (go to 5.3.1.1) □No (interview finished!)

目前你有无借款？ □ 有 (回答 5.3.1.1) □ 没有 (访问结束!)

5.3.1.1 Please specify the amount and length of the loan (¥+years): ____________________

请详细说明借款的金额和期限（元+年）： ____________________

5.3.1.2 Who did you take the loan from? □ micro-lending of rural credit cooperatives □ Agricultural bank of China □ different bank □ Family member working and living outside of household □ friends or neighbours □ Money lender □ mutual funds/village

借款来自何处？ □ 农村信用社小额贷款 □ 中国农业银行 □ 不同的银行 □ 在外工作或居住的家庭成员 □ 朋友或邻居 □ 放债者 □ 共有基金/村用资金

5.3.1.3 Do you think you are able to pay back the loan on time? □ Yes (interview finished!) □No (interview finished!)

你认为你能按时还款吗？□ 能 (访问结束!) □ 不能(访问结束!)

Annex 4. Project Introduction for Participants of Survey

Dear participant,

被访者您好!

thank you for participating in our research project. We are evaluating environmental effects of farming in Hebei province. Our focus lies on farmers, like you, who are producing winter wheat and summer maize. Our aim is to identify measures, ways and policies to reduce environmental effects while maintaining or increasing farm yields. This is for the benefit of all farmers, as reduced environmental effects increase their life quality. Hopefully we will also be able to detect management measures which increase yields.

谢谢您参与我们的研究计划！我们想评估河北省农业种植的环境影响。我们主要是集中研究像您这样种植冬小麦和夏玉米的农户。我们的目的是确定措施、方法和政策来降低环境影响同时维持或增加农业产出。这对所有的农民都有利，因为降低环境的影响将会提高他们的生活质量。我们也希望探索出增加产出的措施。

Our project is a joint co-operation between the University of Hohenheim (Germany) and the China Agriculture University (China). The project is financed by the Chinese and German government and includes international scientists from many countries. The data collection in Hebei province is supported by the local government.

我们的研究项目是由德国的霍恩海母大学和中国农业大学合作的。该项目是由中国和德国政府共同出资，有多个国家的科学家共同参加的重大项目。在河北省进行调研和收集数据得到了政府的支持。

Your answers are very valuable for our research project! Therefore, we remunerate your efforts with 30 ¥. So, please answer all questions to the best of your knowledge. In order to enable you to answer freely, we guarantee the confidential treatment of all answers – so none of the answers can be traced back to you. If you have any questions, please do not hesitate to ask them.

您的回答对于我们的研究非常重要！所以，我们给您的报酬是 30 元。所以，请您尽量回答所有问题。为了让您没有顾虑的回答这些问题，我们将保守秘密，所以没有人能根据这些问卷找到您。如果您有什么问题，请提出。

There are many questions, so please let us go quickly but concentrated through the interview! Please let us start with the interview now.

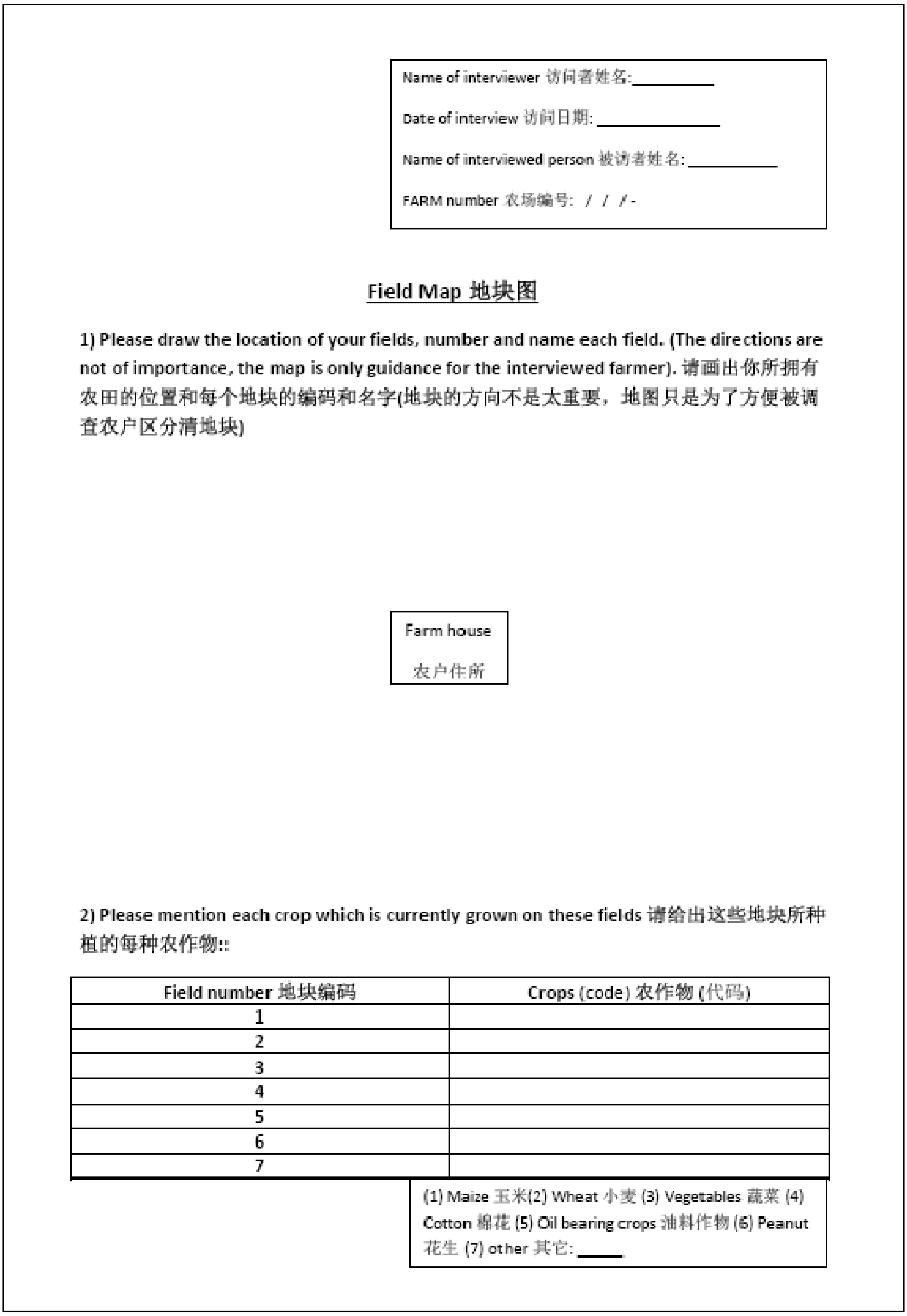
这里有许多问题，让我们把他们集中在采访中，我们现在进入采访。

Thank you very much for your efforts!

谢谢!

Yannick Kühl， July, 2008

Annex 5. Field Map of Survey



Name of interviewer 访问者姓名:__________

Date of interview 访问日期: ______________

Name of interviewed person 被访者姓名: ___________

FARM number 农场编号: / / / -

Field Map 地块图

1) Please draw the location of your fields, number and name each field. (The directions are not of importance, the map is only guidance for the interviewed farmer). 请画出你所拥有农田的位置和每个地块的编码和名字(地块的方向不是太重要，地图只是为了方便被调查农户区分清地块)

Farm house

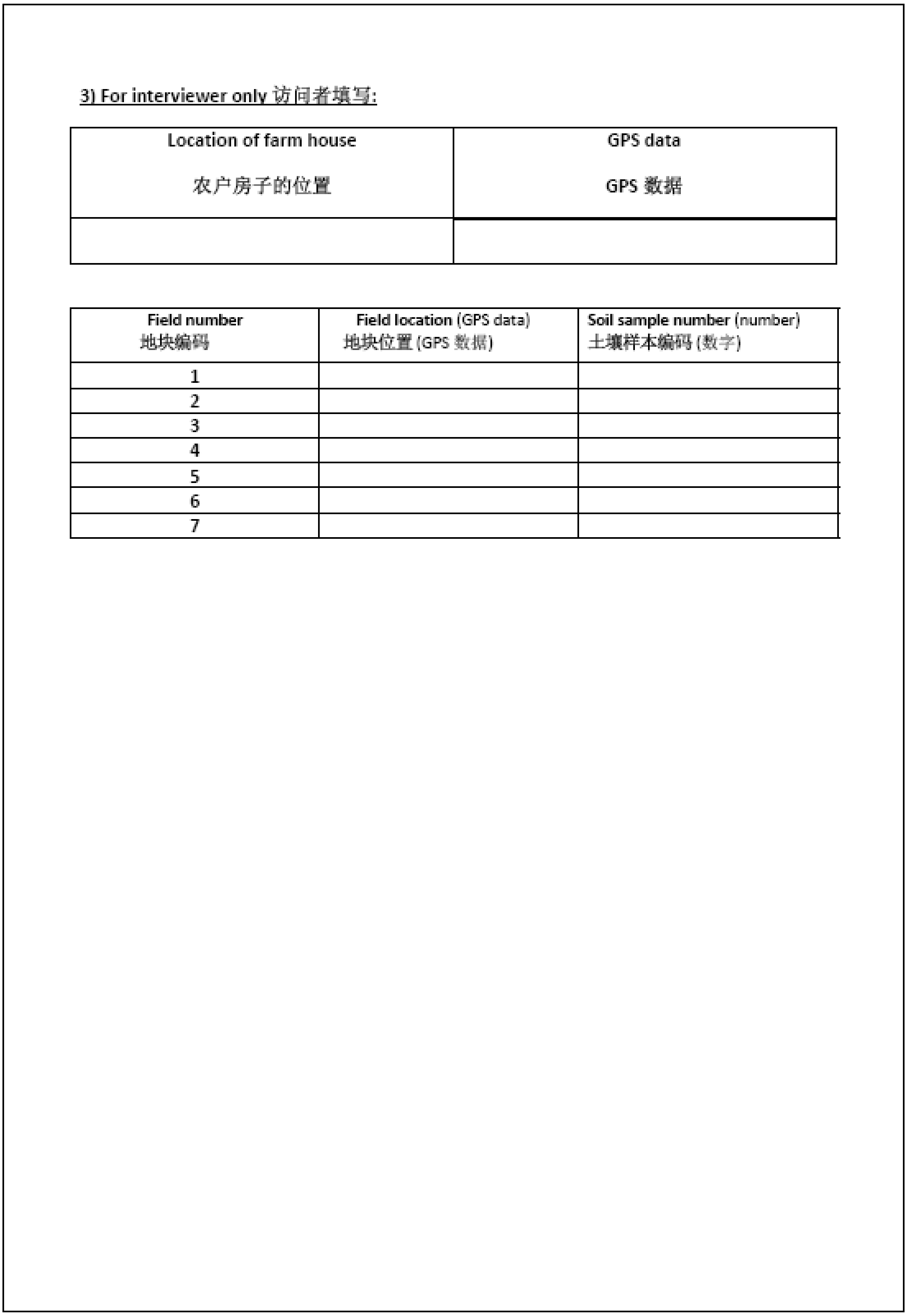
农户住所

2) Please mention each crop which is currently grown on these fields 请给出这些地块所种植的每种农作物::

Field number 地块编码	Crops (code) 农作物 (代码)
1	
2	
3	
4	
5	
6	
7	

(1) Maize 玉米(2) Wheat 小麦 (3) Vegetables 蔬菜 (4) Cotton 棉花 (5) Oil bearing crops 油料作物 (6) Peanut 花生 (7) other 其它: _____

Annex 5. – Continued – Field Map of Survey



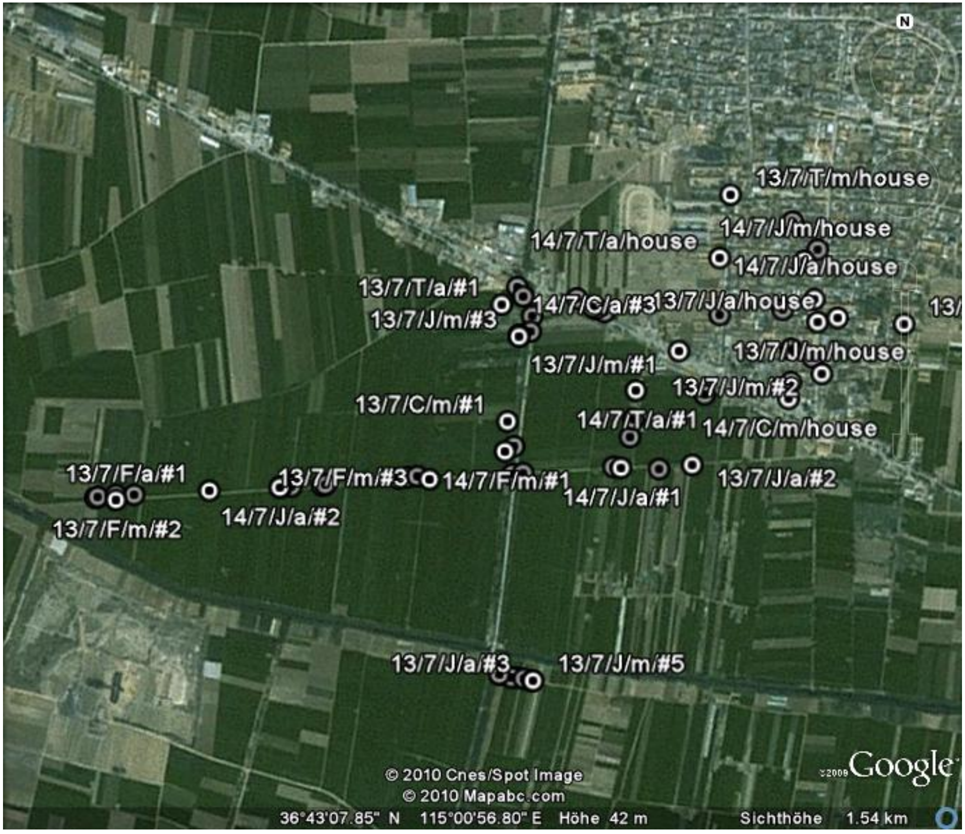
3) For interviewer only 访问者填写:

Location of farm house 农户房子的位置	GPS data GPS 数据

Field number 地块编码	Field location (GPS data) 地块位置 (GPS 数据)	Soil sample number (number) 土壤样本编码 (数字)
1		
2		
3		
4		
5		
6		
7		

Annex 6. Locations of Surveyed Plots and Houses in Wanghuzhuang Village[30]

Annex 7. Locations of Surveyed Plots and Houses in Yongshengcun Village[31]



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[30] The map was constructed using GOOGLE™ Earth 5.0.1 and GARMIN MapSource® 6.14.1 software tools.

