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List of abbreviations

B	nitrogen balance	mu	Chinese area unit 亩 (15 mu = 1 ha)
bill.	billion	N	nitrogen
C	nitrogen content of crop	n/a	not applicable
CDF	Cumulative distribution function	NCP	North China Plain
D	natural nitrogen outflow	O	other variable costs
G	Gross Margin	p	probability
GM	Gross Margin	P	crop price
ha	hectare	pers.	person
HRS	Household Responsibility System	r^2	model fit indicator
I	natural nitrogen inflow	PR China	People's Republic of China
kg	kilogramme	Q	nitrogen price
km	kilometre	S	nitrogen input from straw left on the field
LL	likelihood	SPSS	Statistical software of SPSS Inc.
LU	labour unit	t	Metric tons
m	metre	VTE	Village Township Enterprises
mill.	million	Y	yield
ml	millilitres	¥	Chinese currency (10 ¥ ≈ 1 €)
mm	millimetre		

List of crops

winter wheat	Triticum aestivum	冬小麦
summer maize	Zea mays	玉米
cotton	Gossypium hirsutum.	棉花
garlic	Allium sativum	大蒜
grape	Vitis ssp.	葡萄
onion	Allium cepa var. cepa	洋葱
peanut	Arachis hypogaea	花生
rapeseed	Brassica napus	油菜籽
soybean	Glycine max	大豆
tomato	Lycopersicon lycopersicum	西红柿
watermelon	Citrullus lanatus var. caffer	西瓜

List and explanation of the key variables

code	shortcut	unit	explanation
V_{001}	family size	[pers.]	number of family members
V_{002}	household size	[pers.]	number of family members living on farm
V_{003}	household head age	[a]	age of household head
V_{004}	highest family education	[1-4]	highest education of family members 1 = illiterate; 2 = primary school; 3 = middle school; 4 = high school or above
V_{005}	family work force	[LU]	amount total family labour
V_{006}	farming work force	[LU]	amount family labour available for farm work
V_{007}	off-farm work force	[LU]	amount family labour working off-farm
V_{008}	farming work force ratio	[%]	ratio between farming work force and family work force
V_{009}	high farming work force ratio	[1,0]	farming work force ratio >85% (median)
V_{010}	labour type 4 on farm	[1,0]	labour type 4 (temporary off-farm and temporary on own farm) on farm available
V_{011}	village share labour type 4	[%]	share of households at village level having at least one family member of labour type 4
V_{012}	labour type 5 on farm	[1,0]	labour type 5 (fulltime off-farm) on farm available
V_{013}	village share labour type 5	[%]	share of households at village level having at least one family member of labour type 5
V_{014}	farmland	[ha]	farmland of the farm household
V_{015}	village average farmland	[ha]	village average farmland per farm household
V_{016}	relative farmland	[%]	farmland as percentage of average farm land at village average
V_{017}	high relative farmland	[1,0]	relative farmland exceeds 100%
V_{018}	farmland family ratio	[ha pers.$^{-1}$]	farmland per family member
V_{019}	farmland farming work force ratio	[ha LU^{-1}]	farmland per farming work force
V_{020}	rent-in farmland	[1,0]	farm household rent-in additional land
V_{021}	long term wheat yield	[t ha^{-1}]	estimated long term wheat yield on farm plots
V_{022}	household income type 1	[1,0]	only farming net cash income
V_{023}	household income type 2	[1,0]	farming and local off-farm job income
V_{024}	household income type 3	[1,0]	farming and income from migration
V_{025}	village share income type 1	[%]	share of households at village level which have only farming net cash income
V_{026}	village share income type 2	[%]	share of households at village level which have farming and local off-farm job income
V_{027}	village share income type 3	[%]	share of households at village level which have farming and income from migration
V_{028}	household income	[1 000 ¥]	total cash income of farm household
V_{029}	low household income	[1,0]	household income is less than 4 950 ¥
V_{030}	high household income	[1,0]	household income exceeds 11 050 ¥

List and description of key variables (cont.)

code	shortcut	unit	explanation
V_{031}	village average household income	[1 000 ¥]	average household income at village level
V_{032}	relative household income	[%]	household income as percentage of village average household income
V_{033}	high relative household income	[1,0]	relative household income exceeds 100%
V_{034}	farming net cash income	[¥]	net cash income from farming
V_{035}	farming net non-cash income	[¥]	net non-cash income from own consumption
V_{036}	farming total net income	[¥]	net cash income from farming and net non-cash income from own consumption
V_{037}	farming income ratio	[%]	farming net income to household income ratio
V_{038}	full-farming income	[1,0]	income share from farming exceeds 50%
V_{039}	off-farm income	[¥]	net income from all off-farm income sources
V_{040}	off-farm income ratio	[%]	off-farm income to household income ratio
V_{041}	pure wheat and maize pattern	[1,0]	cultivation of only wheat and maize
V_{042}	manure usage	[1,0]	application of manure
V_{043}	fertilizer costs all farm crops	[¥ ha^{-1}]	average weighted fertilizer costs at all crops cultivated by the farm household
V_{044}	high fertilizer costs all farm crops	[1,0]	fertilizer costs exceeds 1 233 ¥ ha^{-1} (median)
V_{045}	nitrogen input all farm crops	[kg ha^{-1}]	average weighted nitrogen input at all crops cultivated by the farm household
V_{046}	high nitrogen input all farm crops	[1,0]	nitrogen input exceeds 237 kg ha^{-1} (median)
V_{047}	village average nitrogen input all farm crops	[kg ha^{-1}]	village average of nitrogen input at all crops
V_{048}	nitrogen price all farm crops	[¥ kg^{-1}]	average weighted nitrogen price at all crops cultivated by the farm household
V_{049}	use of expensive nitrogen fertilizer	[1,0]	usage of fertilizer (usually compound fertilizer) with an nitrogen price of more than 10 ¥ per kg
V_{050}	nitrogen use efficiency all farm crops	[kg kg^{-1}]	average weighted nitrogen yield ratio at all crops cultivated by the farm household
V_{051}	gross margin all farm crops	[¥ ha^{-1}]	average weighted gross margin at all crops cultivated by the farm household
V_{052}	nitrogen balance all farm crops	[kg ha^{-1}]	average weighted nitrogen balance at all crops cultivated by the farm household
V_{053}	nitrogen balance type 1	[1,0]	farm household characterised by equalised nitrogen balance
V_{054}	nitrogen balance type 3	[1,0]	farm household characterised by heavy nitrogen surplus at nitrogen balance
V_{055}	overuse ratio all farm crops	[%]	average weighted overuse ratio (farm nitrogen balance to nitrogen content of harvested corps) all crops cultivated by the farm household

List and description of key variables (cont.)

wheat	maize	peanut	cotton	shortcut	unit	explanation
V_{060}	V_{090}	V_{120}	V_{150}	cultivation area	[ha]	cultivation area of the crop
V_{061}	V_{091}	V_{121}	V_{151}	seed costs	[¥ ha^{-1}]	seed costs of the crop
V_{062}	V_{092}	V_{122}	V_{152}	fertilizer costs	[¥ ha^{-1}]	fertilizer costs of the crop
V_{063}	V_{093}	V_{123}	V_{153}	village average fertilizer costs	[¥ ha^{-1}]	average fertilizer costs at village level
V_{064}	V_{094}	V_{124}	V_{154}	relative fertilizer costs	[%]	fertilizer costs as percentage of village average fertilizer costs
V_{065}	V_{095}	V_{125}	V_{155}	nitrogen input	[kg ha^{-1}]	nitrogen application level
V_{066}	V_{096}	V_{126}	V_{156}	high nitrogen input	[1,0]	above median nitrogen input
V_{067}	V_{097}	V_{127}	V_{157}	village average nitrogen input	[kg ha^{-1}]	average nitrogen input at village level
V_{068}	V_{098}	V_{128}	V_{158}	relative nitrogen input	[%]	nitrogen input as percentage of village average nitrogen input
V_{069}	V_{099}	V_{129}	V_{159}	nitrogen price	[¥ kg^{-1}]	fertilizer costs to nitrogen input ratio
V_{070}	V_{100}	V_{130}	V_{160}	manure usage	[1,0]	application of manure
V_{071}	V_{101}	V_{131}	V_{161}	herbicide usage	[1,0]	application of herbicides
V_{072}	V_{102}	V_{132}	V_{162}	insecticide usage	[1,0]	application of insecticides
V_{073}	V_{103}	V_{133}	V_{163}	plastic usage	[1,0]	application of plastic to cover soil
V_{074}	V_{104}	V_{134}	V_{164}	variable costs	[¥ ha^{-1}]	total variable costs
V_{075}	V_{105}	V_{135}	V_{165}	yield	[kg ha^{-1}]	harvested yield
V_{076}	V_{106}	V_{136}	V_{166}	village average yield	[kg ha^{-1}]	average yield at village level
V_{077}	V_{107}	V_{137}	V_{167}	relative yield	[%]	nitrogen input as percentage of village average yield
V_{078}	V_{108}	V_{138}	V_{168}	high relative yield	[1,0]	relative yield exceeds 100%
V_{079}	V_{109}	V_{139}	V_{169}	sold-harvest ratio	[%]	amount sold to total harvest ratio
V_{080}	V_{110}	V_{140}	V_{170}	crop price	[¥ kg^{-1}]	price of harvested and sold crop
V_{081}	V_{111}	V_{141}	V_{171}	calculated revenue	[¥ ha^{-1}]	yield multiplied by average crop price
V_{082}	V_{112}	V_{142}	V_{172}	calculated gross margin	[¥ ha^{-1}]	calculated revenue minus variable costs
V_{083}	V_{113}	V_{143}	V_{173}	village average calculated gross margin	[¥ ha^{-1}]	average calculated gross margin at village level
V_{084}	V_{114}	V_{144}	V_{174}	relative calculated gross margin	[%]	gross margin as percentage of village average gross margin
V_{085}	V_{115}	V_{145}	V_{175}	nitrogen use efficiency (yield nitrogen input ratio)	[kg kg^{-1}]	yield per unit nitrogen input
V_{086}	V_{116}	V_{146}	V_{176}	nitrogen balance	[kg ha^{-1}]	nitrogen input minus nitrogen content of harvested crops
V_{087}	V_{117}	V_{147}	V_{177}	nitrogen surplus ratio [%]	[%]	nitrogen content of harvested crops as percentage of nitrogen balance
V_{088}	V_{118}	V_{148}	V_{178}	crop selling	[1,0]	selling of harvested crop
V_{089}	V_{119}	V_{149}	V_{179}	return straw	[1,0]	return straw to the field

1 Introduction

China is a country with limited arable land area per capita. Since the foundation of the PR China in the year 1949, a huge achievement in food production has been made, but the nation passed through several phases with suffering from food shortage. The establishment of people's commune as the basic unit of production and the Great Leap Forward policies in 1958 placed most of the agricultural decisions to upper-level government units and led to a complex planning process in agricultural production. This situation, together with a series of natural disasters, caused production to decline sharply after 1958, leading the nation into one of the most severe famines in modern history. Between 1959 and 1961, at least 30 million people died from starvation, mostly in rural areas. Changes in agricultural policies and several years of favourable weather led to quick recovery of grain production in the early 1960s (HUANG, J. and S. ROZELLE 1995). By the mid 1980ies the country had solved its long-standing problem of inadequate grain production and by the end of the 1990s, China was supplying food for 22 per cent of the global population using only seven per cent of the world's arable land (ZHAI, H. 2004).

China is now confident in its continued ability to feed its population, which is forecast to reach 1.6 billion in the coming decades, but there are two major targets for rural China (SHI, Y. and X. CHENG 2004). Firstly, one goal is rural development to increase the income of rural households in order to slow down the increasing income disparity between rural and urban residents. Secondly, the improvement of the cultivation system towards more sustainability is a further goal.

SHI and CHENG (2004) pointed out that decades of inefficient utilisation of resources and high consumption of materials and energy led to overexploitation of water and land resources and degradation of the environment. The increased and finally excessive use of mineral fertilizer resulted in low efficiencies. This overuse of fertilizers has led to widespread nitrate runoff, as well as residues in food above prescribed limits. ZHANG et al. (1996) wrote already 10 years ago that the removal by crops is only half of the fertilisation amount; the rest is subject to leaching, runoff and volatilization.

The agricultural food production in the North China Plain is characterized by high-level production. This raises serious environmental problems such as water availability, water pollution, air pollution, soil contamination, and soil erosion. The Sino-German Research Training Group "Modelling Material Flows and Production Systems for Sustainable Resource Use in Intensified Crop Production in the North China Plain" with its origins from different disciplines measures and models related material flows and production system.[1] This subproject 3.1 "Modeling of Sustainable Production Systems on Farm Scale, Regional, and Sectoral Levels" is dealing with the hypothesis that substantial changes in farming systems and management practices can reduce environmental pollution and at the same time stabilize or increase the income of

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[1] This International Research Training Group is a co-operation of University of Hohenheim, Stuttgart, Germany and China Agricultural University, Beijing, PR China. It is financed by the German Research Foundation (DFG) and the Chinese Ministry of Education.

farmers. The overall objective of this subproject is to develop partial models for a quantitative analysis of measures in agricultural and environmental policies.

Over-fertilisation and a resulting low nitrogen use efficiency is representative for the agricultural production in the North China Plain (JU, X., C.L. KOU ET AL. 2006). Further, ZHEN et al. (2005) identified that only about six per cent of surveyed households apply the recommendations for balanced input use. The situation arises the question, why farmers do not consider the crop demand as criterion for the nitrogen application.

Further, JU et al. (2004) found out that the nitrogen application in wheat cultivation in the North China Plain shows a broad variation. This fact leads to the next questions, do all farm households apply nitrogen beyond the crop demand. Further, what do farm households have in common, which apply nitrogen far beyond the crop demand? As indicated from the literature review, a nitrogen surplus is expected at the cultivation systems of the majority of surveyed farm households. This situation arises the question of the potential reduction of nitrogen surplus and its impact on net income. Finally, the overall topic of this research project is the identification and evaluation of applicable instruments for a sustainable nitrogen use without a reduction of income of farm households. Scenarios of the identified instruments simulate the impact of these instruments on nitrogen balance and net income.

2 Background of the Agricultural Production in Rural China

On the one hand, inside China the North China Plain (NCP) is often regarded as the food bowl of the country (ZHEN, L., J.K. ROUTRAY ET AL. 2005). On the other hand, the productivity of the cropping systems in the North China Plain is restricted by the resources land and water. Additionally, the excessive application of mineral fertilizer and pesticides has raised serious environmental problems (CHENG, X. 2004).

Farming is both, production of food as well as income source of rural households. For this reason, the cultivation system cannot be considered as an isolated system, it is part of the overall system farm household. Especially, the topic income generation plays a major role, because the income share from off-farm activities often exceeds the income share from farming. For this reason, the analysis of interactions between the off-farm activities and the cultivation system cannot be excluded.

2.1 Problems at the Agriculture System in the North China Plain

2.1.1 Income Generation of Farm Households

The economic boost of the coastal regions shows an enormous increase in income of urban households, but the income disparity between rural and urban households widens (WAN, G. 2007). Rural China shows often still the characteristics of a developing country, which are poor villages, no roads and a less developed infrastructure. The Word Bank estimates that about 200 million people in China have less than 1 US Dollar per day, which is the present internationally accepted definition of poverty (ERLING, J. and K. WENK 2006). Without doubt, there is an enormous income gab between urban and rural households, but rural farm households are not homogenous in household income. Farm households differ in kind of income sources as well as in generated income from each income source. For this reason, the income disparity inside the rural areas is increasing (WAN, G. and Z. ZHOU 2005).

In rural areas of the North China Plain, the typical farm household cultivates 0.5 ha of farmland and the major cultivated crops are wheat and maize. Additionally, farm households cultivate cash crops, such as cotton. Due to the low farm size, the income from farming enables only a low standard of living. Further the limited arable land generated a labour surplus in rural area, there are estimates of 140 million people onwards (QUAN, Y. and Z.-R. LIU 2002). Several authors described the low labour productivity of Chinese farmers and the agricultural labour surplus of about 30 per cent of rural workers (LÖW, D. 2003). For example, in Jiangsu Province the typical farm size is less than 0.1 ha per agricultural worker and an experiment showed that the right farm size to ensure an income equivalent to that of a worker in a rural township or village enterprise would be 1 to 2 ha per person (LÖW, D. 2003).

On the one hand, a low ratio of labour to farmland might lead to the assumption that farm households shift their cultivation to labour intensive crops, which are connected with a high land productivity. On the other hand, CHEN et al. (2006) stated that food security is still the first priority to farm households and in their efforts to

maintain self-sufficiency in food production, farm households feel obliged to practice the wheat maize cropping system although it has a low economic benefit. The Chinese government faced the problem of income disparity between urban and rural residents. Several instruments have been started to support rural development and increase the income of rural households. Agricultural taxes are abolished since 2006 and farm households receive agricultural subsidies as direct payments: direct subsidy to grain growers, good-seed subsidy to major grain producing areas and subsidy to buyers of farming machines (WANG, J. 2006).

Due to the low potential of income from farming, additional income form off-farm activities become more and more important of rural households. Today, the major income source of the majority of rural households in the NCP is income from off-farm activities. In addition, WANG (2006) stated that the social status of these migrant workers is higher than the status they enjoyed before moving to urban areas. Off-farm activities are local off-farm jobs, self run family businesses, and migration of at least one family member to usually urban areas.

A high share of farm households does actually have off-farm income, but not all of them. Further, SOMWARU et al. (2001) found that 52 per cent of rural labour in China are not engaged in any non-agricultural activities and 11 per cent of rural labour work full time (more than 6 month) within non-agricultural activities. This situation rises the questions, which factors increases the probability of off-farm income and which family members work usually on farm and which are predestined for off-farm activities. In another way, as DE BRAUW (2001) already expected, human capital levels, household characteristics or attributes of villages would have significant effects as to whether or not people have opportunities to work in off-farm labour markets.

TUAN et al. (2000) claimed that large households are more likely to have at least one family member who migrates. Furthermore, SOMWARU et al. (2001) found that more farmland lead to a lower probability of off-farm income activities. In case of farm household with less than 0.07 ha only 29 per cent are engaged exclusively in farm work while in household with more than 2 ha has this share is 72 per cent.

Several authors identified that social networks are very important for rural labour for migration. According to a survey form 1994 more than half of the migrated rural labour obtained their jobs through introductions by relatives or neighbours (SATO, H. 2003). And ZHAO (2001) found positive effects of migration networks measured by the number of early migrants form the same village on the probability of migration. CHEN et al. (2003) confirmed this observation of the positive effect of migrant networks measured by proportion of households with migration experience. WANG et al. (2000) even stated that the labour market in the construction sub sector requires neither education nor skill to perform the unskilled construction job, as in other spheres in Chinese societies it is helpful when looking for a job to have some social connections or "guanxi" in Chinese language.

ROZELLE et al. (1999) as well as SOMWARU et al. (2001) reported that rural labour engaged in non-agricultural activities are much younger and more educated compared with full-time rural agricultural labour and young males are more likely to work in non-agricultural sector than young females. TUAN et al. (2000) suggested that farm

households being afraid to lose the use rights on their land if the entire family migrates to non-agricultural activities may explain the gender difference in migration, therefore rural males are seeking full-time off-farm opportunities while females are involved in farming and part-time off-farm activities.

Today, several authors such as ERLING and WENK (2006), WANG (2006), and CHAN (2005) reported that migration becomes less attractive for rural labour due to low and insecure salaries, absence of labour and civil rights, and bad working conditions. This problem is discussed as the other side of the coin of the economic boom in China.

Since the foundation of the P.R. China, the production of enough food to fulfil the demand was the major goal of the Chinese government. For example BROWN (1995) asked more than 10 years ago directly "Who will feed China?". Today, China obtains this goal. The present problem is the development of rural China in order to slow down the widening of the income gap between rural and urban China as well as the growing income disparity inside rural areas.

2.1.2   Fertilizer Application and Nitrogen Use Efficiency

Since the foundation of the PR China rural residents had to suffer from periods of food shortage or even famines. Increased application rates of mineral fertilizer result in increasing growth rates of grain production between the late 1970ies and the mid 1980ies. By the mid 1980ies the country had solved its long-standing problem of inadequate grain production (ZHAI, H. 2004).

The annual grain production growth rate was about 2.5 per cent during the period 1952 to 1978, while it reaches 4.7 per cent for the period between 1978 and 1984 (HUANG, J. and S. ROZELLE 1995). According to HUANG and ROZELLE (1995) the positive growth rates throughout the entire period can be explained by China's commitment to expand its irrigation system and increased input of mineral fertilizer. Additionally, in 1979 the Household Production Responsibility System was established to replace the commune system. The farm households became responsible for the allocated land and the agricultural production rose (LIN, J.Y. 1992). After peaking in 1984, the annual growth rates of grain production and yield fell to two per cent. This decline raises questions about the sustainability of grain production in China (MINISTRY OF AGRICULTURE PR CHINA 1991). HUANG and ROZELLE (1995) ask directly whether the slowdown in growth rates can be explained by increased environmental stress and used a fixed-effect model based on times-series from 1975 to 1990 to estimate a grain yield function. Their results are consistent with the hypothesis that the slowing of grain yield in the late 1980ies is in part due to increases in environmental stress.

The total sowing area of 150 million ha in China has not changed in the last five decades, but the sowing area of grain has dropped from 125 to 110 million ha, while the grain yield reaches now 4.5 tons per ha. Grain refers to wheat, rice, maize, and soybean. The average mineral fertilizer consumption in China continuously increased up to 300 kg per ha, but in the last decade the increase of the grain yields stopped and the total amount of grain production even declines. Figure 1 shows the

development of total grain production and grain yield as well as total fertilizer consumption in relationship to total sowing area between 1949 and 2004.
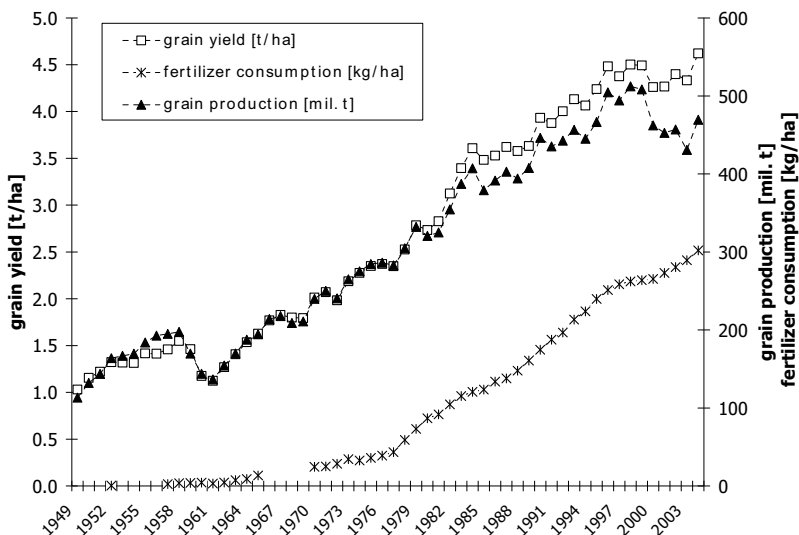
Figure 1   Grain production, grain yield and fertilizer consumption in the PR China between 1949 and 2004

The total nitrogen consumption still increases, but the yield growth rates stagnated and the nitrogen use efficiency decreases. SHI and CHENG (2004) pointed out that the nitrogen efficiency is just about 30 per cent (30 per cent of the applied nitrogen is taken up by the crops), the average amount of applied nitrogen has increased to more than 400 kg per ha and grain production per kg of nitrogen is just 10 kg. The majority of farm households apply nitrogen beyond the crop demand. JU et al. (2006) reported from a survey in Shandong Province that over-fertilisation is common in the study area and is representative for the North China Plain.