[31] The map was constructed using GOOGLE™ Earth 5.0.1 and GARMIN MapSource® 6.14.1 software tools.

Annex 8. Locations of Surveyed Plots and Houses in Houzhai Village[32]

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[32] The map was constructed using GOOGLE™ Earth 5.0.1 and GARMIN MapSource® 6.14.1 software tools.

Annex 9. Characteristics of Integrated Optimization Options - Management Measures (per mu per 2 years)

	Survey Lowest N Fertilization – Maize	*Survey Lowest N Fertilization – Wheat*	*Survey Lowest Irrigation – Maize*
SPECIFIC COSTS *(¥)*	**-¥622.82**	**-¥250.24**	**-¥537.18**
REQUIREMENTS:			
- Total Labor *(hours)*	173.34	61.34	101.50
- Area *(mu)*	1.00	1.00	1.00
Maize:			
- Irrigation *(m^3)*	493.54	239.80	142.08
- N-P-K Fertilizer *(kg)*	4.50/4.50/4.50	17.10/12.70/7.50	4.80/4.50/4.50
- N-P-K Manure *(kg)*	0.00/0.00/0.00	33.00/33.00/22.00	9.00/9.00/6.00
- Yield *(kg)*	957.45	900.00	1,037.04
Wheat:			
- Irrigation *(m^3)*	774.70	436.40	200.32
- N-P-K Fertilizer *(kg)*	30.00/30.00/30.00	0.00/33.60/0.00	25.64/31.70/11.84
- N-P-K Manure *(kg)*	0.00/0.00/0.00	0.00/0.00/0.00	9.00/9.00/6.00
- Yield *(kg)*	957.45	900.00	1,037.04
Other Crops:			
- Irrigation *(m^3)*	0.00	0.00	0.00
- N-P-K Fertilizer *(kg)*	0.00/0.00/0.00	0.00/0.00/0.00	0.00/0.00/0.00
- N-P-K Manure *(kg)*	0.00/0.00/0.00	0.00/0.00/0.00	0.00/0.00/0.00
- Yield *(kg)*	0.00	0.00	0.00
BALANCES:			
Maize:			
-N-P-K Straw *(kg)*	13.79/3.06/30.64	12.96/2.88/28.80	14.93/3.32/33.19
-N-P-K Uptake *(kg)*	21.46/7.86/20.00	21.46/7.86/20.00	21.46/7.86/20.00
-N-P-K Balance *(kg)*	-3.17/-0.30/15.14	41.60/40.72/38.30	7.27/8.96/23.69
-NUE *(kg/kg N)*	212.77	52.63	216.05
-Potential Water Use *(m^3)* **	443.60	443.60	443.60
-Effective Rainfall *(m^3)* **	330.54	330.54	330.54
-Water Balance *(m^3)*	380.48	126.74	29.02
-WUE *(kg/m^3)*	1.16	1.58	2.19
Wheat:			
-N-P-K Straw *(kg)*	5.12/3.07/14.33	4.81/2.89/13.47	5.54/3.33/15.52
-N-P-K Uptake *(kg)*	27.60/10.66/26.94	27.60/10.66/26.94	27.60/10.66/26.94
-N-P-K Balance *(kg)*	7.52/22.41.17.39	-22.79/25.83/-13.47	12.58/33.37/6.42
-NUE *(kg/kg N)*	31.92	n.a.	40.45
-Potential Water Use *(m^3)***	764.40	683.34	490.14
-Effective Rainfall *(m^3)***	202.00	169.40	134.80
-Water Balance *(m^3)*	212.30	-77.54	-155.02
-WUE *(kg/m^3)*	0.98	1.49	3.09
TOTAL WATER BALANCE*(m^3)**, ***	592.78	49.20	-126.00
TOTAL WUE *(kg/m^3)**	1.06	1.53	2.57
TOTAL N-P-K BALANCE *(kg)**	4.34/22.11/32.52	18.81/66.55/24.83	19.86/42.32/30.10
TOTAL NUE *(kg/kg N)**	55.50	105.26	68.14
TOTAL GRAIN *(kg)**	1,914.90	1,800.00	2,074.08

NOTE: *of maize and wheat

**calculated with CROPWAT 8.0

Annex 10. Characteristics of Integrated Optimization Options - Management Measures (per mu per 2 years)

	Survey Highest Gross Margin – Maize	*Survey Highest Gross Margin – SM-WW*
SPECIFIC COSTS *(¥)*	**-¥436.52**	**-¥501.42**
REQUIREMENTS:		
- Total Labor *(hours)*	70.33	69.59
- Area *(mu)*	1.00	1.00
Maize:		
- Irrigation *(m^3)*	168.00	509.02
- N-P-K Fertilizer *(kg)*	10.40/10.40/10.40	9.00/3.60/0.00
- N-P-K Manure *(kg)*	19.50/19.50/13.00	0.00/0.00/0.00
- Yield *(kg)*	1,333.33	1,107.69
Wheat:		
- Irrigation *(m^3)*	389.20	505.62
- N-P-K Fertilizer *(kg)*	58.40/28.00/0.00	14.00/9.80/0.00
- N-P-K Manure *(kg)*	19.50/19.50/13.00	0.00/0.00/0.00
- Yield *(kg)*	900.00	915.39
Other Crops:		
- Irrigation *(m^3)*	0.00	0.00
- N-P-K Fertilizer *(kg)*	0.00/0.00/0.00	0.00/0.00/0.00
- N-P-K Manure *(kg)*	0.00/0.00/0.00	0.00/0.00/0.00
- Yield *(kg)*	0.00	0.00
BALANCES:		
Maize:		
-N-P-K Straw *(kg)*	12.96/2.88/28.80	13.18/2.93/29.29
-N-P-K Uptake *(kg)*	29.33/11.33/28.66	25.06/6.26/24.40
-N-P-K Balance *(kg)*	13.53/21.45/23.54	-2.88/0.27/4.89
-NUE *(kg/kg N)*	128.20	123.08
-Potential Water Use *(m^3)* **	443.60	443.60
-Effective Rainfall *(m^3)* **	330.54	330.54
-Water Balance *(m^3)*	54.94	395.96
-WUE *(kg/m^3)*	2.67	1.32
Wheat:		
-N-P-K Straw *(kg)*	7.13/4.28/19.95	5.92/3.55/16.57
-N-P-K Uptake *(kg)*	27.60/10.66/26.94	27.60/10.66/26.94
-N-P-K Balance *(kg)*	57.43/41.12/6.01	-7.68/2.69/-10.37
-NUE *(kg/kg N)*	15.41	65.39
-Potential Water Use *(m^3)***	490.14	683.34
-Effective Rainfall *(m^3)***	134.80	169.40
-Water Balance *(m^3)*	33.86	-8.32
-WUE *(kg/m^3)*	1.72	1.36
TOTAL WATER BALANCE*(m^3)**, **	88.80	387.64
TOTAL WUE *(kg/m^3)**	2.18	1.34
TOTAL N-P-K BALANCE *(kg)**	70.96/62.57/29.55	-10.56/2.96/-5.47
TOTAL NUE *(kg/kg N)**	32.46	87.96
TOTAL GRAIN *(kg)**	2,233.33	2,023.08

NOTE: *of maize and wheat

**calculated with CROPWAT 8.0

Annex 11. Characteristics of Integrated Optimization Options - Management Measures (per mu per 2 years)

	SM-WW Balanced Input Use I	*SM-WW Balanced Input Use II*	*SM-WW Balanced Input Use III*
SPECIFIC COSTS *(¥)*	**-¥427.40**	**-¥427.40**	**-¥427.40**
REQUIREMENTS:			
- Total Labor *(hours)*	66.25	66.25	66.25
- Area *(mu)*	1.00	1.00	1.00
Maize:			
- Irrigation *(m^3)*	133.74	133.74	133.74
- N-P-K Fertilizer *(kg)*	12.05/7.49/0.00	10.66/7.06/0.00	9.94/5.30/0.00
- N-P-K Manure *(kg)*	0.00/0.00/0.00	0.00/0.00/0.00	0.00/0.00/0.00
- Yield *(kg)*	1,400.00	1,200.00	1,000.00
Wheat:			
- Irrigation *(m^3)*	513.94	513.94	513.94
- N-P-K Fertilizer *(kg)*	27.86/8.17/13.05	21.19/6.81/8.98	16.80/5.33/6.64
- N-P-K Manure *(kg)*	0.00/0.00/0.00	0.00/0.00/0.00	0.00/0.00/0.00
- Yield *(kg)*	1,200.00	1,000.00	800.00
Other Crops:			
- Irrigation *(m^3)*	0.00	0.00	0.00
- N-P-K Fertilizer *(kg)*	0.00/0.00/0.00	0.00/0.00/0.00	0.00/0.00/0.00
- N-P-K Manure *(kg)*	0.00/0.00/0.00	0.00/0.00/0.00	0.00/0.00/0.00
- Yield *(kg)*	0.00	0.00	0.00
BALANCES:			
Maize:			
-N-P-K Straw *(kg)*	17.28/3.84/38.40	14.40/3.20/32.00	11.52/2.56/25.60
-N-P-K Uptake *(kg)*	29.33/11.33/28.66	25.06/10.26/24.40	21.46/7.86/20.00
-N-P-K Balance *(kg)*	0.00/0.00/9.74	0.00/0.00/7.60	0.00/0.00/5.60
-NUE *(kg/kg N)*	116.18	112.57	100.60
-Potential Water Use *(m^3)* **	617.74	617.74	617.74
-Effective Rainfall *(m^3)* **	484.00	484.00	484.00
-Water Balance *(m^3)*	0.00	0.00	0.00
-WUE *(kg/m^3)*	2.27	1.94	1.62
Wheat:			
-N-P-K Straw *(kg)*	7.48/4.49/20.95	6.41/3.85/17.96	5.34/3.21/14.96
-N-P-K Uptake *(kg)*	35.34/12.66/34.00	27.60/10.66/26.94	22.14/8.54/21.60
-N-P-K Balance *(kg)*	0.00/0.00/0.00	0.00/0.00/0.00	0.00/0.00/0.00
-NUE *(kg/kg N)*	43.07	47.19	47.62
-Potential Water Use *(m^3)***	683.34	683.34	683.34
-Effective Rainfall *(m^3)***	169.40	169.40	169.40
-Water Balance *(m^3)*	0.00	0.00	0.00
-WUE *(kg/m^3)*	1.76	1.46	1.17
TOTAL WATER BALANCE*(m^3)**, **	0.00	0.00	0.00
TOTAL WUE *(kg/m^3)**	2.00	1.69	1.38
TOTAL N-P-K BALANCE *(kg)**	0.00/0.00/9.74	0.00/0.00/7.60	0.00/0.00/5.60
TOTAL NUE *(kg/kg N)**	65.15	69.07	67.31
TOTAL GRAIN *(kg)**	2,600.00	2,200.00	1,800.00

NOTE: *of maize and wheat

**calculated with CROPWAT 8.0

Annex 12. Characteristics of Integrated Optimization Options - Management Measures (per mu per 2 years)

	SM-WW Balanced Input Use IV	*SM-WW Recommended Fertilization and Optimized Irrigation I*	*SM-WW Recommended Fertilization and Optimized Irrigation II*
SPECIFIC COSTS *(¥)*	**-¥427.40**	**-¥427.40**	**-¥427.40**
REQUIREMENTS:			
- Total Labor *(hours)*	66.25	66.25	66.25
- Area *(mu)*	1.00	1.00	1.00
Maize:			
- Irrigation *(m^3)*	133.74	133.74	133.74
- N-P-K Fertilizer *(kg)*	9.22/3.54/0.00	30.00/11.00/13.00	27.00/9.00/9.00
- N-P-K Manure *(kg)*	0.00/0.00/0.00	0.00/0.00/0.00	0.00/0.00/0.00
- Yield *(kg)*	800.00	1,400.02	1,300.00
Wheat:			
- Irrigation *(m^3)*	513.94	513.94	513.94
- N-P-K Fertilizer *(kg)*	12.38/3.83/4.29	30.00/18.00/11.00	26.00/14.00/9.00
- N-P-K Manure *(kg)*	0.00/0.00/0.00	0.00/0.00/0.00	0.00/0.00/0.00
- Yield *(kg)*	600.00	1,200.02	1,100.00
Other Crops:			
- Irrigation *(m^3)*	0.00	0.00	0.00
- N-P-K Fertilizer *(kg)*	0.00/0.00/0.00	0.00/0.00/0.00	0.00/0.00/0.00
- N-P-K Manure *(kg)*	0.00/0.00/0.00	0.00/0.00/0.00	0.00/0.00/0.00
- Yield *(kg)*	0.00	0.00	0.00
BALANCES:			
Maize:			
-N-P-K Straw *(kg)*	8.64/1.92/19.20	17.28/3.84/38.40	15.84/3.52/35.20
-N-P-K Uptake *(kg)*	17.86/5.46/15.60	29.33/11.33/28.66	25.06/10.26/24.40
-N-P-K Balance *(kg)*	0.00/0.00/3.60	17.95/3.51/22.74	17.78/2.26/19.80
-NUE *(kg/kg N)*	86.77	46.67	48.15
-Potential Water Use *(m^3)* **	617.74	617.74	617.74
-Effective Rainfall *(m^3)* **	484.00	484.00	484.00
-Water Balance *(m^3)*	0.00	0.00	0.00
-WUE *(kg/m^3)*	1.30	2.27	2.10
Wheat:			
-N-P-K Straw *(kg)*	4.28/2.57/11.97	7.48/4.49/20.95	6.95/4.17/19.45
-N-P-K Uptake *(kg)*	16.66/6.40/16.26	35.34/12.66/34.00	27.60/10.66/26.94
-N-P-K Balance *(kg)*	0.00/0.00/0.00	2.14/9.83/-2.05	5.35/7.51/1.51
-NUE *(kg/kg N)*	48.47	40.00	42.31
-Potential Water Use *(m^3)***	683.34	683.34	683.34
-Effective Rainfall *(m^3)***	169.40	169.40	169.40
-Water Balance *(m^3)*	0.00	0.00	0.00
-WUE *(kg/m^3)*	0.88	1.76	1.61
TOTAL WATER BALANCE*(m^3)***, **	0.00	0.00	0.00
TOTAL WUE *(kg/m^3)**	1.08	2.00	1.84
TOTAL N-P-K BALANCE *(kg)**	0.00/0.00/3.60	20.09/13.34/20.69	23.13/9.77/21.31
TOTAL NUE *(kg/kg N)**	64.81	43.33	45.28
TOTAL GRAIN *(kg)**	1,400.00	2,600.04	2,400.00