At present, overuse of fertilizers in the NCP contributes to environmental damage, which is indicated by deterioration in soil and groundwater quality (JU, X., C.L. KOU ET AL. 2006). ZHANG et al. (1996) regard the present agricultural system in the NCP as unsustainable. Further, JU et al. (2007) stated that long term applications of large amounts of fertilizer may lead to soil acidification. A study by SCHLEEF and KLEINHANß (1994) indicated that 100 kg per ha of annual nitrogen surplus could be regarded as a baseline for nitrate leaching into ground or surface water on a regional scale. In addition, nitrous oxide (N_2O) is an important trace gas, which contributes to the greenhouse effect and its fluxes are strongly affected by the nitrogen application rates (MCSWINEY, C.P. and G.P. ROBERTSON 2005).

Furthermore, the production of nitrogen fertilizer itself is extremely energy intensive, about 59 MJ per kg of nitrogen (SCHOLZ, V., H.J. HELLEBRAND et al. 2001). PATYK and RHEINHARDT (1997) discussed the overall energy balance of the cultivation of energy crops and showed that the production of nitrogen fertilizer shows a significant impact. Therefore, a reduction of nitrogen consumption and finally reduced production of nitrogen fertilizer might be a potential participant in energy saving programmes.

JU et al. (2006) estimated the nitrogen balance of the wheat and maize rotation system. These estimates range from a deficit of 66 kg to a surplus of 688 kg of nitrogen per ha and the nitrogen balance shows a positive correlation with nitrogen application rates. The majority of data points varies between nitrogen application rates of 400 to 800 kg per ha to the wheat and maize rotation system, which results in a nitrogen surplus of 200 to 500 kg per ha up to nitrogen.

2.1.3   Water Availability and Its Usage for Irrigation

High levels of grain production in the NCP depend largely on the use of irrigation. However, irrigation is causing a rapid decline of the groundwater table. To assure sustainable agricultural development in this densely populated region, improvement is needed in farmland water-use efficiency to reduce the overall application of irrigation water. Field experimental results, carried out in the NCP from 1997 to 2000, showed that the common practice of irrigating winter wheat four times each season did not produce as high a yield as three irrigations in a dry year, or one irrigation in a wet year. The latter produced the highest grain production and highest relative water-use efficiency (ZHANG, X., D. PEI et al. 2003).

In the NCP, 71 per cent out of 17 million ha are irrigated. This irrigation system consumes more than 70 percent of the total water supply. Increasing water demands associated with rapid urban and industrial development and expansion of irrigated land have led to overexploitation of both surface and the ratio of groundwater resources, particularly north of the Yellow River. In 1993, the ratio of groundwater exploitation to recharge in many parts of the NCP exceeded the equilibrium. Consequently, about 1.06 million ha of water-short irrigated areas in the NCP also have poor water quality. Persistent groundwater overexploitation in the northern parts of the NCP has resulted in water-level declines in both shallow and deep aquifers. According to data from 600 shallow groundwater observation wells in the Hebei Plain, the average depth to water increased from 7.23 m in 1983 to 11.52 m in 1993, indicating an average water-table decline of 0.425 m per year. Water table declines are not uniformly distributed throughout the area. Depletion rates are generally greatest beneath cities and intensively groundwater-irrigated areas. Water-table declines have also varied over time. With the continued decline of groundwater levels, large depression cones have formed both in unconfined and confined aquifers beneath the Hebei Plain. Groundwater depletion in the NCP has severely affected the environment. In order to balance groundwater exploitation with recharge, the major remedial measures suggested are to strengthen groundwater management, to raise water use efficiency, to adjust the water consumption structure, and to increase water supply (LIU, C., J. YU

et al. 2001). Further, ground and surface water pollution increases due to excessive use of chemical fertilizers and pesticides (ZHANG, W.L., Z.X. TIAN et al. 1996)

2.1.4   Impacts of Off-farm Activities on the Cultivation System

There are two major goals for rural China, rural development to increase the income of rural households and sustainable cultivation, which is an increase in efficiency of cultivation inputs and a decrease of environmental impacts. Therefore, the question arises whether there are interactions between off-farm activities of family members as well as additional cash income from off-farm sources and the cultivation system. Certain farm household characteristic are expected to increase or decrease the probability of higher yield. For example, there are contradictory expectations, whether the income structure and the degree of off-farm job activities influences the cultivation system and finally the crop yield. On the one hand, additional income from off-farm activities may improve in terms of quality and quantity the application of certain cultivation factors. On the other hand, a high income from off-farm job activities may lead farm households to reduce interest in farming activities.

This interdisciplinary approach which focuses on environmental, economic, and socio-institutional aspects to assess farming practices in the NCP is relatively new, while most studies have been confined the exploitation of the soil and water resources (LIU, C., J. YU et al. 2001). However, ZHEN et al. (2005) stated that little is known about socio economic factors influencing farming practices, but there are a few studies which consider the relationship between off-farm activities and the cultivation system.

Several authors analyse the impact of off-farm income on the cultivation system. DE BRAUW (2001) stated that due to off-farm activities the labour force available for farm work in the farm household decreases or as QUAN and LIU (2002) stated leaving the old and women at home for farm work, which may lead to decrease of productivity and farming income. In the late 1980ies YE (1991) found out that chemical fertilizer has been substituted systematically for organic fertilizer as opportunities for off-farm labour and farm household income increase. CHEN et al. (2006) takes data of a survey conducted in Quzhou County, Hebei Province into account and found no significant difference in nitrogen input between farm households of different levels of off-farm income activities. Further, CHEN et al. (2006) stated that farm work is done mainly by older family members, while younger family labour prefer to work off-farm. Therefore, CHEN et al. (2006) pointed out this might explain why there is no relationship between socio-economic factors and nutrient input.

2.2 Characteristics of Off-farm Activities of Rural Households

2.2.1 Barriers and Factors Forcing Off-farm Income Activities

The large income gap between rural and urban populations forced more and more rural labour to move from the agricultural sector to the non-agricultural sector to urban areas. It is estimated that there are about 140 million surplus labours within the rural work force totalling 350 million (QUAN, Y. and Z.-R. LIU 2002). SOMWARU et al. (2001) as well as TUAN et al. (2000) claimed several barriers which prevent rural labour to move to non-agricultural employment. These barriers are the lack of non-farm industry in rural areas, low education level of rural labour, and especially the household registration system. ROZELLE et al. (1999) found out that there are no policies preventing migration and take the tremendous movement of rural labour out of agriculture over the period 1988-98 as evidence.

After the foundation of the PR China in 1949, the Chinese government adopted an economic development strategy. This based on a highly centralized planning economy system and set up a social and economic structure, which distinguishes urban areas from rural areas. It distinguished industry from agriculture as well as "workers" as urban residents from "peasants" as rural residents to form a binary social and economic structure. This binary structure is still not be cancelled thoroughly and is regarded as the biggest obstacle for the growth of income of the rural population (WANG, J. 1998; ZHANG, S. 2003). For this reason the background of the household registration system or "hukou" system in Chinese is explained, based on ZHAO (2000).

Rural labour migration from rural to urban areas has emerged as a prominent phenomenon in China since the mid 1980ies. Before then, the household registration system had successfully confined the population to the place of birth. Since the mid 1980ies, a large number of migrants have successfully entered cities without official approval. Although there is no accurate estimation of the scale of migration, it is commonly believed that by the end of the 1990ies tens of million of rural migrants are residing in rural areas without the permanent legal status required to be there, and a large proportion of these people are circular migrants, moving back and forth frequently (ZHAO, Y. 2000).

The strict enforcement of the rural-to-urban migration control started in the early 1960ies as a result of the devastating Great Famine. The food shortage continued into the 1970ies and ended in the 1980ies. To control the migration, a household registration system was utilised in conjunction with the practices of job assignment and rationing of living necessities in urban areas. Together with rural collective farming, the system was effective in controlling migration. However, as the economic reforms were carried out in the early 1980ies, these controlling apparatuses lost their effectiveness. The primary apparatus of controlling population mobility in China has been the household registration system. The system registers each person at a specific place, usually the place of birth, and since 1958 government approval has been required for change of registration (ZHAO, Y. 2000).

However, when the household registration system was started it was not intended to restrict population mobility. The Ministry of Public Security stipulated that the purpose of the regulation was to protect social order. The turning point for a more restrictive system came in 1955 when food rationing began in urban areas. The rationing was in response to food shortages. As the government made clear its intention to guarantee the provision of low-cost living necessities to urban residents, cities became more attractive to rural people. In 1957, the government hastened the rural collectivisation movement in order to enforce the mandatory procurement of agricultural products, raise agricultural productivity, and support the industrialization. As a result, a large number of farmers deserted the land and the collectives, migrating to cities to seek jobs. In order to safeguard the movement towards collectivization as well as to control the total demand by urban residents for food, the regulations on "hukou" registration in China have been issued in 1958. This regulation stated that when a person migrates from a rural area to a city, this person must apply for moving-out at the "hukou" registration agency of the place of residency, and present a certificate of employment from an urban bureau of labour, admission letter from a school, or certificate of moving-in from an urban "hukou" registration agency. This regulation effectively centralised the power of controlling migration into the hands of urban "hukou" administrators, which are the police offices. There are opportunities for rural people to get urban "hukou", e.g. demobilized army officers are usually guaranteed urban "hukou", all these opportunities are very rare (ZHAO, Y. 2000). ZHAO (2000) stated that in sum, rural people basically cannot count on the change of registration status to go to cities.

Although travelling was restricted from time to time, it was not the main factor prohibiting spontaneous migration to cities without urban registration before the economic reforms. The main factor was the requirement of urban registration for employment and the supply of living necessities. Without local "hukou", one would not qualify for job assignment, which was the only method of gaining employment before the 1980s because private employment virtually did not exist. Without a work unit, it was impossible to have housing. Even though employment and housing were available, one would find it difficult to gain access to almost all living necessities such as grain, meat, and major types of vegetables because these were rationed to urban residents. Even restaurants demanded ration coupons from their customers. As a result, even though rural people could stay with urban relatives (ZHAO, Y. 2000).

The situation changed in the beginning of the 1980s. The loss of effective control on migration was an unintended consequence of the rural reform, this came from two major sources. First, the adoption of the household responsibility system in rural areas in the early 1980s solved China's food shortage problem. The increased supply of food gave rise to the emergence and expansion of the free market for grain in urban areas. Ration coupons were abandoned in the early 1990ies, but food had been available on the free market long before. The food market made it possible for temporary migrants to live in cities. The second role played by the rural reform is that rural labour no longer have to report to the collectives for daily work. As long as they are not needed in the fields, or as long as the rest of their family members can handle the work

without them, they can leave the land. Meanwhile, in 1984, rural people were allowed to move their registration to small towns under the condition that they do not request rationed food allotment from the government. However, migration to cities was still actively discouraged. Since the mid 1980ies, urban state owned enterprises were given financial autonomy, which resulted in a construction boom in urban areas. There were already 5 million rural construction workers in urban areas in 1988 (ZHAO, Y. 2000).