NOTE: *of maize and wheat

**calculated with CROPWAT 8.0

Annex 13. Characteristics of Integrated Optimization Options - Management Measures (per mu per 2 years)

	SM-WW Recommended Fertilization and Optimized Irrigation III	*SM-WW Recommended Fertilization and Optimized Irrigation IV*	*SprM Balanced Input Use I*
SPECIFIC COSTS *(¥)*	**-¥427.40**	**-¥427.40**	**-¥207.74**
REQUIREMENTS:			
- Total Labor *(hours)*	66.25	66.25	60.00
- Area *(mu)*	1.00	1.00	1.0
Maize:			
- Irrigation *(m^3)*	133.74	133.74	279.60
- N-P-K Fertilizer *(kg)*	22.00/7.00/6.00	20.00/5.00/3.00	11.28/4.90/0.00
- N-P-K Manure *(kg)*	0.00/0.00/0.00	0.00/0.00/0.00	0.00/0.00/0.00
- Yield *(kg)*	1,050.00	899.98	1,300.02
Wheat:			
- Irrigation *(m^3)*	513.94	513.94	0.00
- N-P-K Fertilizer *(kg)*	22.00/10.00/3.00	18.00/7.00/3.00	0.00/0.00/0.00
- N-P-K Manure *(kg)*	0.00/0.00/0.00	0.00/0.00/0.00	0.00/0.00/0.00
- Yield *(kg)*	800.00	599.98	0.00
Other Crops:			
- Irrigation *(m^3)*	0.00	0.00	0.00
- N-P-K Fertilizer *(kg)*	0.00/0.00/0.00	0.00/0.00/0.00	0.00/0.00/0.00
- N-P-K Manure *(kg)*	0.00/0.00/0.00	0.00/0.00/0.00	0.00/0.00/0.00
- Yield *(kg)*	0.00	0.00	0.00
BALANCES:			
Maize:			
-N-P-K Straw *(kg)*	11.52/2.56/25.60	8.64/1.92/19.20	18.72/4.16/41.60
-N-P-K Uptake *(kg)*	21.46/7.86/20.00	17.86/5.46/15.60	30.00/9.06/29.06
-N-P-K Balance *(kg)*	12.06/1.70/11.60	10.78/1.46/6.60	0.00/0.00/12.54
-NUE *(kg/kg N)*	47.73	45.00	115.25
-Potential Water Use *(m^3)* **	617.74	617.74	787.60
-Effective Rainfall *(m^3)* **	484.00	484.00	508.00
-Water Balance *(m^3)*	0.00	0.00	0.00
-WUE *(kg/m^3)*	1.70	1.46	1.65
Wheat:			
-N-P-K Straw *(kg)*	5.61/3.37/15.71	4.81/2.89/13.47	-
-N-P-K Uptake *(kg)*	22.14/8.54/21.60	16.66/6.40/16.26	-
-N-P-K Balance *(kg)*	5.47/4.83/-2.89	6.15/3.49/0.21	-
-NUE *(kg/kg N)*	36.36	33.33	-
-Potential Water Use *(m^3)***	683.34	683.34	-
-Effective Rainfall *(m^3)***	169.40	169.40	-
-Water Balance *(m^3)*	0.00	0.00	-
-WUE *(kg/m^3)*	1.17	0.88	-
TOTAL WATER BALANCE*(m^3)**$^{*, **}$	0.00	0.00	0.00
TOTAL WUE *(kg/m^3)**	1.42	1.15	1.65
TOTAL N-P-K BALANCE *(kg)**	17.53/6.53/8.71	16.93/4.95/6.81	0.00/0.00/12.54
TOTAL NUE *(kg/kg N)**	42.05	39.47	115.25
TOTAL GRAIN *(kg)**	1,850.00	1,499.96	1,300.02

NOTE: *of maize and wheat

**calculated with CROPWAT 8.0

Annex 14. Characteristics of Integrated Optimization Options - Management Measures (per mu per 2 years)

	SprM Balanced Input Use II	*SprM Balanced Input Use III*	*SprM Recommended Fertilization and Optimized Irrigation I*
SPECIFIC COSTS *(¥)*	**-¥207.74**	**-¥207.74**	**-¥207.74**
REQUIREMENTS:			
- Total Labor *(hours)*	60.00	60.00	60.00
- Area *(mu)*	1.0	1.0	1.0
Maize:			
- Irrigation *(m^3)*	279.60	279.60	279.60
- N-P-K Fertilizer *(kg)*	9.44/4.32/0.00	7.60/3.86/0.00	30.00/9.00/9.00
- N-P-K Manure *(kg)*	0.00/0.00/0.00	0.00/0.00/0.00	0.00/0.00/0.00
- Yield *(kg)*	1,150.00	999.98	1,300.02
Wheat:			
- Irrigation *(m^3)*	0.00	0.00	0.00
- N-P-K Fertilizer *(kg)*	0.00/0.00/0.00	0.00/0.00/0.00	0.00/0.00/0.00
- N-P-K Manure *(kg)*	0.00/0.00/0.00	0.00/0.00/0.00	0.00/0.00/0.00
- Yield *(kg)*	0.00	0.00	0.00
Other Crops:			
- Irrigation *(m^3)*	0.00	0.00	0.00
- N-P-K Fertilizer *(kg)*	0.00/0.00/0.00	0.00/0.00/0.00	0.00/0.00/0.00
- N-P-K Manure *(kg)*	0.00/0.00/0.00	0.00/0.00/0.00	0.00/0.00/0.00
- Yield *(kg)*	0.00	0.00	0.00
BALANCES:			
Maize:			
-N-P-K Straw *(kg)*	16.56/3.68/36.80	14.40/3.20/32.00	18.72/4.16/41.60
-N-P-K Uptake *(kg)*	26.00/8.00/25.06	22.00/7.06/19.06	30.00/9.06/29.06
-N-P-K Balance *(kg)*	0.00/0.00/11.74	0.00/0.00/12.94	18.72/4.10/21.54
-NUE *(kg/kg N)*	121.82	131.58	43.33
-Potential Water Use *(m^3)* **	787.60	787.60	787.60
-Effective Rainfall *(m^3)* **	508.00	508.00	508.00
-Water Balance *(m^3)*	0.00	0.00	0.00
-WUE *(kg/m^3)*	1.46	1.27	1.65
Wheat:			
-N-P-K Straw *(kg)*	-	-	-
-N-P-K Uptake *(kg)*	-	-	-
-N-P-K Balance *(kg)*	-	-	-
-NUE *(kg/kg N)*	-	-	-
-Potential Water Use *(m^3)***	-	-	-
-Effective Rainfall *(m^3)***	-	-	-
-Water Balance *(m^3)*	-	-	-
-WUE *(kg/m^3)*	-	-	-
TOTAL WATER BALANCE*(m^3)**, **	0.00	0.00	0.00
TOTAL WUE *(kg/m^3)**	1.46	1.27	1.65
TOTAL N-P-K BALANCE *(kg)**	0.00/0.00/11.74	0.00/0.00/12.94	18.72/4.10/21.54
TOTAL NUE *(kg/kg N)**	121.82	131.58	43.33
TOTAL GRAIN *(kg)**	1,150.00	999.98	1,300.02

NOTE: *of maize and wheat

**calculated with CROPWAT 8.0

Annex 15. Characteristics of Integrated Optimization Options - Management Measures (per mu per 2 years)

	SprM Recommended Fertilization and Optimized Irrigation II	*SprM Recommended Fertilization and Optimized Irrigation III*	*Conventional SM-WW I*
SPECIFIC COSTS *(¥)*	**-¥207.74**	**-¥207.74**	**-¥427.40**
REQUIREMENTS:			
- Total Labor *(hours)*	60.00	53.00	66.25
- Area *(mu)*	1.00	1.00	1.00
Maize:			
- Irrigation *(m^3)*	279.60	279.60	n.a.
- N-P-K Fertilizer *(kg)*	26.00/10.00/8.00	22.00/9.00/6.00	33.33/20.00/20.00
- N-P-K Manure *(kg)*	0.00/0.00/0.00	0.00/0.00/0.00	0.00/0.00/0.00
- Yield *(kg)*	1,150.00	999.98	1,333.33
Wheat:			
- Irrigation *(m^3)*	0.00	0.00	n.a.
- N-P-K Fertilizer *(kg)*	0.00/0.00/0.00	0.00/0.00/0.00	40.00/20.00/20.00
- N-P-K Manure *(kg)*	0.00/0.00/0.00	0.00/0.00/0.00	0.00/0.00/0.00
- Yield *(kg)*	0.00	0.00	866.67
Other Crops:			
- Irrigation *(m^3)*	0.00	0.00	n.a.
- N-P-K Fertilizer *(kg)*	0.00/0.00/0.00	0.00/0.00/0.00	0.00/0.00/0.00
- N-P-K Manure *(kg)*	0.00/0.00/0.00	0.00/0.00/0.00	0.00/0.00/0.00
- Yield *(kg)*	0.00	0.00	0.00
BALANCES:			
Maize:			
-N-P-K Straw *(kg)*	16.56/3.68/36.80	14.40/3.20/32.00	0.00/0.00/0.00
-N-P-K Uptake *(kg)*	26.00/8.00/25.06	22.00/7.06/19.06	29.34/11.34/28.66
-N-P-K Balance *(kg)*	16.56/5.68/19.74	14.40/5.14/18.94	3.99/8.66/-8.66
-NUE *(kg/kg N)*	44.23	45.45	40.00
-Potential Water Use *(m^3)* **	787.60	787.60	617.74
-Effective Rainfall *(m^3)* **	508.00	508.00	484.00
-Water Balance *(m^3)*	0.00	0.00	n.a.
-WUE *(kg/m^3)*	1.46	1.27	n.a.
Wheat:			
-N-P-K Straw *(kg)*	-	-	0.00/0.00/0.00
-N-P-K Uptake *(kg)*	-	-	22.14/8.54/21.60
-N-P-K Balance *(kg)*	-	-	17.86/11.46/-1.60
-NUE *(kg/kg N)*	-	-	21.67
-Potential Water Use *(m^3)***	-	-	683.34
-Effective Rainfall *(m^3)***	-	-	169.40
-Water Balance *(m^3)*	-	-	n.a.
-WUE *(kg/m^3)*	-	-	n.a.
TOTAL WATER BALANCE*(m^3)**, **	0.00	0.00	n.a.
TOTAL WUE *(kg/m^3)**	1.46	1.27	1.96
TOTAL N-P-K BALANCE *(kg)**	16.56/5.68/19.74	14.40/5.14/18.94	21.85/20.12/-10.26
TOTAL NUE *(kg/kg N)**	44.23	45.45	30.00
TOTAL GRAIN *(kg)**	1,150.00	999.98	2,200.00

NOTE: *of maize and wheat

**calculated with CROPWAT 8.0

Annex 16. Characteristics of Integrated Optimization Options - Management Measures (per mu per 2 years)

	Conventional SM-WW II	*Optimized SM-WW*	*Optimized Continued SprM I*
SPECIFIC COSTS *(¥)*	**-¥356.66**	**-¥427.40**	**-¥207.74**
REQUIREMENTS:			
- Total Labor *(hours)*	236.45	66.25	60.00
- Area *(mu)*	1.00	1.00	1.00
Maize:			
- Irrigation *(m^3)*	153.34	n.a.	200.00
- N-P-K Fertilizer *(kg)*	33.33/0.00/0.00	24.67/18.00/18.00	22.00/15.00/15.00
- N-P-K Manure *(kg)*	0.00/0.00/0.00	0.00/0.00/0.00	0.00/0.00/0.00
- Yield *(kg)*	895.46	1,400.00	1,400.00
Wheat:			
- Irrigation *(m^3)*	320.00	n.a.	n.a.
- N-P-K Fertilizer *(kg)*	40.00/0.00/0.00	24.67/18.00/18.00	0.00/0.00/0.00
- N-P-K Manure *(kg)*	0.00/0.00/0.00	0.00/0.00/0.00	0.00/0.00/0.00
- Yield *(kg)*	520.94	966.67	0.00
Other Crops:			
- Irrigation *(m^3)*	0.00	n.a.	n.a.
- N-P-K Fertilizer *(kg)*	0.00/0.00/0.00	0.00/0.00/0.00	0.00/0.00/0.00
- N-P-K Manure *(kg)*	0.00/0.00/0.00	0.00/0.00/0.00	0.00/0.00/0.00
- Yield *(kg)*	0.00	0.00	0.00
BALANCES:			
Maize:			
-N-P-K Straw *(kg)*	0.00/0.00/0.00	13.92/3.09/30.93	20.16/4.48/44.80
-N-P-K Uptake *(kg)*	17.86/5.46/15.60	29.34/11.34/28.66	30.00/9.00/9.00
-N-P-K Balance *(kg)*	15.47/-5.46/-15.60	9.25/9.75/20.27	12.16/10.48/50.80
-NUE *(kg/kg N)*	26.87	56.75	63.64
-Potential Water Use *(m^3)* **	513.86	617.74	787.60
-Effective Rainfall *(m^3)* **	357.20	484.00	508.00
-Water Balance *(m^3)*	-3.32	n.a.	-79.60
-WUE *(kg/m^3)*	5.84	n.a.	1.98
Wheat:			
-N-P-K Straw *(kg)*	0.00/0.00/0.00	7.48/4.49/20.95	-
-N-P-K Uptake *(kg)*	16.66/6.40/16.26	27.60/10.66/26.94	-
-N-P-K Balance *(kg)*	23.34/-6.40/-16.26	4.55/11.83/12.01	-
-NUE *(kg/kg N)*	13.02	39.18	-
-Potential Water Use *(m^3)***	683.34	638.34	-
-Effective Rainfall *(m^3)***	169.40	169.40	-
-Water Balance *(m^3)*	-193.94	n.a.	-
-WUE *(kg/m^3)*	1.63	n.a.	-
TOTAL WATER BALANCE *(m^3)*,***	-197.26	n.a.	79.60
TOTAL WUE *(kg/m^3)**	2.99	2.40	1.98
TOTAL N-P-K BALANCE *(kg)**	38.81/-11.86/-31.86	13.80/21.58/32.28	12.16/10.48/50.80
TOTAL NUE *(kg/kg N)**	19.32	47.97	63.64
TOTAL GRAIN *(kg)**	1,416.40	2,366.67	1,400.00

NOTE: *of maize and wheat

**calculated with CROPWAT 8.0

Annex 17. Characteristics of Integrated Optimization Options - Management Measures (per mu per 2 years)

	Optimized Continued SprM II	*Reduced Inputs SM-WW*
SPECIFIC COSTS *(¥)*	**-¥162.32**	**-¥356.66**
REQUIREMENTS:		
- Total Labor *(hours)*	134.75	236.45
- Area *(mu)*	1.00	1.00
Maize:		
- Irrigation *(m^3)*	165.33	153.34
- N-P-K Fertilizer *(kg)*	11.34/16.20/12.46	10.66/0.00/0.00
- N-P-K Manure *(kg)*	0.00/0.00/0.00	0.00/0.00/0.00
- Yield *(kg)*	1,146.67	1,046.26
Wheat:		
- Irrigation *(m^3)*	0.00	240.00
- N-P-K Fertilizer *(kg)*	0.00/0.00/0.00	12.00/0.00/0.00
- N-P-K Manure *(kg)*	0.00/0.00/0.00	0.00/0.00/0.00
- Yield *(kg)*	0.00	465.06
Other Crops:		
- Irrigation *(m^3)*	0.00	0.00
- N-P-K Fertilizer *(kg)*	0.00/0.00/0.00	0.00/0.00/0.00
- N-P-K Manure *(kg)*	0.00/0.00/0.00	0.00/0.00/0.00
- Yield *(kg)*	0.00	0.00
BALANCES:		
Maize:		
-N-P-K Straw *(kg)*	0.00/0.00/0.00	0.00/0.00/0.00
-N-P-K Uptake *(kg)*	26.00/8.00/25.06	21.46/7.86/20.00
-N-P-K Balance *(kg)*	-14.66/8.20/-12.60	-10.80/-7.86/-20.00
-NUE *(kg/kg N)*	101.12	98.15
-Potential Water Use *(m^3)* **	787.60	513.86
-Effective Rainfall *(m^3)* **	357.20	357.20
-Water Balance *(m^3)*	-265.07	-3.32
-WUE *(kg/m^3)*	2.19	6.82
Wheat:		
-N-P-K Straw *(kg)*	-	0.00/0.00/0.00
-N-P-K Uptake *(kg)*	-	16.66/6.40/16.26
-N-P-K Balance *(kg)*	-	-4.66/-6.40/-16.26
-NUE *(kg/kg N)*	-	38.76
-Potential Water Use *(m^3)***	-	683.34
-Effective Rainfall *(m^3)***	-	169.40
-Water Balance *(m^3)*	-	-273.94
-WUE *(kg/m^3)*	-	1.94
TOTAL WATER BALANCE*(m^3)*, ***	-265.07	-273.94
TOTAL WUE *(kg/m^3)**	2.19	3.84
TOTAL N-P-K BALANCE *(kg)**	-14.66/8.20/-12.60	-15.46/-14.26/-36.26
TOTAL NUE *(kg/kg N)**	101.12	66.70
TOTAL GRAIN *(kg)**	1,146.67	1,511.32

NOTE: *of maize and wheat

**calculated with CROPWAT 8.0

Annex 18. Characteristics of the Cotton Production Systems "Farmer's Practice" (for a 2-year period)

	Household 2 (HH2)	**Household 3 (HH3)**
Labor Requirement *(hours and available hours)**		
-Jan	0.00 (364.00)	0.00 (312.00)
-Feb	0.00 (364.00)	0.00 (312.00)
-Mar	0.00 (364.00)	0.00 (312.00)
-Apr	36.17 (312.20)	46.29 (299.48)
-May	30.77 (357.00)	17.04 (307.00)
-Jun	36.93 (357.00)	23.70 (307.00)
-Jul	35.39 (361.00)	5.93 (312.00)
-Aug	123.08 (364.00)	0.00 (312.00)
-Sep	0.00 (300.00)	74.07 (312.00)
-Oct	0.00 (364.00)	0.00 (307.50)
-Nov	0.00 (364.00)	0.00 (308.00)
-Dec	0.00 (364.00)	0.00 (312.00)
SM-WW Area *(mu)**	1.30	5.40
Cotton:		
-Irrigation *(m^3/mu)*	240.00	300.00
-N/P/K Fertilizer *(kg/mu)*	27.50/27.50/27.50	48.00/48.00/48.00
-N/P/K Manure *(kg/mu)*	39.00/39.00/26.00	21.00/21.00/14.00
-N/P/K Straw *(kg/mu)*	0.00/0.00/0.00	0.00/0.00/0.00
-Yield *(kg/mu)*	500.00	400.00
Gross Margin *(¥/mu)*	**¥439.20**	**¥513.80**
Total Gross Margin *(¥)*	**¥570.96**	**¥2,774.52**

NOTE: *area and labor are displayed as one-year values

Annex 19. Sensitivity Analysis of the Results in the Scenario *Optimization under Current Conditions*

Name	Reduced Cost HH1	Reduced Cost HH2	Reduced Cost HH3
SM-WW Farmers Practice	¥ -2.334,06	¥ -2.157,19	¥ -2.157,19
Survey Mean	¥ -2.228,14	¥ -2.241,13	¥ -2.241,13
Survey highest Maize Yield	¥ -1.272,55	¥ -1.272,55	¥ -1.272,55
Survey highest Wheat Yield	¥ -935,80	¥ -935,80	¥ -935,80
Survey lowest N Fert Maize	¥ -2.006,32	¥ -2.006,32	¥ -2.006,32
Survey lowest N Fert Wheat	¥ -1.691,69	¥ -1.691,69	¥ -1.691,69
Survey lowest Irri Maize	¥ -1.176,80	¥ -1.176,80	¥ -1.176,80
Survey highest Gross Margin Maize	¥ -1.196,06	¥ -1.196,06	¥ -1.196,06
Survey highest Gross Margin SM-WW	¥ -1.302,13	¥ -1.302,13	¥ -1.302,13
SM-WW Balanced Input Use I	¥ -	¥ -	¥ -
SM-WW Balanced input Use II	¥ -742,63	¥ -742,63	¥ -742,63
SM-WW Balanced Input Use III	¥ -1.495,74	¥ -1.495,74	¥ -1.495,74
SM-WW Balanced Input Use IV	¥ -2.248,62	¥ -2.248,62	¥ -2.248,62
SM-WW Recommended Fertilization and Optimized Irrigation I	¥ -169,83	¥ -169,83	¥ -169,83
SM-WW Recommended Fertilization and Optimized Irrigation II	¥ -495,51	¥ -495,51	¥ -495,51
SM-WW Recommended Fertilization and Optimized Irrigation III	¥ -1.501,60	¥ -1.501,60	¥ -1.501,60
SM-WW Recommended Fertilization and Optimized Irrigation IV	¥ -2.144,62	¥ -2.144,62	¥ -2.144,62
SprM Balanced Input I	¥ -2.014,00	¥ -2.014,00	¥ -2.014,00
SprM Balanced Input II	¥ -2.295,37	¥ -2.295,37	¥ -2.295,37
SprM Balanced Input III	¥ -2.577,27	¥ -2.577,27	¥ -2.577,27
Spr M Recomm I	¥ -2.132,51	¥ -2.132,51	¥ -2.132,51
Spr M Recomm II	¥ -2.409,25	¥ -2.409,25	¥ -2.409,25
Spr M Recomm III	¥ -2.674,33	¥ -2.674,33	¥ -2.674,33
SprM Cabbage Intercropping	¥ -	¥ -	¥ -
SprM Peanut Intercropping	¥ -	¥ -	¥ -
SM-WW-SprM (3 harvests 2 years) I	¥ -1.367,95	¥ -1.367,95	¥ -1.367,95
Wheat-Soy-SprM (3 harvests in 2 years)	¥ -	¥ -	¥ -
Conventional SM-WW I	¥ -1.026,53	¥ -1.026,53	¥ -1.026,53
Optimized SM-WW	¥ -498,00	¥ -498,00	¥ -498,00
Optimized Continous Spr M I	¥ -1.907,79	¥ -1.907,79	¥ -1.907,79
SM (Improved Maize Seeds)-WW	¥ -1.211,59	¥ -1.211,59	¥ -1.211,59
SM-WW-SprM (3 harvests 2 years) II	¥ -2.723,35	¥ -2.723,35	¥ -2.723,35
Conventional SM-WW II	¥ -2.218,56	¥ -2.218,56	¥ -2.218,56
Reduced Input SM-WW	¥ -1.796,01	¥ -1.796,01	¥ -1.796,01
Optimized Continous SprM II	¥ -2.290,90	¥ -2.290,90	¥ -2.290,90
Selling 1 kg Maize	¥ -	¥ -	¥ -
Selling 1 kg Wheat	¥ -	¥ -	¥ -
Selling 1 kg Peanut	¥ -1,79	¥ -1,79	¥ -1,79

Annex 19. – Continued – Sensitivity Analysis of the Results in the Scenario *Optimization under Current Conditions*

Name	Reduced Cost HH1	Reduced Cost HH2	Reduced Cost HH3
Selling 1 kg Soya	¥ -7,64	¥ -7,64	¥ -7,64
Selling 1 kg Cabbage	¥ -	¥ -	¥ -
Sign Buying 1 kg Maize	¥ -1,46	¥ -1,46	¥ -1,46
Sign Buying 1 kg of Wheat	¥ -1,55	¥ -1,55	¥ -1,55
Buying 1 Kg of N fertilizer	¥ -	¥ -	¥ -
Buying 1 kg of P fertilizer	¥ -	¥ -	¥ -
Buying 1 kg of K fertilizer	¥ -	¥ -	¥ -
(Indirect) Water Price	¥ -	¥ -	¥ -
Labor Price Year 1	¥ -	¥ -	¥ -
Labor Price Year 2	¥ -	¥ -	¥ -
Selling of 1 Kg of N of Manure	¥ -	¥ -	¥ -
Selling of 1 Kg of P of Manure	¥ -	¥ -	¥ -
Selling of 1 Kg of K of Manure	¥ -	¥ -	¥ -
Buying of 1 Kg of N of Manure	¥ -	¥ -	¥ -
Buying of 1 Kg of P of Manure	¥ -	¥ -	¥ -
Buying of 1 kg K of Manure	¥ -	¥ -	¥ -

Annex 20. Sensitivity Analysis of the Results in the Scenario *Introduction of Marginal Water Price*

Name	Reduced Cost HH1	Reduced Cost HH2	Reduced Cost HH3
SM-WW Farmers Practice	¥ -7.514,20	¥ -3.241,17	¥ -4.345,05
Survey Mean	¥ -5.601,88	¥ -5.614,87	¥ -5.614,87
Survey highest Maize Yield	¥ -4.309,08	¥ -4.309,08	¥ -4.309,08
Survey highest Wheat Yield	¥ -4.472,75	¥ -4.472,75	¥ -4.472,75
Survey lowest N Fert Maize	¥ -6.193,47	¥ -6.193,47	¥ -6.193,47
Survey lowest N Fert Wheat	¥ -3.203,46	¥ -3.203,46	¥ -3.203,46
Survey lowest Irri Maize	¥ -933,80	¥ -933,80	¥ -933,80
Survey highest Gross Margin Maize	¥ -1.838,24	¥ -1.838,24	¥ -1.838,24
Survey highest Gross Margin SM-WW	¥ -4.228,84	¥ -4.228,84	¥ -4.228,84
SM-WW Balanced Input Use I	¥ -797,23	¥ -797,23	¥ -797,23
SM-WW Balanced input Use II	¥ -1.830,68	¥ -1.830,68	¥ -1.830,68
SM-WW Balanced Input Use III	¥ -2.874,62	¥ -2.874,62	¥ -2.874,62
SM-WW Balanced Input Use IV	¥ -3.918,32	¥ -3.918,32	¥ -3.918,32
SM-WW Recommended Fertilization and Optimized Irrigation I	¥ -967,02	¥ -967,02	¥ -967,02
SM-WW Recommended Fertilization and Optimized Irrigation II	¥ -1.438,15	¥ -1.438,15	¥ -1.438,15
SM-WW Recommended Fertilization and Optimized Irrigation III	¥ -2.844,12	¥ -2.844,12	¥ -2.844,12
SM-WW Recommended Fertilization and Optimized Irrigation IV	¥ -3.741,64	¥ -3.741,64	¥ -3.741,64
SprM Balanced Input I	¥ -2.041,13	¥ -2.041,13	¥ -2.041,13

Annex 20. – Continued – Sensitivity Analysis of the Results in the Scenario *Introduction of Marginal Water Price*