Although food shortages are generally got over, the government continues to deny permanent residency to rural people. The household registration system is still used to allocate government subsidies to urban permanent residents and exclude migrants from many government services. The best example is the denial of education to the children of migrants. Because they are not legal permanent residents, their children do not enjoy the equal right of education with ordinary urban children. Those urban children who attend school in their designated districts do not pay tuition. Children of migrants must pay very high tuition, which can amount to more than the annual salary for a construction worker. Housing is another example of the urban benefits, which are unavailable to migrants. Without urban registration, one is ineligible for subsidized rental or the purchase of housing. In urban China, there are very few apartments on the market and those available are extremely expensive. As a result, employers generally have to provide dormitories for workers. Construction companies build temporary housing for the workers near the building site (ZHAO, Y. 2000).

2.2.2   Characteristics of Migration as Off-farm Income Source

According to official population statistics there are nearly 150 million migrants in China in November 2005 and about 13 per cent of all rural families have at least one family member who migrated to urban areas (NATIONAL BUREAU OF STATISTICS 2006). The average salary is about 9 000 ¥ per year. In 2003, rural migrants sent estimated 370 billion ¥ back to their rural family household. The figure represented 40 percent of the total rural income (CHAN, J. 2005). Migrant workers usually work in labour intensive and low value added sectors such as service jobs with low qualifications and in construction, retail, manufacturing industry, and transport business.

As mentioned, there is no doubt that due to labour surplus in rural areas especially young rural people migrate to urban areas. On the one hand, these family members increase the cash income of their rural family and as stated by WANG (2006) the social status of these migrant workers is higher than the status they enjoyed before moving to urban areas. And DE BRAUW (2001) assumed that farm households use remittances from migrated family members to expand their production possibilities or to start other kinds of business, because migrants in China gain skills, contacts, and entrepreneurial expertise useful for starting a business or managing a family enterprise.

On the other hand, migration workers usually do the dirty, dangerous, hard, and poorly paid jobs, but several authors reported about increasing further problems of migrated rural labour force. First, there is the problem that migration workers are not paid in time. According to newspaper reports there had been about 20 billion ¥ outstanding wages in 2004 and a survey among 3 288 migrants indicates that one-

fourth did not received the full amount of their salaries (FRANKFURTER ALLGEMEINE ZEITUNG 2005). CHAN (2005) estimated that up to 100 billion ¥ in unpaid wages are owed to rural migrant workers. An investigation in Shenzhen shows that migrant workers earn 600 to 800 ¥ per month, a salary that has not changed in the last 10 years (WANG, C. 2006). ERLING and WENK (2006) reported that the average income of rural labour working in the urban industries in the Pearl River Delta increased between 1992 and 2004 on average by 68 ¥ per month.

Mostly, migrants work in an informal environment, often without a written contract. Due to their administrative status of rural registration they do not benefit from government policies in terms of employment or welfare, hence cannot be protected efficiently by laws and policies. Migrant workers have no job security in terms of employment as well as payment as described. There are direct and strong connections between the lack of basic social rights and poor working conditions, lower wages, failure to be paid on time, insults and maltreatment, and social discrimination (WANG, C. 2006). Recent studies from the social sciences analyse the social context of migrants and identified difficult housing conditions and stigmatisations of migrants (LI, X., B. STANTON et al. 2006).

2.2.3   Characteristics of Local Off-farm Income Sources

Beside migration to urban areas working at Village and Township Enterprises (VTE) is another off-farm income source for rural households in China. The VTE have experienced rapid growth since the economic reform in 1978. It is one of the major achievements in the agricultural reform. The development of the VTE is associated with the rural development strategy and labour policy to keep surplus rural labour of who wants to leave their place to stay at the countryside. On the one hand, the increasing employment had reached 130 million out of 480 million rural labour, in the NCP about 30 per cent of the rural labour force is working at VTEs. On the other hand, the VTEs also compete with farm households for resources such as land, water, and electricity (QUAN, Y. and Z.-R. LIU 2002).

2.3   Objectives of Research

As described already, the present cultivation system in the North China Plain is characterised by high levels of nitrogen input, which exceeds the crop demand. The research hypothesis of this thesis is that modifications of the cultivation system towards more sustainability does not reduce the income of farm households.

This thesis can be divided into three sections. First, there is the analysis of the present agricultural system and its inefficiencies. Second, factors will be identified, which are reasons for the described inefficiencies. Finally, suitable instruments to reduce the described inefficiencies are identified and by simulation of scenarios the impact of these instruments on nitrogen balance and farm household income is investigated.

The family based Chinese agricultural system is characterised by the high share of own consumption of wheat and maize as well as the high share of farm households with additional off-farm income. For this reason, the cultivation system is not isolated from the farm household. An analysis of the cultivation system must consider all components of the farm level agricultural system and interaction between these components. The farm level agricultural triangle system consists on farm household structure, income generation of the farm household, and the cultivation system of the cultivated crops (Figure 2). The described agricultural system is a shortcut of the concept of farming system, which is described by DOPPLER (1991). This farming system considers the interactions between the family, the farm, and the household.
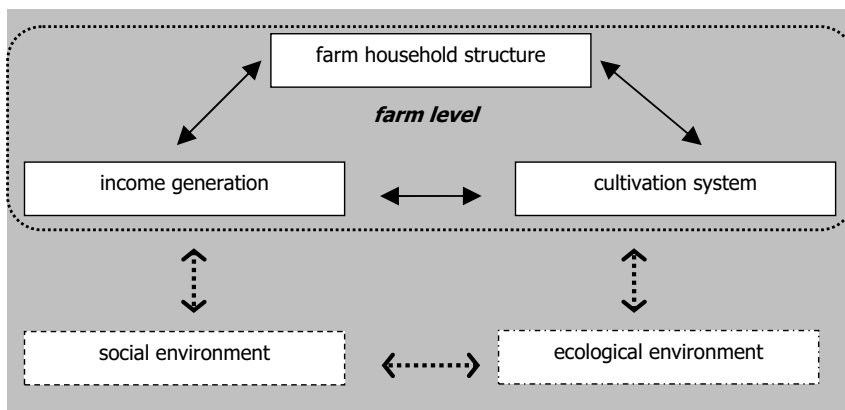
Source: adapted from DOPPLER (1991)

Figure 2   Farm level agricultural triangle interaction system

The component "farm household structure" summarizes the production factor endowment of the farm household, such as farmland, number and characteristics of family labour as well as the farmer as decision maker. The component "income generation" considers all cash and non-cash income sources of the rural household, which are farming, livestock production and off-farm activities. The component

"cultivation system" consists of the agronomic point of view, but considers in this case the nitrogen balance as interface to the ecological environment. There is no doubt, there are interactions of this farm level agricultural triangle system to social and ecological environment.

The descriptive analyses focus on the family labour and farmland. The income section describes the total farm household income, the income from farming, and off-farm activities as income sources. The cultivation analysis identifies the major cultivated crops and the corresponding cultivation techniques.

As described, several authors reported that the agricultural production in the NCP is characterized by inefficient high application rates of nitrogen. In addition, CHEN (2003) found out that application rates of 70 to 100 kg of nitrogen was sufficient to produce wheat yields of 5 to 6 tons per ha and ZHEN et al. (2005) identified that only about six per cent of surveyed households apply the recommendations for balanced input use. Ju et al. (2006) pointed out that the annual fertilizer rates in the wheat and maize cultivation system were much higher than the rates recommended by the local extension service. The situation rises the question, why farmers do not consider the crop demand as criterion for the nitrogen application level and whether or not all farm households do apply nitrogen beyond the crop demand. JU et al. (2004) reported that the nitrogen application in wheat cultivation in the NCP shows a range between 173 kg and 754 kg of nitrogen per ha. This fact leads to the next questions, what do these farm households have in common, which apply nitrogen far beyond the crop demand?

Firstly, due to the expected interaction inside the farm level agricultural system triangle, the income structure and the income level are analysed. Inefficiencies in nitrogen application depend on the nitrogen input in relation to the yield. In the first step, the nitrogen application level is analysed by the question, which factors lead to high nitrogen application levels The major section is the analysis of yield and considers the question whether or not the surveyed farm households apply nitrogen inefficiently from the agronomic point of view.

An optimum analysis requires the economic point of view. Hence, nitrogen price, fertilizer costs, and gross margin are included. The key question is whether or not the surveyed farm households apply nitrogen inefficiently from the economic point of view. The environmental point of view requires the estimated nitrogen balance in order to analyse whether or not all farm households show a high nitrogen surplus. If not, what do farm households with an equalised nitrogen balance have in common and what do those farm households with a heavy nitrogen surplus have in common?

In some cases, a scenario is simulated that all elements of a target group modify their present behaviour and act as predetermined. In this case, such an approach this approach might be too ambitious. It cannot be simulated that actually all farmers would convert their present cultivation system and follow the nitrogen application recommendations, apply the precisely the recommended amount of nitrogen, and harvest the expected yield. Instead, the surveyed farm households are grouped according their nitrogen use efficiency. The simulated scenario considers a theoretical shift of a share of farm households from their present group to a group of higher nitrogen use efficiency. In another way, it is simulated that a certain share of farm

households modifies their cultivation system to that of farm households, which are characterised by a more nitrogen efficient cultivation system. This simulation approach base on the question what is the potential of nitrogen surplus reduction and its impact on income, if farm household characterised by low cultivation efficiency would increase their efficiency level. The corresponding scenario simulates the impact on nitrogen surplus and income, if these farm households would act like farm households of the next higher cultivation efficiency level. Without doubt, this approach requires the identification of an applicable instrument. Finally, scenarios of the application of these instruments are simulated and their impact on the nitrogen balance and the income of farm households are estimated. As mentioned already, there is a broad variation in nitrogen input. This situation must be considered at the discussion about instruments to reduce the nitrogen overuse. In general, instrumented can be divided into two kinds concerning their target group. On the one hand, there are target group unspecific instruments. For example, these instruments affect all wheat cultivating farm households regardless of the individual nitrogen application rate. On the other hand, there are target group specific instruments. In this case only farm households are affected, which actually are characterised by nitrogen overuse. However, the later option requires an identification of the target group.

3 Theoretical Concepts for Economic Analysis of Agricultural Systems

This chapter considers the objectives of research and discusses suitable instruments. The major instrument of this thesis is the binary logistic regression. It is used as factor analysis instrument and its results are the basis of the scenario simulations.

3.1 Research Objectives and Considered Economic Instruments

Income generation is an essential component of the agricultural system. In another way, whether a farm household does have additional off-farm income sources is of major importance as described in chapter 2.1.4. For this reason, the binary logistic regression model is used to identify farm household related factors, which increase the probability of off-farm activities. The binary logistic regression is a specialized form of regression, which is used when the dependent variable is dichotomic and the independent variables are of any type. In the logistic regression the independent or predictor variable is named covariate. In an other way, it allows to predict a discrete outcome, such as group membership expressed as a [1,0] interval, from a set of covariates. These may be continuous, discrete, dichotomous, or a mix of any of these. The discriminate analysis is also used to predict group membership with only two groups, but it can only be used with continuous independent variables. Thus, in instances where the independent variables are a categorical, or a mix of continuous and categorical, logistic regression is preferred. The binary logistic regression model is the major econometric instrument of this thesis and its theoretical background is described in chapter 3.2.

The cultivation system analysis focuses on factors leading to high nitrogen input. In this case, the identification of influencing factors is more important than the quantification of the relationship. The major focus is, whether the nitrogen input exceeds a certain level or not. In this case, the quantification of the nitrogen application rate is of minor importance. The binary logistic regression analysis is selected as a suitable tool to analyse the impact of farm household related characteristics on the nitrogen input, or more precise, the probability of exceeding a certain nitrogen input level. In addition, a correlation analysis estimates possible interactions between the cultivated crops. The correlation approach of Pearson is used, more information is presented by BACKHAUS et al. (2000).

The binary logistic regression analysis cannot distinguish between parallel existing impacts. For example, additional income from off-farm activities might increase the probability of high nitrogen input at some farm households, while it decreases this probability at other farm households or is without any impact. For this reason, the farm households are grouped in fully homogenous groups according to one binary nitrogen input related variable and a set of pre-selected dichotomous income structure related factors. Hence, the theoretical maximum number of groups is required in order to get fully homogenous groups. This is the number of possible combinations, it can be calculated by consideration the number of pre-selected dichotomous variables as

exponent. The distribution and size of the clusters indicates the impact of the pre-selected income structure related factors on the nitrogen input.

The analysis of yield in wheat and maize is the major section. Impact factors on yield are analysed in several ways. First, a multiple regression analysis focuses on pre-selected cultivation related factors (Equation 1).

$$y = aA + bA^2 + dB + fB^2 + gD + hD^2 + c$$

Y = yield [t ha^{-1}]
A, B, D = factors
a, b, c, d, f, g, h = coefficients

Equation 1   Multifactorial quadratic production function

There is no doubt, from the agronomic point of view nitrogen is the major factor determining yield. In the next step, the yield analysis limits its focus on the impact of nitrogen in several ways. A quadratic regression as well as a Liebig function analysis considers the nitrogen input and yield data in wheat, maize, and cotton of all farm households. BAUDOUX (2000) discusses the applicability of several production functions to describe the nitrogen yield relationship and cited FUCHS and LÖTHE (1996), who recommended the quadratic production function for economic and ecologic optimum analysis of nitrogen input in relation to yield (Equation 2). Further, in some cases (e.g. low database) the Liebig function is an applicable tool.

$$y = aN^2 + bN + c$$

Y = yield [t ha^{-1}]
N = nitrogen input [kg ha^{-1}]
a, b, c = coefficients

Equation 2   One-factor quadratic production function

The Liebig function estimates the optimum nitrogen input level and considers a linear relationship up to that nitrogen level. Similar to the quadratic production function the least square method is used to estimate the related coefficients. The yield at the optimum nitrogen level is considered as maximum yield level (Equation 3).

$$Y = aN + c \text{ ; if } N < N_{opt}$$
$$Y = Y_{max} \text{ ; if } N \geq N_{opt}$$

Y = yield [t ha^{-1}]
N = nitrogen input [kg ha^{-1}]
a, b, c = coefficients

Equation 3   Liebig production function

Winter wheat and summer maize are cultivated in rotation, hence its cultivation is usually considered as one common cultivation system and several authors such as JU et al. (2007) take the overall nitrogen input and overall yield into account. The overall nitrogen input and yield of wheat and maize data are analysed.

The official statistics provide a variation in yield between the provinces. Hence, there might be differences between the survey sites in yield. The impact of the local

cultivation conditions are taken into account in several ways. First, one factor production function are estimated at each village. Secondly, impacts originating from the location are excluded by consideration of the relative yield, which indicates the yield as percentage of the village average yield. Finally, the method of KRAYL (1993) is applied to estimate a location independent single factor quadratic production function of the major grain crops. This location independent function can include the location specific maximum yield and the corresponding nitrogen input in order to provide a location specific single factor production function. Table 1 presents the coefficients α, β, and γ of the location independent production function of winter wheat and of summer maize. These coefficients base on various field experiments.

Table 1   Estimated coefficients of the location independent production functions for wheat and for maize based on the concept of Krayl

	α	β	γ
winter wheat	0.5374	1.0748	0.4626
summer maize	0.4995	0.9989	0.5005

Source: KRAYL (1993)

These location independent coefficients (α, β, γ) are converted into location specific coefficients (a, b, c) by consideration of the maximum yield and the corresponding nitrogen input (Equation 4). The resulting location specific coefficients can be used to describe a quadratic productions function, such as equation 2.

$$a = \alpha Y_{max} \left(N_{max} \right)^{-2}$$
$$b = \beta Y_{max} \left(N_{max} \right)^{-1}$$
$$c = \gamma Y_{max}$$

Y_{max} = maximum yield [t ha^{-1}]
N_{max} = nitrogen input at maximum yield input [kg ha^{-1}]
α, β, γ = coefficients of a location independent quadratic production function
a, b, c = coefficients of a location specific quadratic production function

Equation 4   Conversion of the location independent coefficients into location specific coefficients of a one-factor quadratic production function

Furthermore, a binary logistic regression estimates the impact of farm household related characteristics on yield, or more precisely their impact on the probability to exceed a certain yield level. Similar to nitrogen input and yield, a binary logistic regression models is used to analyse the impact of farm household related characteristics on gross margin, which is their impact on the probability to exceed a certain gross margin level. Further, a sensitivity analysis evaluates the impact of the key components of the gross margin to the gross margin. A sensitivity analysis compares the percental change of the dependent variable in case of a certain percental change of the independent variables. In this way, the impact of the considered independent variables can be compared.

The analysis of the economic optimum of nitrogen input includes the nitrogen price and the crop price. At the optimum nitrogen input, the relationship between crop

revenue (yield multiplied by crop price) and nitrogen costs (nitrogen input multiplied by the nitrogen price) is maximized. Usually, the economic optimum of nitrogen input is determined by the first derivative of the production function. In this case, this economic optimisation is extended by consideration of the full variable costs in order to provide the gross margin as economic criteria. In this way, the economic optimum of nitrogen input would provide the maximum gross margin. For simplification, the costs of other components of the cultivation can be summarised to a constant in order to determine the maximum gross margin and the corresponding nitrogen input (Equation 5). Furthermore, the yield can be expressed directly as a one factor quadratic function of nitrogen input (Equation 2).

$$G = Y * P - N * Q - O$$

$$G(N) = (aN + bN^2 + c) * P - N * Q - O$$

$$G'(N) = 0 = 2Pb * N + Pa - Q$$

G = gross margin [¥ ha^{-1}]
Y = yield [t ha^{-1}]
N = nitrogen input [kg ha^{-1}]
Q = nitrogen price [¥ kg^{-1}]
P = crop price (constant) [¥ kg^{-1}]
O = other variable costs (constant)
a, b, c = coefficients of the estimated yield function

Equation 5   Calculation of gross margin (G)

The gross margin indicates the economic optimum, while the nitrogen balance considers the environmental impacts of cultivation. The ecological optimum of the nitrogen input considers an equalised nitrogen balance (Equation 6).

$$B = I + N + S - Y * C - D$$

$$B(N) = 0 = I + N + S - (aN + bN^2 + c) * C - D$$

B = nitrogen balance [kg ha^{-1}]
I = natural nitrogen inflow
Y = yield [t ha^{-1}]
N = nitrogen input [kg ha^{-1}]
S = nitrogen input from straw left on the field (constant) [kg N ha^{-1}]
C = nitrogen content of crop (constant) [kg N t^{-1} yield]
D = natural nitrogen outflow
a, b, c = coefficients of yield function

Equation 6   Calculation of the nitrogen balance (B)

Finally, the economic and the ecologic optimum of nitrogen input are compared. A difference in these optima raises the question, which factors must be modified to equalise the economic and ecologic optimum. The general aim of the nitrogen balance estimation is the comparison between farm households or groups of farm households. For this reason, the nitrogen balance estimation focus on nitrogen input and nitrogen output from agricultural activities. In this case, natural inflows and outflows are of less

importance. The estimated nitrogen balance is the basis of a grouping procedure in order to provide three types of farm households: *equalised nitrogen balance*, *slightly nitrogen surplus*, and *heavy nitrogen surplus*. The grouping procedure considers a certain level of nitrogen balance as borders, because these borders are more important than the variation beyond a certain level of nitrogen surplus.

Similar to the analysis of nitrogen input a binary logistic regression model analyses the impact of farm household related factors on the probability of a farm household to belong to the type *equalised nitrogen balance* or to the type *heavy nitrogen surplus*. In addition, a grouping procedure is conducted in order to identify parallel impacts, which might not be indicated by the logistic regression model. The cluster analysis considers farm household and cultivation system related pre-selected variables in order to provide homogenous clusters. The characteristics and size of each homogenous cluster provide information about opposing impacts. There exist several mathematical algorithms, and hence, a variety of statistical methods for classification, too. Since each method has its advantages and disadvantages the selection of the most suitable method depends on the general scientific aim of the classification, the characteristics of the variables, the flexibility in algorithm selection, and the output demand.

The k-Means Cluster Analysis is selected, because this procedure attempts to identify relatively homogeneous groups of cases based on selected characteristics and uses an algorithm, which can handle large numbers of cases. The k-Means cluster analysis minimises the distance inside a group and maximise it between the groups. On the other hand, the number of clusters must be specified a priori and it only can handle variables at the interval or ratio level. Detailed information about cluster analysis are presented by textbooks such as BACKHAUS et al. (2000).

The binary logistic regression model is the basis of the scenario simulation, which evaluates the impact of selected instruments on the reduction of nitrogen surplus. In detail, it considers pre-selected influencing variables (covariate) and provides as output the individual probability of group membership. Since the dependent is a dichotomous variable, the output can be regarded as a group membership. Furthermore, the average probability can be interpreted as the share of elements belonging to the considered group. A modification of at least one covariate will result in a modified individual probability. The modified individual probability of membership can be construed as a shift of elements out or in that group. In this case, the previously mentioned nitrogen balance type are such groups. A shift a certain share of elements out or in a nitrogen balance type would have an impact on the overall nitrogen balance. This simulation considers a theoretical shift of farm households from the group membership *heavy nitrogen surplus* to *slightly nitrogen surplus* and from *slightly nitrogen surplus* to *equalised nitrogen balance.* The modification of covariates can be regarded as an instrument and its impact can be evaluated by the consideration of such as shift. In this way, several scenarios are simulated in order to estimate the impact of selected instruments in the nitrogen balance and on other characteristics such as net income.

3.2   Theoretical Background of the Logistic Regression Model

The binary logistic regression is a suitable tool to predict and to explain a binary variable, hence the presence or absence of a certain characteristic based on values of a set of predictor variables are referred to as covariates. The binary logistic regression is done by using the routine included in the software SPSS estimates analyses the odds ratio, which is the ratio between the probability of membership and probability of non-membership. As logistic regression routine, the stepwise backward method, which removes covariates of less significant influence considering the likelihood ratio is used. A helpful introduction as well as further information about logistic regression can be found in BACKHAUS et al. (2000), FIELD (2006), GARSON (2006), HOSMER and LEMESHOW (2000), and MENARD (1995).