Name	Reduced Cost HH1	Reduced Cost HH2	Reduced Cost HH3
SprM Balanced Input II	¥ -2.431,58	¥ -2.431,58	¥ -2.431,58
SprM Balanced Input III	¥ -2.822,56	¥ -2.822,56	¥ -2.822,56
Spr M Recomm I	¥ -2.159,64	¥ -2.159,64	¥ -2.159,64
Spr M Recomm II	¥ -2.545,46	¥ -2.545,46	¥ -2.545,46
Spr M Recomm III	¥ -2.919,62	¥ -2.919,62	¥ -2.919,62
SprM Cabbage Intercropping	¥ -	¥ -	¥ -
SprM Peanut Intercropping	¥ -	¥ -	¥ -
SM-WW-SprM (3 harvests 2 years) I	¥ -1.162,98	¥ -1.162,98	¥ -1.162,98
Wheat-Soy-SprM (3 harvests in 2 years)	¥ -	¥ -	¥ -
Conventional SM-WW I	¥ -1.271,07	¥ -1.271,07	¥ -1.271,07
Optimized SM-WW	¥ -	¥ -	¥ -
Optimized Continous Spr M I	¥ -1.491,31	¥ -1.491,31	¥ -1.491,31
SM (Improved Maize Seeds)-WW	¥ -2.745,71	¥ -2.745,71	¥ -2.745,71
SM-WW-SprM (3 harvests 2 years) II	¥ -2.878,01	¥ -2.878,01	¥ -2.878,01
Conventional SM-WW II	¥ -3.063,91	¥ -3.063,91	¥ -3.063,91
Reduced Input SM-WW	¥ -2.199,55	¥ -2.199,55	¥ -2.199,55
Optimized Continous SprM II	¥ -1.897,03	¥ -1.897,03	¥ -1.897,03
Selling 1 kg Maize	¥ -	¥ -	¥ -
Selling 1 kg Wheat	¥ -	¥ -	¥ -
Selling 1 kg Peanut	¥ -	¥ -	¥ -
Selling 1 kg Soya	¥ -8,45	¥ -8,45	¥ -8,45
Selling 1 kg Cabbage	¥ -0,19	¥ -0,19	¥ -0,19
Sign Buying 1 kg Maize	¥ -1,46	¥ -1,46	¥ -1,46
Sign Buying 1 kg of Wheat	¥ -1,55	¥ -1,55	¥ -1,55
Buying 1 Kg of N fertilizer	¥ -	¥ -	¥ -
Buying 1 kg of P fertilizer	¥ -	¥ -	¥ -
Buying 1 kg of K fertilizer	¥ -	¥ -	¥ -
(Indirect) Water Price	¥ -	¥ -	¥ -
Labor Price Year 1	¥ -	¥ -	¥ -
Labor Price Year 2	¥ -	¥ -	¥ -
Selling of 1 Kg of N of Manure	¥ -	¥ -	¥ -
Selling of 1 Kg of P of Manure	¥ -	¥ -	¥ -
Selling of 1 Kg of K of Manure	¥ -	¥ -	¥ -
Buying of 1 Kg of N of Manure	¥ -	¥ -	¥ -
Buying of 1 Kg of P of Manure	¥ -	¥ -	¥ -
Buying of 1 kg K of Manure	¥ -	¥ -	¥ -

Annex 21. Sensitivity Analysis of the Results in the Scenario *Output Price Increase: Maize*

Name	Reduced Cost HH1	Reduced Cost HH2	Reduced Cost HH3
SM-WW Farmers Practice	¥ -2.849,61	¥-2.306,78	¥-2.835,45
Survey Mean	¥ -2.578,36	¥-2.591,36	¥-2.591,36
Survey highest Maize Yield	¥ -1.148,13	¥-1.148,13	¥-1.148,13
Survey highest Wheat Yield	¥ -1.163,74	¥-1.163,74	¥-1.163,74
Survey lowest N Fert Maize	¥ -2.394,09	¥-2.394,09	¥-2.394,09
Survey lowest N Fert Wheat	¥ -2.117,30	¥-2.117,30	¥-2.117,30
Survey lowest Irri Maize	¥ -1.512,13	¥-1.512,13	¥-1.512,13
Survey highest Gross Margin Maize	¥ -1.127,79	¥-1.127,79	¥-1.127,79
Survey highest Gross Margin SM-WW	¥ -1.498,43	¥-1.498,43	¥-1.498,43
SM-WW Balanced Input Use I	¥ -	¥ -	¥ -
SM-WW Balanced input Use II	¥ -874,41	¥ -874,41	¥ -874,41
SM-WW Balanced Input Use III	¥ -1.759,30	¥-1.759,30	¥-1.759,30
SM-WW Balanced Input Use IV	¥ -2.643,96	¥-2.643,96	¥-2.643,96
SM-WW Recommended Fertilization and Optimized Irrigation I	¥ -169,81	¥ -169,81	¥ -169,81
SM-WW Recommended Fertilization and Optimized Irrigation II	¥ -561,40	¥ -561,40	¥ -561,40
SM-WW Recommended Fertilization and Optimized Irrigation III	¥ -1.708,17	¥-1.708,17	¥-1.708,17
SM-WW Recommended Fertilization and Optimized Irrigation IV	¥ -2.425,99	¥-2.425,99	¥-2.425,99
SprM Balanced Input I	¥ -1.550,92	¥-1.550,92	¥-1.550,92
SprM Balanced Input II	¥ -2.003,28	¥-2.003,28	¥-2.003,28
SprM Balanced Input III	¥ -2.456,17	¥-2.456,17	¥-2.456,17
Spr M Recomm I	¥ -1.669,43	¥-1.669,43	¥-1.669,43
Spr M Recomm II	¥ -2.117,16	¥-2.117,16	¥-2.117,16
Spr M Recomm III	¥ -2.553,22	¥-2.553,22	¥-2.553,22
SprM Cabbage Intercropping	¥ -	¥ -	¥ -
SprM Peanut Intercropping	¥ -	¥ -	¥ -
SM-WW-SprM (3 harvests 2 years) I	¥ -1.175,31	¥-1.175,31	¥-1.175,31
Wheat-Soy-SprM (3 harvests in 2 years)	¥ -	¥ -	¥ -
Conventional SM-WW I	¥ -942,23	¥ -942,23	¥ -942,23
Optimized SM-WW	¥ -385,80	¥ -385,80	¥ -385,80
Optimized Continous Spr M I	¥ -1.330,77	¥-1.330,77	¥-1.330,77
SM (Improved Maize Seeds)-WW	¥ -1.271,24	¥-1.271,24	¥-1.271,24
SM-WW-SprM (3 harvests 2 years) II	¥ -2.993,66	¥-2.993,66	¥-2.993,66
Conventional SM-WW II	¥ -2.467,07	¥-2.467,07	¥-2.467,07
Reduced Input SM-WW	¥ -1.845,79	¥-1.845,79	¥-1.845,79
Optimized Continous SprM II	¥ -2.002,60	¥-2.002,60	¥-2.002,60
Selling 1 kg Maize	¥ -	¥ -	¥ -
Selling 1 kg Wheat	¥ -	¥ -	¥ -
Selling 1 kg Peanut	¥ -0,52	¥ -0,52	¥ -0,52
Selling 1 kg Soya	¥ -10,02	¥ -10,02	¥ -10,02
Selling 1 kg Cabbage	¥ -0,00	¥ -0,00	¥ -0,00

Annex 21 – Continued – Sensitivity Analysis of the Results in the Scenario *Output Price Increase: Maize*

Name	Reduced Cost HH1	Reduced Cost HH2	Reduced Cost HH3
Sign Buying 1 kg Maize	¥ -3,08	¥ -3,08	¥ -3,08
Sign Buying 1 kg of Wheat	¥ -1,55	¥ -1,55	¥ -1,55
Buying 1 Kg of N fertilizer	¥ -	¥ -	¥ -
Buying 1 kg of P fertilizer	¥ -	¥ -	¥ -
Buying 1 kg of K fertilizer	¥ -	¥ -	¥ -
(Indirect) Water Price	¥ -	¥ -	¥ -
Labor Price Year 1	¥ -	¥ -	¥ -
Labor Price Year 2	¥ -	¥ -	¥ -
Selling of 1 Kg of N of Manure	¥ -	¥ -	¥ -
Selling of 1 Kg of P of Manure	¥ -	¥ -	¥ -0,00
Selling of 1 Kg of K of Manure	¥ -	¥ -	¥ -0,00
Buying of 1 Kg of N of Manure	¥ -	¥ -	¥ -
Buying of 1 Kg of P of Manure	¥ -	¥ -	¥ -
Buying of 1 kg K of Manure	¥ -	¥ -	¥ -

Annex 22. Sensitivity Analysis of the Results in the Scenario *Output Price Increase: Wheat*

Name	Reduced Cost HH1	Reduced Cost HH2	Reduced Cost HH3
SM-WW Farmers Practice	¥ -2.479,42	¥-2.508,80	¥-2.551,29
Survey Mean	¥ -2.438,91	¥-2.451,90	¥-2.451,90
Survey highest Maize Yield	¥ -1.604,74	¥-1.604,74	¥-1.604,74
Survey highest Wheat Yield	¥ -839,62	¥ -839,62	¥ -839,62
Survey lowest N Fert Maize	¥ -2.094,20	¥-2.094,20	¥-2.094,20
Survey lowest N Fert Wheat	¥ -1.823,15	¥-1.823,15	¥-1.823,15
Survey lowest Irri Maize	¥ -1.204,28	¥-1.204,28	¥-1.204,28
Survey highest Gross Margin Maize	¥ -1.535,89	¥-1.535,89	¥-1.535,89
Survey highest Gross Margin SM-WW	¥ -1.514,38	¥-1.514,38	¥-1.514,38
SM-WW Balanced Input Use I	¥ -	¥ -	¥ -
SM-WW Balanced input Use II	¥ -894,39	¥ -894,39	¥ -894,39
SM-WW Balanced Input Use III	¥ -1.799,26	¥-1.799,26	¥-1.799,26
SM-WW Balanced Input Use IV	¥ -2.703,90	¥-2.703,90	¥-2.703,90
SM-WW Recommended Fertilization and Optimized Irrigation I	¥ -169,81	¥ -169,81	¥ -169,81
SM-WW Recommended Fertilization and Optimized Irrigation II	¥ -571,39	¥ -571,39	¥ -571,39
SM-WW Recommended Fertilization and Optimized Irrigation III	¥ -1.829,16	¥-1.829,16	¥-1.829,16
SM-WW Recommended Fertilization and Optimized Irrigation IV	¥ -2.647,99	¥-2.647,99	¥-2.647,99
SprM Balanced Input I	¥ -3.453,49	¥-3.453,49	¥-3.453,49
SprM Balanced Input II	¥ -3.662,73	¥-3.662,73	¥-3.662,73
SprM Balanced Input III	¥ -3.872,49	¥-3.872,49	¥-3.872,49
Spr M Recomm I	¥ -3.572,00	¥-3.572,00	¥-3.572,00

Annex 22. – Continued – Sensitivity Analysis of the Results in the Scenario *Output Price Increase: Wheat*

Name	Reduced Cost HH1	Reduced Cost HH2	Reduced Cost HH3
Spr M Recomm II	¥ -3.776,61	¥-3.776,61	¥-3.776,61
Spr M Recomm III	¥ -3.969,55	¥-3.969,55	¥-3.969,55
SprM Cabbage Intercropping	¥ -	¥ -	¥ -
SprM Peanut Intercropping	¥ -	¥ -	¥-1.911,57
SM-WW-SprM (3 harvests 2 years) I	¥ -2.192,24	¥-2.192,24	¥-2.192,24
Wheat-Soy-SprM (3 harvests in 2 years)	¥ -	¥ -	¥ -
Conventional SM-WW I	¥ -1.407,68	¥-1.407,68	¥-1.407,68
Optimized SM-WW	¥ -787,25	¥ -787,25	¥ -787,25
Optimized Continous Spr M I	¥ -3.395,37	¥-3.395,37	¥-3.395,37
SM (Improved Maize Seeds)-WW	¥ -1.549,30	¥-1.549,30	¥-1.549,30
SM-WW-SprM (3 harvests 2 years) II	¥ -3.500,93	¥-3.500,93	¥-3.500,93
Conventional SM-WW II	¥ -2.817,74	¥-2.817,74	¥-2.817,74
Reduced Input SM-WW	¥ -2.536,98	¥-2.536,98	¥-2.536,98
Optimized Continous SprM II	¥ -3.656,66	¥-3.656,66	¥-3.656,66
Selling 1 kg Maize	¥ -	¥ -	¥ -
Selling 1 kg Wheat	¥ -	¥ -	¥ -
Selling 1 kg Peanut	¥ -6,67	¥ -6,67	¥ -
Selling 1 kg Soya	¥ -9,48	¥ -9,48	¥ -9,48
Selling 1 kg Cabbage	¥ -0,30	¥ -0,30	¥ -0,30
Sign Buying 1 kg Maize	¥ -1,46	¥ -1,46	¥ -1,46
Sign Buying 1 kg of Wheat	¥ -3,27	¥ -3,27	¥ -3,27
Buying 1 Kg of N fertilizer	¥ -	¥ -	¥ -
Buying 1 kg of P fertilizer	¥ -	¥ -	¥ -
Buying 1 kg of K fertilizer	¥ -	¥ -	¥ -
(Indirect) Water Price	¥ -	¥ -	¥ -
Labor Price Year 1	¥ -	¥ -	¥ -
Labor Price Year 2	¥ -	¥ -	¥ -
Selling of 1 Kg of N of Manure	¥ -	¥ -	¥ -
Selling of 1 Kg of P of Manure	¥ -	¥ -	¥ -
Selling of 1 Kg of K of Manure	¥ -	¥ -	¥ -
Buying of 1 Kg of N of Manure	¥ -	¥ -	¥ -
Buying of 1 Kg of P of Manure	¥ -	¥ -	¥ -
Buying of 1 kg K of Manure	¥ -	¥ -	¥ -

Annex 23. Sensitivity Analysis of the Results in the Scenario *Output Price Increase: SM-WW*