Instead of classifying an observation into one group (dependent variable = 1) or the other (dependent variable = 0), logistic regression predicts the log odds that an observation will have an dependent variable equal to 1. The odds of an event is defined as the ratio of the probability that an event occurs to the probability that it fails to occur inside the interval zero to positive infinity (Equation 7).

$$\frac{p(y_i = 1)}{(1 - p(y_i = 1))} = \frac{p(y_i = 1)}{p(y_i = 0)} = Odds_i$$

$p(y_i = 1)$ probability of dependent variable is equal to 1 (group membership)

$p(y_i = 0)$ probability of dependent variable is equal to 0 (no group membership)

Equation 7   Definition of the odds ratio

There is a nonlinear relationship between odds and probability and the odds must be zero or positive, but there is no upper bound. The lower bound can be eliminated by taking the natural logarithm. These log odds can be any number from negative to positive infinity, while the probability varies between 0 and 1. This transformation of the values of the discrete binary dependent variable results into an S-shaped logistic curve representing the probability of an event. At the extremes, changes in the log odds produce very little change in the probabilities. In the middle of the S-curve, changes in the log odds produce much larger changes in the probabilities. To put it in another way, linear, additive increases in the log odds produce nonlinear changes in the probabilities. This probability is used to form the odds ratio, which acts as the dependent variable in logistic regression. The covariates on the right hand side appear similar to the linear regression with constant β_0, coefficient of the covariates β_j, and covariates x_i (Equation 8).

$$LogOdds_i = \ln\left(\frac{p(y_i = 1)}{p(y_i = 0)}\right) = \beta_0 + \beta_1 x_{i1} + ... + \beta_j x_{ij} + ... \beta_k x_{ik} = z_i$$

β_0 constant of the equation

β_j coefficient of the covariates

x_i covariates

z_i shorthand for $\beta_0 + \beta_1 x_{i1} + ... + \beta_j x_{ij} + ... \beta_k x_{ik}$

Equation 8   Natural logarithm of the odds ratio (LogOdds) described by a multifactorial linear function

Since it is less difficult to think in odds than in terms of log odds the influence of the covariates might be better expressed by the exponentiated coefficients.

$$\frac{p(y_i = 1)}{p(y_i = 0)} = e^{\beta_0} e^{\beta_1 x_{i1}} ... e^{\beta_j x_{ij}} ... e^{\beta_k x_{ik}}$$

β_0 constant of the equation

β_j coefficient of the covariates

x_i covariates

Equation 9   Odd ratio described by a multifactorial exponentiated function

As mentioned previously, the covariates in a logistic regression can take any form. The logistic regression makes no assumption about the distribution of the covariates, which do not have to be normally distributed, linearly related or of equal variance within each group. The relationship between the dependent variable and covariates is not a linear function in logistic regression, or in other way, if x_1 increases by 1, the odds will increase by e^{β_1}. Instead, the probability that an event occurs is described by the logit transformation of $p(y_i = 1)$ The most direct method of assessing the magnitude of the change in probability due to each covariate is to examine the exponentiated coefficient. The exponentiated coefficient minus one equals the percentage change in odds. The probability itself can easily be directly calculated from the odds (Equation 10). Thus, large increases in the odds are needed to reach larger probability.

$$\frac{p(y_i = 1)}{p(y_i = 0)} = Odds_i = e^z \quad \Leftrightarrow \quad p(y_i = 1) = \frac{e^{z_i}}{1 + e^{z_i}} = \frac{1}{1 + e^{-z_i}}$$

z_i shorthand for $\beta_0 + \beta_1 x_{i1} + ... + \beta_j x_{ij} + ... \beta_k x_{ik}$

Equation 10   Calculation of the probability from the odds ratio

In the logistic regression, the parameters of the model are estimated using the method of Maximum-Likelihood. Those coefficients, which makes the observed results most likely are selected. Since the logistic regression model is nonlinear, an iterative algorithm is necessary for parameter estimation. Several computer programs including

the used SPSS, include logistic regression routines and can be used to conduct this estimation procedure. Categorical variables are transformed into binary variables comparing each category with a pre-selected reference category, hence whether there is a significant difference between this category and the reference category.

The goal of logistic regression offers several methods to analyse the impact of several covariates. The covariates can be entered into the model block wise or stepwise. With the forced entry method, a covariate in the variable list is entered into the model. Alternatively, the covariates can enter the model stepwise, in case there are two options: forward and backward stepwise. In case of forward stepwise each covariates enter the model, tested for model improvement and kept in the model or removed. The backward stepwise method starts with all covariates in the model and tests each covariate whether its removal improves the model or not and therefore removes the covariates stepwise. In both cases the Wald statistics, the likelihood ratio, or a conditional algorithm is used for variable removal. The differences of these options are described in detail in HOSMER and LEMESHOW (2000), but FIELD (2006) advises the likelihood ratio.

Stepwise regression is used in the exploratory phase of research, but it is not recommended for theory testing. Theory testing is the testing of a-priori theories or hypotheses of the relationships between selected variables. Exploratory testing makes no a-priori assumptions regarding the relationships between the covariates, thus the goal is to discover relationships. Backward stepwise regression appears to be the preferred method of exploratory analyses, where the analysis begins with a full or saturated model and covariates are eliminated from the model in an iterative process. The fit of the model is tested after the elimination of each covariate to ensure that the model still fits the data adequately. When no more covariates can be eliminated from the model, the analysis is completed (MENARD, S. 1995).

To the extent that one covariate is a linear function of another covariates, the problem of multi-collinearity will occur in logistic regression. FIELD (2006) suggests to test for collinearity and advises that resulting tolerances must be higher than 0.1 otherwise it indicates a serious multi-collinearity problem.[2]

The goodness-of-fit for a logistic regression model can be assessed in several ways. One way is to assess the model estimation fit by using pseudo r^2 values, similar to that in multiple regression. The second approach is to examine predictive accuracy, or how well the maximum likelihood estimation procedure fits is the likelihood value. The probability of the observed results given the parameter estimates is known as the likelihood (LL). Since the likelihood is a small number lower than 1, it is customary to use minus two times the log of the likelihood, which is often referred as -2LL. The value of -2LL is a measure how well the estimated model fits the likelihood and is also called deviance. If a model fits perfect, the likelihood results in 1, and mines two times log likelihood is 0. Because the -2LL has approximately a chi-square distribution, -2LL can be used for assessing the significance of logistic regression. The initial log

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[2]   In SPSS 11.5 this test is offered as option for the linear regression, but this option can be used to test the independent variables of the logistic regression.

likelihood function $-2LL_0$ is for the initial model in which only the constant is included. The $-2LL_M$ for a model consist of all selected covariates and it indicates the extent to which the model fails to perfectly predict the values of the dependent variables, it tells how much improvement is needed before the covariates provide the best possible prediction of the dependent variable. The likelihood ratio test is a test for the significance of the difference between $-2LL_0$ and $-2LL_M$, hence it reflects the difference between error not knowing the independent variables and error when the covariates are included in the model.

However, there is no widely-accepted direct analogy to a linear regression based on ordinary least squares. This is because an r^2 measure seeks to make a statement about the percentage of variance explained by the model, but the variance of a dichotomous dependent variable depends on the frequency distribution of that variable. Nonetheless, several logistic r^2 measures have been proposed. Cox and Snell's r^2 is an attempt to imitate the interpretation of multiple r^2 based on the likelihood, but its maximum cannot reach 1. Nagelkerkes r^2 is a further modification for the Cox and Snell coefficient to assure that it can vary between 0 and 1. Both statistics are included in the SPSS logistic regression routines.

The Wald statistic is commonly used to test the significance of individual logistic regression coefficients for each covariate. The Wald statistic is the squared ratio of the not standardised logit coefficient to its standard error and tests the statistical significance of each coefficient in the model to differ from zero. However, several authors have identified problems with the use of the Wald statistic, MENARD (1995) warns that for large coefficients, the standard error is inflated, lowering the Wald statistic and leading to Type II errors.[3]

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[3] Type II errors: thinking the effect is not significant when it is

4 Study Location and Data Basis

This chapter describes the data collection at selected study locations. First, the administrative affiliation and geographic location of the North China Plain is described. Second, a farm survey conducted in 20 villages is the core data basis.

4.1 Characteristics of the North China Plain

The North China Plain is located South of the capital Beijing in the Eastern costal part of the PR China, between in latitude N 34° to N 40° and between in longitude E 113° to E 119°. Since there are the lower reaches of the Haihe River, the Huanghe River, and the Huahe River it is called in Chinese often Huang-Huai-Hai Plain. Figure 3 gives an overview of the provinces of China and the location of the NCP.

Note: This map does not consider recent political changes outside the NCP.
          Chongching does not belong to Sichuan Province, it has now provincial status
          Hong Kong does not belong to the United Kingdom, it is Hong Kong Special Administrative
          Region of PR China
          Macau does not belong to Portugal, it is Macau Special Administrative Region of PR China
          The shown area of the former Soviet Union is part of Russia, Kyrgyzstan, and Kazakhstan

Source: UNIVERSITY OF TEXAS AT AUSTIN (1991); NCP boarder adapted from BARETH (2003)

Figure 3   Map of the PR China and the location of the North China Plain

The North China Plain covers about 310 000 km² of which 178 000 km² are arable land and has a population of about 214 million people. This is only about 3 per cent of the area of the PR China with its 9.6 million km², but about 16 per cent of the population of about 1.3 billion people (Zuo, D.K. 1992).

In administrative terms the North China Plain belongs to parts of the provinces of Beijing, Tianjin, Hebei, Henan, Anhui, Jiangsu and Shandong. These seven provinces cover an area of 780 000 km² and have a total population of about 416 million. About 80 per cent of the population in these five provinces are rural population and the rural work force in agriculture is still more than 60 per cent (Annex Table 1). On the one, hand the gross domestic product of these seven provinces accounted for more than 33 per cent of gross domestic product of China. On the other hand there is a broad regional distribution, especially Beijing, Tianjin, and Jiangsu Province are relatively well developed in contrast to rural areas of Henan and Anhui (RURAL SURVEY ORGANISATION OF NATIONAL BUREAU OF STATISTICS 2004). For this reason, the presented data describing the NCP excludes the municipalities of Beijing and Tianjin.[4]

Inside China the North China Plain is regarded as the most important agricultural production area, because this area is responsible for one-fourth of the national grain production and half of the cotton production. The farming system of the North China Plain is dominated by the winter wheat and summer maize rotation system. This means sowing of wheat in autumn, harvesting of wheat in late spring combined with sowing of maize, and harvesting of maize in autumn. Cash crops such as mainly peanuts or cotton often extend this cropping pattern. Wheat is the traditional staple food in North China, rice is the staple food in South China. Cotton is the most important cash crop in the North China Plain (CHENG, X. 2004).

The North China Plain belongs to the semi-arid and semi-humid temperate zone with continental monsoon climate. The average temperature is 13°C and during the year are 2 400 to 3 100 sunshine hours. In Northern region of the NCP the period without frost is about 120 days, in the central region this period takes 150 to 200 days, and in the Southern and coastal regions there are 200 to 220 days without frost. For the whole North China Plain the average annual rainfall sums up to 547 mm, but the NCP suffers drought nearly every year due to unequal precipitation distribution (CHENG, X. 2004). The North China Plain is affected by continental monsoon climate, annual rainfall is about 800 mm in the South to 500 mm in the North and is concentrated to the summer months (RURAL SURVEY ORGANISATION OF NATIONAL BUREAU OF STATISTICS 2004). The major constraint in crop production is water availability. Due to the high population density the average annual amount of water per capita is only about 1 500 m³ and due to shortage of surface water, more and more places become dependent on groundwater causing a drop of the water table (CHENG, X. 2004). A detailed definition of the Nord China Plain is presented by BARETH (2003) as well as by CHEN (2003).

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[4]   There are only data available for the whole provinces, for that reason the presented data includes those parts of Hebei, Jiangsu, Anhui, Shandong, and Henan which not belong to the NCP.

4.2   Data Collection

4.2.1   Farm Household Survey

A household survey among 340 farmers has been conducted in spring 2005 and later on it has be named IRTG survey. The field survey was done in co-operation of the subprojects 3.1 and 3.3 of the International Research Training Group, a cooperation of the University of Hohenheim (Stuttgart, Germany) and the China Agricultural University (Beijing, PR China), in which this thesis is embedded. Five counties have been selected in the provinces of Henan, Hebei and Shandon to represent the winter wheat and summer maize cropping system, which characterizes the North China Plain (NCP). The administrative affiliation of the selected survey sites is shown in table 2 and figure 4. For simplification, a number is given to each township and each village.