Name	Reduced Cost HH1	Reduced Cost HH2	Reduced Cost HH3
SM-WW Farmers Practice	¥ -2.586,50	¥-2.349,60	¥-2.349,60
Survey Mean	¥ -2.442,76	¥-2.455,76	¥-2.455,76
Survey highest Maize Yield	¥ -1.353,06	¥-1.353,06	¥-1.353,06
Survey highest Wheat Yield	¥ -985,62	¥ -985,62	¥ -985,62
Survey lowest N Fert Maize	¥ -2.187,93	¥-2.187,93	¥-2.187,93
Survey lowest N Fert Wheat	¥ -1.904,50	¥-1.904,50	¥-1.904,50
Survey lowest Irri Maize	¥ -1.315,17	¥-1.315,17	¥-1.315,17
Survey highest Gross Margin Maize	¥ -1.300,91	¥-1.300,91	¥-1.300,91
Survey highest Gross Margin SM-WW	¥ -1.458,67	¥-1.458,67	¥-1.458,67
SM-WW Balanced Input Use I	¥ -	¥ -	¥ -
SM-WW Balanced input Use II	¥ -851,29	¥ -851,29	¥ -851,29
SM-WW Balanced Input Use III	¥ -1.713,06	¥-1.713,06	¥-1.713,06
SM-WW Balanced Input Use IV	¥ -2.574,60	¥-2.574,60	¥-2.574,60
SM-WW Recommended Fertilization and Optimized Irrigation I	¥ -169,82	¥ -169,82	¥ -169,82
SM-WW Recommended Fertilization and Optimized Irrigation II	¥ -549,84	¥ -549,84	¥ -549,84
SM-WW Recommended Fertilization and Optimized Irrigation III	¥ -1.706,46	¥-1.706,46	¥-1.706,46
SM-WW Recommended Fertilization and Optimized Irrigation IV	¥ -2.445,69	¥-2.445,69	¥-2.445,69
SprM Balanced Input I	¥ -2.391,88	¥-2.391,88	¥-2.391,88
SprM Balanced Input II	¥ -2.710,63	¥-2.710,63	¥-2.710,63
SprM Balanced Input III	¥ -3.029,91	¥-3.029,91	¥-3.029,91
Spr M Recomm I	¥ -2.510,39	¥-2.510,39	¥-2.510,39
Spr M Recomm II	¥ -2.824,51	¥-2.824,51	¥-2.824,51
Spr M Recomm III	¥ -3.126,97	¥-3.126,97	¥-3.126,97
SprM Cabbage Intercropping	¥ -	¥ -	¥ -
SprM Peanut Intercropping	¥ -	¥ -	¥ -
SM-WW-SprM (3 harvests 2 years) I	¥ -1.611,97	¥-1.611,97	¥-1.611,97
Wheat-Soy-SprM (3 harvests in 2 years)	¥ -	¥ -	¥ -
Conventional SM-WW I	¥ -1.141,18	¥-1.141,18	¥-1.141,18
Optimized SM-WW	¥ -566,63	¥ -566,63	¥ -566,63
Optimized Continous Spr M I	¥ -2.260,77	¥-2.260,77	¥-2.260,77
SM (Improved Maize Seeds)-WW	¥ -1.364,37	¥-1.364,37	¥-1.364,37
SM-WW-SprM (3 harvests 2 years) II	¥ -3.125,80	¥-3.125,80	¥-3.125,80
Conventional SM-WW II	¥ -2.544,00	¥-2.544,00	¥-2.544,00
Reduced Input SM-WW	¥ -2.100,33	¥-2.100,33	¥-2.100,33
Optimized Continous SprM II	¥ -2.706,99	¥-2.706,99	¥-2.706,99
Selling 1 kg Maize	¥ -	¥ -	¥ -
Selling 1 kg Wheat	¥ -	¥ -	¥ -
Selling 1 kg Peanut	¥ -3,19	¥ -3,19	¥ -3,19
Selling 1 kg Soya	¥ -9,26	¥ -9,26	¥ -9,26
Selling 1 kg Cabbage	¥ -0,12	¥ -0,12	¥ -0,12

Annex 23 – Continued – Sensitivity Analysis of the Results in the Scenario *Output Price Increase: SM-WW*

Name	Reduced Cost HH1	Reduced Cost HH2	Reduced Cost HH3
Sign Buying 1 kg Maize	¥ -2,19	¥ -2,19	¥ -2,19
Sign Buying 1 kg of Wheat	¥ -2,32	¥ -2,32	¥ -2,32
Buying 1 Kg of N fertilizer	¥ -	¥ -	¥ -
Buying 1 kg of P fertilizer	¥ -	¥ -	¥ -
Buying 1 kg of K fertilizer	¥ -	¥ -	¥ -
(Indirect) Water Price	¥ -	¥ -	¥ -
Labor Price Year 1	¥ -	¥ -	¥ -
Labor Price Year 2	¥ -	¥ -	¥ -
Selling of 1 Kg of N of Manure	¥ -	¥ -	¥ -
Selling of 1 Kg of P of Manure	¥ -	¥ -	¥ -
Selling of 1 Kg of K of Manure	¥ -	¥ -	¥ -
Buying of 1 Kg of N of Manure	¥ -	¥ -	¥ -
Buying of 1 Kg of P of Manure	¥ -	¥ -	¥ -
Buying of 1 kg K of Manure	¥ -	¥ -	¥ -

Annex 24. Sensitivity Analysis of the Results in the Scenario *Output Price Increase: Peanut*

Name	Reduced Cost HH1	Reduced Cost HH2	Reduced Cost HH3
SM-WW Farmers Practice	¥ -2.738,21	¥ -2.454,99	¥ -2.769,37
Survey Mean	¥ -2.568,04	¥ -2.581,04	¥ -2.581,04
Survey highest Maize Yield	¥ -1.389,30	¥ -1.389,30	¥ - 1.389,30
Survey highest Wheat Yield	¥ -1.020,88	¥ -1.020,88	¥ -1.020,88
Survey lowest N Fert Maize	¥ -2.297,78	¥ -2.297,78	¥ -2.297,78
Survey lowest N Fert Wheat	¥ -2.032,02	¥ -2.032,02	¥ -2.032,02
Survey lowest Irri Maize	¥ -1.400,54	¥ -1.400,54	¥ -1.400,54
Survey highest Gross Margin Maize	¥ -1.352,05	¥ -1.352,05	¥ -1.352,05
Survey highest Gross Margin SM-WW	¥ -1.547,56	¥ -1.547,56	¥ -1.547,56
SM-WW Balanced Input Use I	¥ -	¥ -	¥ -
SM-WW Balanced input Use II	¥ -912,80	¥ -912,80	¥ -912,80
SM-WW Balanced Input Use III	¥ -1.836,08	¥ -1.836,08	¥ -1.836,08
SM-WW Balanced Input Use IV	¥ -2.759,12	¥ -2.759,12	¥ -2.759,12
SM-WW Recommended Fertilization and Optimized Irrigation I	¥ -169,81	¥ -169,81	¥ -169,81
SM-WW Recommended Fertilization and Optimized Irrigation II	¥ -580,59	¥ -580,59	¥ -580,59
SM-WW Recommended Fertilization and Optimized Irrigation III	¥ -1.820,66	¥ -1.820,66	¥ -1.820,66
SM-WW Recommended Fertilization and Optimized Irrigation IV	¥ -2.612,59	¥ -2.612,59	¥ -2.612,59
SprM Balanced Input I	¥ -2.567,03	¥ -2.567,03	¥ -2.567,03
SprM Balanced Input II	¥ -2.912,23	¥ -2.912,23	¥ -2.912,23
SprM Balanced Input III	¥ -3.257,95	¥ -3.257,95	¥ -3.257,95
Spr M Recomm I	¥ -2.685,54	¥ -2.685,54	¥ -2.685,54

Annex 24. – Continued – Sensitivity Analysis of the Results in the Scenario *Output Price Increase: Peanut*

Name	Reduced Cost HH1	Reduced Cost HH2	Reduced Cost HH3
Spr M Recomm II	¥ -3.026,11	¥ -3.026,11	¥ -3.026,11
Spr M Recomm III	¥ -3.355,01	¥ -3.355,01	¥ -3.355,01
SprM Cabbage Intercropping	¥ -	¥ -	¥ -
SprM Peanut Intercropping	¥ -	¥ -	¥ -
SM-WW-SprM (3 harvests 2 years) I	¥ -1.729,55	¥ -1.729,55	¥ -1.729,55
Wheat-Soy-SprM (3 harvests in 2 years)	¥ -	¥ -	¥ -
Conventional SM-WW I	¥ -1.196,69	¥ -1.196,69	¥ -1.196,69
Optimized SM-WW	¥ -597,26	¥ -597,26	¥ -597,26
Optimized Continous Spr M I	¥ -2.418,30	¥ -2.418,30	¥ -2.418,30
SM (Improved Maize Seeds)-WW	¥ -1.445,57	¥ -1.445,57	¥ -1.445,57
SM-WW-SprM (3 harvests 2 years) II	¥ -3.344,45	¥ -3.344,45	¥ -3.344,45
Conventional SM-WW II	¥ -2.722,08	¥ -2.722,08	¥ -2.722,08
Reduced Input SM-WW	¥ -2.259,16	¥ -2.259,16	¥ -2.259,16
Optimized Continous SprM II	¥ -2.909,17	¥ -2.909,17	¥ -2.909,17
Selling 1 kg Maize	¥ -	¥ -	¥ -
Selling 1 kg Wheat	¥ -	¥ -	¥ -
Selling 1 kg Peanut	¥ -	¥ -	¥ -
Selling 1 kg Soya	¥ -10,19	¥ -10,19	¥ -10,19
Selling 1 kg Cabbage	¥ -0,18	¥ -0,18	¥ -0,18
Sign Buying 1 kg Maize	¥ -1,46	¥ -1,46	¥ -1,46
Sign Buying 1 kg of Wheat	¥ -1,55	¥ -1,55	¥ -1,55
Buying 1 Kg of N fertilizer	¥ -	¥ -	¥ -
Buying 1 kg of P fertilizer	¥ -	¥ -	¥ -
Buying 1 kg of K fertilizer	¥ -	¥ -	¥ -
(Indirect) Water Price	¥ -	¥ -	¥ -
Labor Price Year 1	¥ -	¥ -	¥ -
Labor Price Year 2	¥ -	¥ -	¥ -
Selling of 1 Kg of N of Manure	¥ -	¥ -	¥ -
Selling of 1 Kg of P of Manure	¥ -	¥ -	¥ -
Selling of 1 Kg of K of Manure	¥ -	¥ -	¥ -
Buying of 1 Kg of N of Manure	¥ -	¥ -	¥ -
Buying of 1 Kg of P of Manure	¥ -	¥ -	¥ -
Buying of 1 kg K of Manure	¥ -	¥ -	¥ -

Annex 25. Sensitivity Analysis of the Results in the Scenario *Fertilization Cap*

Name	Reduced Cost HH1	Reduced Cost HH2	Reduced Cost HH3
SM-WW Farmers Practice	¥ -3.152,93	¥ -4.252,51	¥ -3.859,00
Survey Mean	¥ -4.084,24	¥ -4.097,23	¥ -4.097,23
Survey highest Maize Yield	¥ -2.095,43	¥ -2.095,43	¥ -2.095,43
Survey highest Wheat Yield	¥ -3.325,23	¥ -3.325,23	¥ -3.325,23
Survey lowest N Fert Maize	¥ -1.693,59	¥ -1.693,59	¥ -1.693,59
Survey lowest N Fert Wheat	¥ -50,71	¥ -50,71	¥ -50,71
Survey lowest Irri Maize	¥ -525,44	¥ -525,44	¥ -525,44
Survey highest Gross Margin Maize	¥ -3.487,45	¥ -3.487,45	¥ -3.487,45
Survey highest Gross Margin SM-WW	¥ -83,11	¥ -83,11	¥ -83,11
SM-WW Balanced Input Use I	¥ -	¥ -	¥ -
SM-WW Balanced input Use II	¥ -180,90	¥ -180,90	¥ -180,90
SM-WW Balanced Input Use III	¥ -600,48	¥ -600,48	¥ -600,48
SM-WW Balanced Input Use IV	¥ -1.017,50	¥ -1.017,50	¥ -1.017,50
SM-WW Recommended Fertilization and Optimized Irrigation I	¥ -1.723,89	¥ -1.723,89	¥ -1.723,89
SM-WW Recommended Fertilization and Optimized Irrigation II	¥ -1.538,96	¥ -1.538,96	¥ -1.538,96
SM-WW Recommended Fertilization and Optimized Irrigation III	¥ -1.933,76	¥ -1.933,76	¥ -1.933,76
SM-WW Recommended Fertilization and Optimized Irrigation IV	¥ -2.166,68	¥ -2.166,68	¥ -2.166,68
SprM Balanced Input I	¥ -	¥ -	¥ -
SprM Balanced Input II	¥ -162,20	¥ -162,20	¥ -162,20
SprM Balanced Input III	¥ -324,93	¥ -324,93	¥ -324,93
Spr M Recomm I	¥ -1.566,60	¥ -1.566,60	¥ -1.566,60
Spr M Recomm II	¥ -1.557,08	¥ -1.557,08	¥ -1.557,08
Spr M Recomm III	¥ -1.535,90	¥ -1.535,90	¥ -1.535,90
SprM Cabbage Intercropping	¥ -	¥ -	¥ -
SprM Peanut Intercropping	¥ -	¥ -	¥ -
SM-WW-SprM (3 harvests 2 years) I	¥ -1.062,11	¥ -1.062,11	¥ -1.062,11
Wheat-Soy-SprM (3 harvests in 2 years)	¥ -	¥ -	¥ -
Conventional SM-WW I	¥ -3.673,48	¥ -3.673,48	¥ -3.673,48
Optimized SM-WW	¥ -1.263,48	¥ -1.263,48	¥ -1.263,48
Optimized Continous Spr M I	¥ -707,61	¥ -707,61	¥ -707,61
SM (Improved Maize Seeds)-WW	¥ -2.674,19	¥ -2.674,19	¥ -2.674,19
SM-WW-SprM (3 harvests 2 years) II	¥ -1.661,54	¥ -1.661,54	¥ -1.661,54
Conventional SM-WW II	¥ -4.986,48	¥ -4.986,48	¥ -4.986,48
Reduced Input SM-WW	¥ -629,70	¥ -629,70	¥ -629,70
Optimized Continous SprM II	¥ -305,22	¥ -305,22	¥ -305,22
Selling 1 kg Maize	¥ -	¥ -	¥ -
Selling 1 kg Wheat	¥ -	¥ -	¥ -
Selling 1 kg Peanut	¥ -5,44	¥ -5,44	¥ -5,44
Selling 1 kg Soya	¥ -5,67	¥ -5,67	¥ -5,67
Selling 1 kg Cabbage	¥ -	¥ -	¥ -
Sign Buying 1 kg Maize	¥ -1,46	¥ -1,46	¥ -1,46

Annex 25 – Continued – Sensitivity Analysis of the Results in the Scenario *Fertilization Cap*