Table 2   Administrative affiliations of the survey sites

province	county	township (township number)	village (village number)	distance to township
Henan 河南	Kaifeng 开封	Fan Cun 范村 (#5)	Mi Dian 米店 (#9)	9.0 km
			Chi Cang 赤仓 (#10)	4.0 km
		Tu Shan Gang 土山岗 (#6)	Yue Lin 月林 (#11)	3.0 km
			Qian Gang 前岗 (#12)	0.5 km
	Yanjin 延津	Zeng Gu 僧固 (#9)	Xiao Bu 小布 (#17)	2.0 km
			Qing Zhuang 青庄 (#18)	1.0 km
		Xin An 新安 (#10)	Lu Chang 卢厂 (#19)	7.0 km
			Xi Gu Qiang 西古墙 (#20)	3.0 km
Shandong 山东	Huimin 惠民	Zao Hu Li 皂户李 (#3)	Xie Ma Ting 歇马亭 (#7)	4.5 km
			Li Dong 李栋 (#8)	1.5 km
		Li Zhuang 李庄 (#4)	Qian Wang 前王 (#5)	2.5 km
			Da Zhai 大翟 (#6)	3.0 km
	Liangshan 梁山	Ma Yin 马营 (#1)	Yang Tun 杨屯 (#1)	2.5 km
			Xue Tun 薛屯 (#2)	2.0 km
		Hei Hu Miao 黑虎庙 (#2)	Shi Zhuang 师庄 (#3)	3.0 km
			Bao Na Li 包那里 (#4)	3.0 km
Hebei 河北	Quzhou 曲周	Huai Qiao 槐桥 (#7)	Dong Nan Zhai 东南寨 (#13)	2.0 km
			Dong Zhang Tou 东漳头 (#14)	3.0 km
		Da He Dao 大河道 (#8)	Xi Da You 西大由 (#15)	10.0 km
			Xue Zhuang 薛庄 (#16)	2.0 km

The NCP has about the size of Germany, but more than double of the population. In the next step two different townships have been identified in each county according the ratio between cultivated land and farm household size. Finally, according to the transportation conditions and the share of household with off-farm income two villages have been selected under advice of a township officer. In each village, 17 rural farm

households have been interviewed. Additionally local experts of the corresponding County Agricultural Bureau and the village leaders at each survey site have been interviewed.

Y: Yanjin County, Henan Province   K: Kaifeng County, Henan Province
Q: Quzhou County, Hebei Province   L: Liangshan County, Shandong Province
H: Huimin County, Shandong Province

Source: FALK VERLAG (2001)
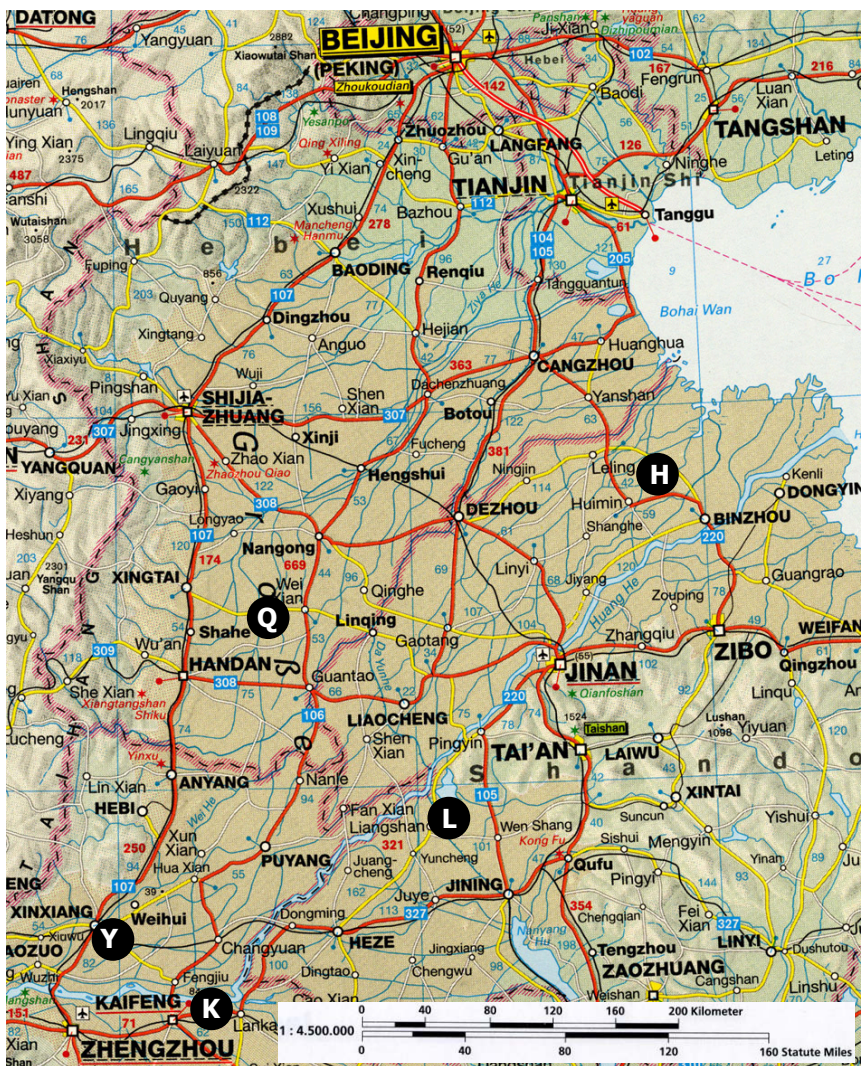
Figure 4   Location of the surveyed counties

The selected survey counties are located in the centre of the NCP and except Quzhou County close to the Huanghe or Yellow River. The total population in the selected villages of these counties is about 24 000 people, who are living in 6 000 households. The total arable land of the survey sites is 2 600 ha.

Since the overall research project focuses on the winter wheat summer maize farming system the emphasis of the farm survey lays on field crops. In general, the cultivation of vegetables in greenhouses is much more intensive in terms of labour, capital and technology. Due to its differences in cultivation technology towards field crops its characteristics cannot be identified in the same way as field crops, hence a different questionnaire would be necessary.

4.2.2   Questionnaire Design and Survey Data Evaluation

The questionnaire used in the survey in spring 2005 was designed in co-operation with the counterparts of the involved subprojects and it was tested in autumn 2004.[5] It covers the following topics: key characteristics of the farm household and the family members including off-farm activities, land resources and land use rights, cultivation system with special focus on irrigation including water sources and fertilizer application, machinery, livestock, self-run family businesses, household balance, and credit access of the farm household. The farm households were asked to describe the cultivation season of the crops harvested in 2004. In case of wheat, sown in autumn 2003 and harvested in spring 2004. The relevant sections of the questionnaire for this thesis are shown in the annex box 1.

Without doubt, farm survey data include a high error potential. Farmer might not report the actual values for several reasons, the interviewer misunderstand the answers of the farmers, or the interviewer did a mistake when filling in the questionnaire. Further, the data transfer from the questionnaire into the data processing software is open for human mistakes. For this reason, the software EpiData is used for simple data entry (LAURITSEN, J.M. 2006).

Finally, an intensive data screening and cross checking have been done in order to identify obvious mistakes and unrealistic values. Identified mistakes have been corrected into realistic values. In total six farm households have been excluded from further calculation due to lack of data or high rate of obviously wrong values.

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[5]   Further results of this field survey are published in MA (2006), WANG (2006), and PIOTROWSKI and JIA (2006) as well as in the forthcoming publications of PIOTROWSKI and JIA.

5 Descriptive Analysis of the Agricultural System

This chapter presents the survey results for each surveyed township. It presents the farm household characteristics in terms of family labour and family farmland. Further, the income level and the sources of income generation are described. The major crops are wheat, maize, peanuts and cotton. The cultivation system of these crops and key economic criteria are indicated. Finally, the key nitrogen fertilizer and their impact as nitrogen source are presented.

5.1 Farm Household and Farm Family Characteristics

The average family size in the NCP is 4.3 family members. Some of these family members do actually not live on the farm, hence neither food is needed nor are these family members available for farm work. The household size[6] without those family members living not in the farm house due to off-farm activities are accordingly lower, 3.6 person on average (Table 4). These figures are in line with the official statistics, in China the average household size is about 3.4 person (NATIONAL BUREAU OF STATISTICS 2003). According to the official statistics at village level presented by the village leaders at the survey sites the average household size at the survey sites is 4.1 person per household, this figure may include those registered family members who actually live not on farm due to migration.

5.1.1 Family Work Force

Since not all family members are available for farm work as well as off-farm work in the same way, the individual farming work force and individual off-farm work force of each family member is evaluated according to a classification scheme of five levels of labour units (LU): 0, 0.25, 0.5, 0.75, and 1.0 labour units (Table 3).

Table 3   Work force for farming and work force for off-farm activities

labour units (LU)		gender	living	occupation	off-farm job
farming	off-farm		place		duration
1.00	0	male	on farm	fulltime farm work	
0.75	0	female	on farm	fulltime farm work	
0.75	0.25		on farm	off-farm job, but farm work when needed	1-4 month
0.50	0.50		on farm	off-farm job, but farm work when needed	5-10 month
0.25	0.75		on farm	off-farm job, but farm work when needed	11-12 month
0.25	0		on farm	going to school	
0	0		on farm	working not at all	
0	1.00		on farm	permanent fulltime off-farm	
0	1.00		outside	permanent fulltime off-farm	

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[6]   For further calculations the household size is defined as the sum of all family member actually living on the farm and children less than five years old are counted as 0.5 persons.

All males working fulltime on the own farm at all time are fully available for farm work and counted as 1.0 labour unit. According to the Chinese traditional male-female roles, females are counted as 0.75 labour units. This differentiation in gender is only done in case of fulltime farm work. Many farmers have some kind of off-farm job and are still living on the farm, hence are available for farming when needed. Their availability for farm work depends on the duration of the off-farm job. An off-farm job for one to four month will result in an individual farming work force of 0.75 labour units and five to ten month in 0.5 labour units. Even those farmers who are having an off-farm job for 11 or 12 month explained being available for farm work, therefore have an individual farming work force of 0.25 labour units. There are other family members still living on farm, but having a permanent fulltime off-farm job and explained not being available for farm work. Family members going to school are counted as 0.25 labour units. Family members working not at all due to age and those living outside of the farm are counted as not available for farm work. The individual off-farm work force corresponds to this evaluation system as shown in table 3. The average family work force per farm household is about 3.0 labour units and the corresponding farming work force amounts to 2.3 labour units, while the off-farm work force is on average 0.7 labour units. The average age of family member, which are belonging to the family work force is about 40 years. However, the average age of the household head is 47 years (Table 4).