Name	Reduced Cost HH1	Reduced Cost HH2	Reduced Cost HH3
Sign Buying 1 kg of Wheat	¥ -1,55	¥ -1,55	¥ -1,55
Buying 1 Kg of N fertilizer	¥ -	¥ -	¥ -
Buying 1 kg of P fertilizer	¥ -	¥ -	¥ -
Buying 1 kg of K fertilizer	¥ -	¥ -	¥ -
(Indirect) Water Price	¥ -	¥ -	¥ -
Labor Price Year 1	¥ -	¥ -	¥ -
Labor Price Year 2	¥ -	¥ -	¥ -
Selling of 1 Kg of N of Manure	¥ -	¥ -	¥ -
Selling of 1 Kg of P of Manure	¥ -	¥ -	¥ -
Selling of 1 Kg of K of Manure	¥ -	¥ -	¥ -
Buying of 1 Kg of N of Manure	¥ -	¥ -	¥ -
Buying of 1 Kg of P of Manure	¥ -	¥ -	¥ -
Buying of 1 kg K of Manure	¥ -	¥ -	¥ -

Annex 26. Sensitivity Analysis of the Results in the Scenario *Introduction of Price for Labor*

Name	Reduced Cost HH1	Reduced Cost HH2	Reduced Cost HH3
SM-WW Farmers Practice	¥ -1.877,25	¥ -1.479,80	¥ -2.445,69
Survey Mean	¥ -2.003,94	¥ -2.016,94	¥ -2.016,94
Survey highest Maize Yield	¥ -1.321,00	¥ -1.321,00	¥ -1.321,00
Survey highest Wheat Yield	¥ -1.907,62	¥ -1.907,62	¥ -1.907,62
Survey lowest N Fert Maize	¥ -3.818,69	¥ -3.818,69	¥ -3.818,69
Survey lowest N Fert Wheat	¥ -1.208,80	¥ -1.208,80	¥ -1.208,80
Survey lowest Irri Maize	¥ -1.628,91	¥ -1.628,91	¥ -1.628,91
Survey highest Gross Margin Maize	¥ -1.101,34	¥ -1.101,34	¥ -1.101,34
Survey highest Gross Margin SM-WW	¥ -1.091,51	¥ -1.091,51	¥ -1.091,51
SM-WW Balanced Input Use I	¥ -	¥ -	¥ -
SM-WW Balanced input Use II	¥ -550,29	¥ -550,29	¥ -550,29
SM-WW Balanced Input Use III	¥ -1.111,06	¥ -1.111,06	¥ -1.111,06
SM-WW Balanced Input Use IV	¥ -1.671,60	¥ -1.671,60	¥ -1.671,60
SM-WW Recommended Fertilization and Optimized Irrigation I	¥ -169,85	¥ -169,85	¥ -169,85
SM-WW Recommended Fertilization and Optimized Irrigation II	¥ -399,34	¥ -399,34	¥ -399,34
SM-WW Recommended Fertilization and Optimized Irrigation III	¥ -1.140,96	¥ -1.140,96	¥ -1.140,96
SM-WW Recommended Fertilization and Optimized Irrigation IV	¥ -1.615,66	¥ -1.615,66	¥ -1.615,66
SprM Balanced Input I	¥ -1.263,89	¥ -1.263,89	¥ -1.263,89
SprM Balanced Input II	¥ -1.473,13	¥ -1.473,13	¥ -1.473,13
SprM Balanced Input III	¥ -1.682,89	¥ -1.682,89	¥ -1.682,89
Spr M Recomm I	¥ -1.382,40	¥ -1.382,40	¥ -1.382,40

Annex 26. – Continued – Sensitivity Analysis of the Results in the Scenario *Introduction of Price for Labor*

Name	Reduced Cost HH1	Reduced Cost HH2	Reduced Cost HH3
Spr M Recomm II	¥ -1.587,01	¥ -1.587,01	¥ -1.587,01
Spr M Recomm III	¥ -1.709,95	¥ -1.709,95	¥ -1.709,95
SprM Cabbage Intercropping	¥ -	¥ -	¥ -
SprM Peanut Intercropping	¥ -	¥ -	¥ -
SM-WW-SprM (3 harvests 2 years) I	¥ -896,73	¥ -896,73	¥ -896,73
Wheat-Soy-SprM (3 harvests in 2 years)	¥ -	¥ -	¥ -
Conventional SM-WW I	¥ -834,18	¥ -834,18	¥ -834,18
Optimized SM-WW	¥ -385,80	¥ -385,80	¥ -385,80
Optimized Continous Spr M I	¥ -1.205,77	¥ -1.205,77	¥ -1.205,77
SM (Improved Maize Seeds)-WW	¥ -247,12	¥ -247,12	¥ -247,12
SM-WW-SprM (3 harvests 2 years) II	¥ -4.408,30	¥ -4.408,30	¥ -4.408,30
Conventional SM-WW II	¥ -5.053,42	¥ -5.053,42	¥ -5.053,42
Reduced Input SM-WW	¥ -4.676,52	¥ -4.676,52	¥ -4.676,52
Optimized Continous SprM II	¥ -2.962,06	¥ -2.962,06	¥ -2.962,06
Selling 1 kg Maize	¥ -	¥ -	¥ -
Selling 1 kg Wheat	¥ -	¥ -	¥ -
Selling 1 kg Peanut	¥ -4,58	¥ -4,58	¥ -4,58
Selling 1 kg Soya	¥ -4,31	¥ -4,31	¥ -4,31
Selling 1 kg Cabbage	¥ -0,12	¥ -0,12	¥ -0,12
Sign Buying 1 kg Maize	¥ -1,46	¥ -1,46	¥ -1,46
Sign Buying 1 kg of Wheat	¥ -1,55	¥ -1,55	¥ -1,55
Buying 1 Kg of N fertilizer	¥ -	¥ -	¥ -
Buying 1 kg of P fertilizer	¥ -	¥ -	¥ -
Buying 1 kg of K fertilizer	¥ -	¥ -	¥ -
(Indirect) Water Price	¥ -	¥ -	¥ -
Labor Price Year 1	¥ -	¥ -	¥ -
Labor Price Year 2	¥ -	¥ -	¥ -
Selling of 1 Kg of N of Manure	¥ -	¥ -	¥ -
Selling of 1 Kg of P of Manure	¥ -	¥ -	¥ -
Selling of 1 Kg of K of Manure	¥ -	¥ -	¥ -
Buying of 1 Kg of N of Manure	¥ -	¥ -	¥ -
Buying of 1 Kg of P of Manure	¥ -	¥ -	¥ -
Buying of 1 kg K of Manure	¥ -	¥ -	¥ -

Annex 27. Sensitivity Analysis of the Results in the Scenario *Area Subsidy: Wheat*

Name	Reduced Cost HH1	Reduced Cost HH2	Reduced Cost HH3
SM-WW Farmers Practice	¥ -1.707,40	¥ -1.650,75	¥ -1.685,89
Survey Mean	¥ -1.674,09	¥ -1.687,09	¥ -1.679,73
Survey highest Maize Yield	¥ -970,75	¥ -970,75	¥ -963,40
Survey highest Wheat Yield	¥ -669,78	¥ -669,78	¥ -662,42
Survey lowest N Fert Maize	¥ -1.507,04	¥ -1.507,04	¥ -1.499,69
Survey lowest N Fert Wheat	¥ -1.137,16	¥ -1.137,16	¥ -1.129,80
Survey lowest Irri Maize	¥ -754,07	¥ -754,07	¥ -746,71
Survey highest Gross Margin Maize	¥ -849,90	¥ -849,90	¥ -842,54
Survey highest Gross Margin SM-WW	¥ -854,87	¥ -854,87	¥ -847,51
SM-WW Balanced Input Use I	¥ 169,85	¥ 169,85	¥ 177,20
SM-WW Balanced input Use II	¥ -380,44	¥ -380,44	¥ -373,09
SM-WW Balanced Input Use III	¥ -941,21	¥ -941,21	¥ -933,86
SM-WW Balanced Input Use IV	¥ -1.501,75	¥ -1.501,75	¥-1.494,39
SM-WW Recommended Fertilization and Optimized Irrigation I	¥ -	¥ -	¥ 7,36
SM-WW Recommended Fertilization and Optimized Irrigation II	¥ -229,49	¥ -229,49	¥ -222,13
SM-WW Recommended Fertilization and Optimized Irrigation III	¥ -971,11	¥ -971,11	¥ -963,75
SM-WW Recommended Fertilization and Optimized Irrigation IV	¥ -1.445,81	¥ -1.445,81	¥-1.438,45
SprM Balanced Input I	¥ -2.219,05	¥ -2.219,05	¥-2.211,69
SprM Balanced Input II	¥ -2.428,29	¥ -2.428,29	¥-2.420,93
SprM Balanced Input III	¥ -2.638,05	¥ -2.638,05	¥-2.630,69
Spr M Recomm I	¥ -2.337,56	¥ -2.337,56	¥-2.330,20
Spr M Recomm II	¥ -2.542,17	¥ -2.542,17	¥-2.534,81
Spr M Recomm III	¥ -2.735,11	¥ -2.735,11	¥-2.727,75
SprM Cabbage Intercropping	¥ -	¥ -	¥ -
SprM Peanut Intercropping	¥ -677,12	¥ -	¥ -
SM-WW-SprM (3 harvests 2 years) I	¥ -1.289,38	¥ -1.289,38	¥-1.282,03
Wheat-Soy-SprM (3 harvests in 2 years)	¥ -	¥ -	¥ -
Conventional SM-WW I	¥ -664,34	¥ -664,34	¥ -656,98
Optimized SM-WW	¥ -215,96	¥ -215,96	¥ -208,60
Optimized Continous Spr M I	¥ -2.160,92	¥ -2.160,92	¥ -2.153,57
SM (Improved Maize Seeds)-WW	¥ -777,28	¥ -777,28	¥ -769,92
SM-WW-SprM (3 harvests 2 years) II	¥ -1.851,45	¥ -1.851,45	¥-1.844,09
Conventional SM-WW II	¥ -1.479,57	¥ -1.479,57	¥-1.472,22
Reduced Input SM-WW	¥ -1.102,67	¥ -1.102,67	¥-1.095,31
Optimized Continous SprM II	¥ -2.422,21	¥ -2.422,21	¥-2.414,86
Selling 1 kg Maize	¥ -	¥ -	¥ -
Selling 1 kg Wheat	¥ -	¥ -	¥ -
Selling 1 kg Peanut	¥ -	¥ -2,36	¥ -2,34
Selling 1 kg Soya	¥ -5,99	¥ -5,99	¥ -5,96
Selling 1 kg Cabbage	¥ -0,00	¥ -0,00	¥ -
Sign Buying 1 kg Maize	¥ -1,46	¥ -1,46	¥ -1,46

Annex 27. – Continued – Sensitivity Analysis of the Results in the Scenario *Area Subsidy: Wheat*

Name	Reduced Cost HH1	Reduced Cost HH2	Reduced Cost HH3
Sign Buying 1 kg of Wheat	¥ -1,55	¥ -1,55	¥ -1,55
Buying 1 Kg of N fertilizer	¥ -	¥ -	¥ -
Buying 1 kg of P fertilizer	¥ -	¥ -	¥ -
Buying 1 kg of K fertilizer	¥ -	¥ -	¥ -
(Indirect) Water Price	¥ -	¥ -	¥ -
Labor Price Year 1	¥ -	¥ -	¥ -
Labor Price Year 2	¥ -	¥ -	¥ -
Selling of 1 Kg of N of Manure	¥ -	¥ -	¥ -
Selling of 1 Kg of P of Manure	¥ -	¥ -	¥ -0,00
Selling of 1 Kg of K of Manure	¥ -	¥ -	¥ -
Buying of 1 Kg of N of Manure	¥ -	¥ -	¥ -
Buying of 1 Kg of P of Manure	¥ -	¥ -	¥ -
Buying of 1 kg K of Manure	¥ -	¥ -	¥ -

Annex 28. Sensitivity Analysis of the Results in the Scenario *Yield Premium*

Name	Reduced Cost HH1	Reduced Cost HH2	Reduced Cost HH3
SM-WW Farmers Practice	¥ -2.827,25	¥ -2.520,60	¥ -2.863,09
Survey Mean	¥ -2.642,93	¥ -2.655,93	¥ -2.655,93
Survey highest Maize Yield	¥ -1.415,02	¥ -1.415,02	¥ -1.415,02
Survey highest Wheat Yield	¥ -1.039,62	¥ -1.039,62	¥ -1.039,62
Survey lowest N Fert Maize	¥ -2.361,99	¥ -2.361,99	¥ -2.361,99
Survey lowest N Fert Wheat	¥ -2.107,00	¥ -2.107,00	¥ -2.107,00
Survey lowest Irri Maize	¥ -1.449,83	¥ -1.449,83	¥ -1.449,83
Survey highest Gross Margin Maize	¥ -1.386,41	¥ -1.386,41	¥ -1.386,41
Survey highest Gross Margin SM-WW	¥ -1.601,63	¥ -1.601,63	¥ -1.601,63
SM-WW Balanced Input Use I	¥ -	¥ -	¥ -
SM-WW Balanced input Use II	¥ -950,29	¥ -950,29	¥ -950,29
SM-WW Balanced Input Use III	¥ -1.911,06	¥ -1.911,06	¥ -1.911,06
SM-WW Balanced Input Use IV	¥ -2.871,60	¥ -2.871,60	¥ -2.871,60
SM-WW Recommended Fertilization and Optimized Irrigation I	¥ -169,81	¥ -169,81	¥ -169,81
SM-WW Recommended Fertilization and Optimized Irrigation II	¥ -599,34	¥ -599,34	¥ -599,34
SM-WW Recommended Fertilization and Optimized Irrigation III	¥ -1.890,96	¥-1.890,96	¥-1.890,96
SM-WW Recommended Fertilization and Optimized Irrigation IV	¥ -2.715,70	¥-2.715,70	¥-2.715,70
SprM Balanced Input I	¥ -2.688,87	¥-2.688,87	¥-2.688,87
SprM Balanced Input II	¥ -3.048,13	¥-3.048,13	¥-3.048,13
SprM Balanced Input III	¥ -3.407,91	¥-3.407,91	¥-3.407,91
Spr M Recomm I	¥ -2.807,38	¥-2.807,38	¥-2.807,38
Spr M Recomm II	¥ -3.162,01	¥-3.162,01	¥-3.162,01

Annex 28. – Continued – Sensitivity Analysis of the Results in the Scenario *Yield Premium*

Name	Reduced Cost HH1	Reduced Cost HH2	Reduced Cost HH3
Spr M Recomm III	¥ -3.504,97	¥-3.504,97	¥-3.504,97
SprM Cabbage Intercropping	¥ -	¥ -	¥ -
SprM Peanut Intercropping	¥ -	¥ -	¥-1.233,65
SM-WW-SprM (3 harvests 2 years) I	¥ -1.809,22	¥-1.809,22	¥-1.809,22
Wheat-Soy-SprM (3 harvests in 2 years)	¥ -	¥ -	¥ -
Conventional SM-WW I	¥ -1.234,18	¥-1.234,18	¥-1.234,18
Optimized SM-WW	¥ -619,13	¥ -619,13	¥ -619,13
Optimized Continous Spr M I	¥ -2.530,77	¥-2.530,77	¥-2.530,77
SM (Improved Maize Seeds)-WW	¥ -1.497,12	¥-1.497,12	¥-1.497,12
SM-WW-SprM (3 harvests 2 years) II	¥ -3.481,30	¥-3.481,30	¥-3.481,30
Conventional SM-WW II	¥ -2.833,02	¥-2.833,02	¥-2.833,02
Reduced Input SM-WW	¥ -2.361,20	¥-2.361,20	¥-2.361,20
Optimized Continous SprM II	¥ -3.045,39	¥-3.045,39	¥-3.045,39
Selling 1 kg Maize	¥ -	¥ -	¥ -
Selling 1 kg Wheat	¥ -	¥ -	¥ -
Selling 1 kg Peanut	¥ -4,30	¥ -4,30	¥ -
Selling 1 kg Soya	¥ -10,75	¥ -10,75	¥ -10,75
Selling 1 kg Cabbage	¥ -0,22	¥ -0,22	¥ -0,22
Sign Buying 1 kg Maize	¥ -1,46	¥ -1,46	¥ -1,46
Sign Buying 1 kg of Wheat	¥ -1,55	¥ -1,55	¥ -1,55
Buying 1 Kg of N fertilizer	¥ -	¥ -	¥ -
Buying 1 kg of P fertilizer	¥ -	¥ -	¥ -
Buying 1 kg of K fertilizer	¥ -	¥ -	¥ -
(Indirect) Water Price	¥ -	¥ -	¥ -
Labor Price Year 1	¥ -	¥ -	¥ -
Labor Price Year 2	¥ -	¥ -	¥ -
Selling of 1 Kg of N of Manure	¥ -	¥ -0,00	¥ -
Selling of 1 Kg of P of Manure	¥ -	¥ -	¥ -
Selling of 1 Kg of K of Manure	¥ -	¥ -	¥ -
Buying of 1 Kg of N of Manure	¥ -0,00	¥ -	¥ -
Buying of 1 Kg of P of Manure	¥ -	¥ -	¥ -
Buying of 1 kg K of Manure	¥ -	¥ -	¥ -

Annex 29. Sensitivity Analysis of the Results in the Scenario *Premium for Reduced Water Use*

Name	Reduced Cost HH1	Reduced Cost HH2	Reduced Cost HH3
SM-WW Farmers Practice	¥ -7.929,20	¥ -3.357,06	¥ -4.528,15
Survey Mean	¥ -5.884,93	¥ -5.897,93	¥ -5.897,93
Survey highest Maize Yield	¥ -4.567,00	¥ -4.567,00	¥ -4.567,00
Survey highest Wheat Yield	¥ -4.767,11	¥ -4.767,11	¥ -4.767,11
Survey lowest N Fert Maize	¥ -6.535,75	¥ -6.535,75	¥ -6.535,75
Survey lowest N Fert Wheat	¥ -3.350,67	¥ -3.350,67	¥ -3.350,67
Survey lowest Irri Maize	¥ -952,70	¥ -952,70	¥ -952,70
Survey highest Gross Margin Maize	¥ -1.921,56	¥ -1.921,56	¥ -1.921,56
Survey highest Gross Margin SM-WW	¥ -4.479,06	¥ -4.479,06	¥ -4.479,06
SM-WW Balanced Input Use I	¥ -891,50	¥ -891,50	¥ -891,50
SM-WW Balanced input Use II	¥ -1.946,57	¥ -1.946,57	¥ -1.946,57
SM-WW Balanced Input Use III	¥ -3.012,12	¥ -3.012,12	¥ -3.012,12
SM-WW Balanced Input Use IV	¥ -4.077,44	¥ -4.077,44	¥ -4.077,44
SM-WW Recommended Fertilization and Optimized Irrigation I	¥ -1.061,29	¥ -1.061,29	¥ -1.061,29
SM-WW Recommended Fertilization and Optimized Irrigation II	¥ -1.543,22	¥ -1.543,22	¥ -1.543,22
SM-WW Recommended Fertilization and Optimized Irrigation III	¥ -2.978,92	¥ -2.978,92	¥ -2.978,92
SM-WW Recommended Fertilization and Optimized Irrigation IV	¥ -3.895,36	¥ -3.895,36	¥ -3.895,36
SprM Balanced Input I	¥ -2.080,51	¥ -2.080,51	¥ -2.080,51
SprM Balanced Input II	¥ -2.479,07	¥ -2.479,07	¥ -2.479,07
SprM Balanced Input III	¥ -2.878,15	¥ -2.878,15	¥ -2.878,15
Spr M Recomm I	¥ -2.199,02	¥ -2.199,02	¥ -2.199,02
Spr M Recomm II	¥ -2.592,95	¥ -2.592,95	¥ -2.592,95
Spr M Recomm III	¥ -2.975,21	¥ -2.975,21	¥ -2.975,21
SprM Cabbage Intercropping	¥ -	¥ -	¥ -
SprM Peanut Intercropping	¥ -	¥ -	¥ -
SM-WW-SprM (3 harvests 2 years) I	¥ -1.184,98	¥ -1.184,98	¥ -1.184,98
Wheat-Soy-SprM (3 harvests in 2 years)	¥ -	¥ -	¥ -
Conventional SM-WW I	¥ -1.325,41	¥ -1.325,41	¥ -1.325,41
Optimized SM-WW	¥ -	¥ -	¥ -
Optimized Continous Spr M I	¥ -1.498,22	¥ -1.498,22	¥ -1.498,22
SM (Improved Maize Seeds)-WW	¥ -2.894,30	¥ -2.894,30	¥ -2.894,30
SM-WW-SprM (3 harvests 2 years) II	¥ -2.926,85	¥ -2.926,85	¥ -2.926,85
Conventional SM-WW II	¥ -3.162,87	¥ -3.162,87	¥ -3.162,87
Reduced Input SM-WW	¥ -2.266,18	¥ -2.266,18	¥ -2.266,18
Optimized Continous SprM II	¥ -1.905,85	¥ -1.905,85	¥ -1.905,85
Selling 1 kg Maize	¥ -	¥ -	¥ -
Selling 1 kg Wheat	¥ -	¥ -	¥ -
Selling 1 kg Peanut	¥ -	¥ -	¥ -
Selling 1 kg Soya	¥ -8,65	¥ -8,65	¥ -8,65
Selling 1 kg Cabbage	¥ -0,22	¥ -0,22	¥ -0,22

Annex 29. – Continued – Sensitivity Analysis of the Results in the Scenario *Premium for Reduced Water Use*

Name	Reduced Cost HH1	Reduced Cost HH2	Reduced Cost HH3
Sign Buying 1 kg Maize	¥ -1,46	¥ -1,46	¥ -1,46
Sign Buying 1 kg of Wheat	¥ -1,55	¥ -1,55	¥ -1,55
Buying 1 Kg of N fertilizer	¥ -	¥ -	¥ -
Buying 1 kg of P fertilizer	¥ -	¥ -	¥ -
Buying 1 kg of K fertilizer	¥ -	¥ -	¥ -
(Indirect) Water Price	¥ -	¥ -	¥ -
Labor Price Year 1	¥ -	¥ -	¥ -
Labor Price Year 2	¥ -	¥ -	¥ -
Selling of 1 Kg of N of Manure	¥ -	¥ -	¥ -
Selling of 1 Kg of P of Manure	¥ -	¥ -	¥ -
Selling of 1 Kg of K of Manure	¥ -	¥ -	¥ -
Buying of 1 Kg of N of Manure	¥ -	¥ -	¥ -
Buying of 1 Kg of P of Manure	¥ -	¥ -	¥ -
Buying of 1 kg K of Manure	¥ -	¥ -	¥ -

Annex 30. Sensitivity Analysis of the Results in the Scenario *Environmental Fee*

Name	Reduced Cost HH1	Reduced Cost HH2	Reduced Cost HH3
SM-WW Farmers Practice	¥ -8.167,08	¥ -3.488,14	¥ -4.664,99
Survey Mean	¥ -6.100,72	¥ -6.113,72	¥ -6.113,72
Survey highest Maize Yield	¥ -4.721,17	¥ -4.721,17	¥ -4.721,17
Survey highest Wheat Yield	¥ -5.024,66	¥ -5.024,66	¥ -5.024,66
Survey lowest N Fert Maize	¥ -6.675,67	¥ -6.675,67	¥ -6.675,67
Survey lowest N Fert Wheat	¥ -3.305,70	¥ -3.305,70	¥ -3.305,70
Survey lowest Irri Maize	¥ -886,87	¥ -886,87	¥ -886,87
Survey highest Gross Margin Maize	¥ -2.047,80	¥ -2.047,80	¥ -2.047,80
Survey highest Gross Margin SM-WW	¥ -4.519,31	¥ -4.519,31	¥ -4.519,31
SM-WW Balanced Input Use I	¥ -910,30	¥ -910,30	¥ -910,30
SM-WW Balanced input Use II	¥ -1.944,01	¥ -1.944,01	¥ -1.944,01
SM-WW Balanced Input Use III	¥ -3.000,01	¥ -3.000,01	¥ -3.000,01
SM-WW Balanced Input Use IV	¥ -4.055,66	¥ -4.055,66	¥ -4.055,66
SM-WW Recommended Fertilization and Optimized Irrigation I	¥ -1.160,45	¥ -1.160,45	¥ -1.160,45
SM-WW Recommended Fertilization and Optimized Irrigation II	¥ -1.619,83	¥ -1.619,83	¥ -1.619,83
SM-WW Recommended Fertilization and Optimized Irrigation III	¥ -3.034,49	¥ -3.034,49	¥ -3.034,49
SM-WW Recommended Fertilization and Optimized Irrigation IV	¥ -3.936,45	¥ -3.936,45	¥ -3.936,45
SprM Balanced Input I	¥ -1.946,55	¥ -1.946,55	¥ -1.946,55
SprM Balanced Input II	¥ -2.341,83	¥ -2.341,83	¥ -2.341,83
SprM Balanced Input III	¥ -2.737,64	¥ -2.737,64	¥ -2.737,64
Spr M Recomm I	¥ -2.139,94	¥ -2.139,94	¥ -2.139,94

Annex 30. – Continued – Sensitivity Analysis of the Results in the Scenario *Environmental Fee*

Name		Reduced Cost HH1		Reduced Cost HH2		Reduced Cost HH3
Spr M Recomm II	¥	-2.521,95	¥	-2.521,95	¥	-2.521,95
Spr M Recomm III	¥	-2.892,29	¥	-2.892,29	¥	-2.892,29
SprM Cabbage Intercropping	¥	-	¥	-	¥	-
SprM Peanut Intercropping	¥	-	¥	-	¥	-
SM-WW-SprM (3 harvests 2 years) I	¥	-1.134,77	¥	-1.134,77	¥	-1.134,77
Wheat-Soy-SprM (3 harvests in 2 years)	¥	-	¥	-	¥	-
Conventional SM-WW I	¥	-1.452,58	¥	-1.452,58	¥	-1.452,58
Optimized SM-WW	¥	-	¥	-	¥	-
Optimized Continous Spr M I	¥	-1.388,50	¥	-1.388,50	¥	-1.388,50
SM (Improved Maize Seeds)-WW	¥	-3.013,77	¥	-3.013,77	¥	-3.013,77
SM-WW-SprM (3 harvests 2 years) II	¥	-2.845,69	¥	-2.845,69	¥	-2.845,69
Conventional SM-WW II	¥	-3.312,69	¥	-3.312,69	¥	-3.312,69
Reduced Input SM-WW	¥	-2.194,74	¥	-2.194,74	¥	-2.194,74
Optimized Continous SprM II	¥	-1.753,45	¥	-1.753,45	¥	-1.753,45
Selling 1 kg Maize	¥	-	¥	-	¥	-
Selling 1 kg Wheat	¥	-	¥	-	¥	-
Selling 1 kg Peanut	¥	-	¥	-	¥	-
Selling 1 kg Soya	¥	-8,45	¥	-8,45	¥	-8,45
Selling 1 kg Cabbage	¥	-0,22	¥	-0,22	¥	-0,22
Sign Buying 1 kg Maize	¥	-1,46	¥	-1,46	¥	-1,46
Sign Buying 1 kg of Wheat	¥	-1,55	¥	-1,55	¥	-1,55
Buying 1 Kg of N fertilizer	¥	-	¥	-	¥	-
Buying 1 kg of P fertilizer	¥	-	¥	-	¥	-
Buying 1 kg of K fertilizer	¥	-	¥	-	¥	-
(Indirect) Water Price	¥	-	¥	-	¥	-
Labor Price Year 1	¥	-	¥	-	¥	-
Labor Price Year 2	¥	-	¥	-	¥	-
Selling of 1 Kg of N of Manure	¥	-	¥	-	¥	-
Selling of 1 Kg of P of Manure	¥	-	¥	-	¥	-
Selling of 1 Kg of K of Manure	¥	-	¥	-	¥	-
Buying of 1 Kg of N of Manure	¥	-	¥	-	¥	-
Buying of 1 Kg of P of Manure	¥	-	¥	-	¥	-
Buying of 1 kg K of Manure	¥	-	¥	-	¥	-