Table 4   Farm household characteristics at the survey sites

county	Liangshan		Huimin		Kaifeng		Quzhou		Yanjin		all
township	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	farms
number of farms	34	32	32	32	33	33	35	34	34	34	333
family size [pers.]	4.2	4.4	3.8	4.5	4.5	4.5	4.2	4.4	4.3	4.8	4.3
household size [pers.]	3.4	3.4	3.3	3.8	3.8	3.9	3.3	3.8	3.6	4.0	3.6
household head age [years]	49	48	47	46	50	48	48	46	46	45	47
family labour force [LU][1]	2.7	3.2	2.5	3.0	3.1	2.8	3.1	3.1	2.9	3.1	3.0
farming labour force [LU][1]	2.0	2.2	1.9	2.1	2.6	2.5	2.3	2.4	2.2	2.8	2.3
off-farm labour force [LU][1]	0.6	1.0	0.7	0.9	0.5	0.3	0.9	0.7	0.7	0.4	0.7
labour age [years]	43	40	41	40	39	41	41	39	38	37	40
total local people [pers.]	144	141	121	143	148	147	147	148	145	164	1 448
total labour force [pers.]	90	99	85	99	109	93	116	106	104	112	1 013
job: only farming [%]	69	58	61	64	84	88	70	74	69	80	72
job: universal [%]	17	24	28	17	3	2	12	11	17	19	15
job: only off-farm [%]	14	18	11	19	13	10	18	15	13	1	13
farming work force ratio [%]	78	73	76	72	86	91	78	79	80	89	80

Note: [1] labour units (LU) are described in Table 3

The Statistical Bureaus of the NCP provinces reported that on average more than half of the rural work force obtained middle school education. This means 9 years of school education in total, 6 years primary school and 3 years middle school. About one fourth attended only a primary school. More than 5 per cent of rural work force are

regarded as illiterate (Annex Table 2). Similar results are found at the survey sites. About 50 per cent of the 1 000 survey rural work force have middle school education and 25 per cent primary school. About 12 per cent are illiterate and the same percentage have high school education or above. There is some variation in education level between the survey sites, in Liangshan County less than half of the work force have at least middle school education, while in Yanjin County this share is nearly 80 per cent (Annex Table 3). The education level of a farm household might be better indicated by the highest family education than the average education level of all family members. Primary school is the highest family education at 16 per cent of the farm households, while 57 per cent have middle school as highest family education (Table 5).

Table 5   Distribution of the highest family education at survey sites

county	Liangshan		Huimin		Kaifeng		Quzhou		Yanjin		all
township	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	farms
primary school or below [%]	29	22	22	13	18	15	17	15	9	0	16
middle school [%]	56	59	53	53	58	55	43	74	50	68	57
high school or above [%]	15	19	25	34	24	30	40	12	41	32	27

In terms of occupation, five categories are used: Working not at all (*labour type 1*), going to school (*labour type 2*), fulltime on own farm all the time (*labour type 3*), off-farm job and working on own farm only when needed (*labour type 4*), and fulltime off-farm job (*labour type 5*). In general, those family members, who are working exclusively on farm are older and less educated than those with off-farm activities. About 72 per cent of family work force are belonging to this group that is in absolute figures 730 people or on average 2.2 person per household. Their average age is about 43 years, about 25 per cent have primary school education and about 50 per cent middle school education, (Annex Table 4). SOMWARU et al. (2001) found that 52 per cent of the rural work force in China are not engaged in any non-agricultural activities and only 11 per cent of rural work force work full time with (more than 6 month) in non-agricultural activities.

The share of the rural work force, which belongs to the fourth and fifth category varies between the survey sites. However, on average 15 per cent of the family work force or 150 in total have an off-farm job and work at the own farm only when needed. On average these family labours are 35 years old (Annex Table 5). About 13 per cent of family work force or 134 in total work exclusively off-farm and have an average age of 24 years (Annex Table 6). About 60 per cent of the family work force works off-farm (*labour type 4* or *labour type 5*) and have a middle school education, about 20 per cent even high school education, and only about 10 per cent have only primary school education. Further, usually male family members are working off-farm. Only 28 out of 149 people or 19 per cent of the *labour type 4* are females and about 39 per cent (47 out of 127 people) of migrating family members (*labour type 5*) are females.

There are differences between the survey sites in occupation structure. The distribution of the share of family members belonging to each labour type to the family work force indicates this fact. The share of family work force working exclusively on farm varies between 60 and 80 per cent on township average, while the aggregated share of *labour type 4* and *labour type 5* vary between 20 and 40 per cent (Annex Table 7). These differences between the survey sites are in line with the differences in the percentage of farm households having any kind of additional off-farm income source, see chapter 5.2 for more details. The calculations of the following chapters consider, whether or not a farm household does have at least one family member belonging to a certain labour type, especially *labour type 4* and *labour type 5*. As presented in table 6, 37 per cent of the farm households have at least one family member of *labour type 4* and in case of *labour type 5* the share is 29 per cent. However, only 20 farm households or about 6 per cent of all farm households have family members belonging to *labour type 4* and to *labour type 5*.

Table 6   Share of farm households having at least one family member belonging to labour type 4 and labour type 5 at township level

| county township | Liangshan | | Huimin | | Kaifeng | | Quzhou | | Yanjin | | all |
	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	farms
share of farm households with labour type 4 [%]	37	38	56	63	47	96	29	29	38	53	37
share of farm households with labour type 5 [%]	29	38	25	47	30	18	34	38	27	3	29
share of farms with off-farm income [%]	59	81	78	75	48	52	54	59	59	56	64

TUAN et al. (2000) suggested that farm households being afraid to lose the use rights on their land if the entire family migrates to non-agricultural activities may explain the gender difference in migration, therefore rural males are seeking full-time off-farm opportunities while females involved with farming and part-time off-farm activities. ROZELLE et al. (1999) as well as SOMWARU at al. (2001) confirm the survey results that rural labour engaged in non-agricultural activities are much younger and more educated as compared with full-time rural agricultural labour and young males are more likely to work in non-agricultural sector than young females.

5.1.2   Availability of farm land

Since the household responsibility system (HRS) has been installed in the early 1980ies, farm households make decisions about planting on their allocated land as well as use of farming outputs. This system provided the farm households with legal right to claim all outputs of their labour, but the ownership rights of land are still nominally held by the village collective (SOMWARU, A., X. DIAO et al. 2001). The village leaders at the survey sites reported that this use right is given for the period of 30 years to the farm households.

There are no significant differences between the surveyed townships in terms of family size and household size. In terms of farmland the average size of allocated land per household varies from township to township between 0.30 to 0.87 ha, the average of all surveyed households is 0.53 ha or 7.95 mu.[7] The corresponding farmland to family size ratio is 0.13 ha per family member and varies between 0.07 ha and 0.18 ha per family member. If only the farming work force is considered, 0.24 ha are cultivated per unit farming work force. This variable *farmland farming work force ratio* is the ratio between labour input and cultivated land. Several authors described the low labour productivity of Chinese farmers and the agricultural labour surplus of about 30 per cent of rural workers (Löw, D. 2003). Furthermore, Löw (2003) reported that in Jiangsu Province the typical farm size is less than 0.1 ha per agricultural worker and an experiment showed that the right farm size to ensure an income equivalent to that of a worker in a rural township or village enterprise would be 1 to 2 ha per person. However, these results confirm that a typical family labour can cultivate more than 0.24 ha. Therefore, a typical farm household would be able to cultivate more land, cultivate more labour intensive crops, or increase its off-farm activities (Table 7). This situation leads to the assumption of a high surplus of rural work force (chapter 2.2).

Table 7   Farm characteristics at the survey sites

county	Liangshan		Huimin		Kaifeng		Quzhou		Yanjin		all
township	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	farms
number of farms	34	32	32	32	33	33	35	34	34	34	334
farmland [ha]	0.53	0.30	0.56	0.37	0.76	0.49	0.48	0.50	0.41	0.87	0.53
land ratio[1] [ha pers.$^{-1}$]	0.13	0.07	0.15	0.08	0.18	0.12	0.12	0.12	0.10	0.18	0.13
labour ratio[2] [ha pers.$^{-1}$]	0.27	0.14	0.31	0.19	0.31	0.20	0.23	0.22	0.19	0.34	0.24
plot number[no.]	4.9	2.4	4.1	3.6	3.5	2.2	4.1	3.7	1.8	2.6	3.3
average plot size [ha]	0.11	0.14	0.15	0.12	0.24	0.25	0.13	0.15	0.27	0.50	0.21
plot cultivated years [a]	15.5	9.0	4.5	8.0	6.0	6.0	12.0	10.0	11.0	2.0	8.5
long term yield [t ha^{-1}]	4.89	5.71	5.12	6.03	4.35	5.37	5.22	5.46	6.29	5.10	5.34

Note: [1] ratio between those family members living on farm and total cultivated land
            [2] ratio between farming labour force and total cultivated land

The farm households have been asked to estimate the wheat yield in a normal year at each of their plots. The long term wheat yield can be used as indicator for plot quality and shows a variation between the surveyed townships.

According to information presented by the local village leaders the average farmland per household is 0.45 ha and 0.11 ha per person. Farm households have on average about three farming plots, which have an average size of 0.21 ha. Due to the locally organised reallocation system of farmland, the cultivation period of the presently cultivated plots of a farm varies form survey site to survey site and even inside a village. The farm households have their current plots on average since 8.5 years.

Nearly no farmer reported to rent-out land, but only cultivating farm households have been interviewed. Only in Liangshan County about 25 per cent of the farmers

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[7]   The Chinese measure unit for land area is mu, 1 ha is equal to 15 mu.

reported that there is no demand by other farmers to rent-in additional land. About 75 per cent of farmer answered not to rent out because they need all land by themselves. At the other survey sites, this is the answer in nearly all cases. About 10 per cent of farm households rent-in farmland in addition to their allocated farmland, but there is a high variation between the surveyed townships. The average size of the land is 0.23 ha and the rent is on average about 3 000 ¥ per ha (Annex Table 8). The reasons for not renting any land vary between the survey sites. The most common answer (40 per cent) of all farmers is that no land is available followed by no need to rent-in land (29 per cent). It is not profitable to rent-in land is the answer in 14 per cent of the cases, but in Liangshan County, this share is over 40 per cent. Lack of labour is answered by 19 per cent (Annex Table 9).

5.1.3   Livestock Keeping

Livestock keeping among farm households in the North China Plain shows a high variation in frequency. In the counties of Kaifeng, Quzhou, Yanjin only a minority of farm households keep livestock. On average about 40 per cent of farm households breed livestock and produce about 5.5 tons of manure per farm household. There is a high local variation according to the frequency of farm households keeping a certain kind of livestock. However, 17 per cent of farm households have the average amount of two cattle, 6 per cent have three goats, and 17 per cent have five pigs. Only a minority of farm households reported to have poultry (Annex Table 10).[8]

5.1.4   Farm machinery

Rural households rent-in or own 2-wheel or 4-wheel tractors. The frequency of ownership or renting of these types of tractor shows local variation (Table 8).

Table 8   Share of farms owning or renting a certain kinds of tractors

county	Liangshan		Huimin		Kaifeng		Quzhou		Yanjin		all
township	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	farms
rent 2-wheel tractor [%]	5	8				2	1				16
own 2-wheel tractor [%]	7	1	3	1	13	7	8		6	19	65
own 3-wheel tractor [%]	6	13	5	7	18	18	10	16	12	9	114
rent 4-wheel tractor [%]	11	12	7	8			2				40
own 4-wheel tractor [%]	4	4	12	6	2		11	4	2	5	50

While in Huimin County most farm households own or rent-in a 4-wheel tractor in Kaifeng County only about one third of the farm households owns a 2-wheel tractor, but half of them have a 3-wheel tractor. On average one third of the farm households owns a 3-wheel tractor which is mainly used for transport. This kind of machine is normally not rented-out to other farmers, but farmers offer transport services. About 15 per cent of farm households rent-in and the same percentage own a 4-wheel

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8   There is a relative low variation in the amount of cattle, goat, and pig per farm household.

tractor. About 20 per cent own a 2-wheel tractor and only in Liangshan County about 20 percent of farm households rent-in this kind of tractor. In rural China, only a minority of farm household uses formal credits to purchase an agricultural machine. Informal credits without an interest from relatives and friends are the main credit source. For this reason, capital costs are not considered. The maintenance costs are on average 250 ¥ per farm household or 330 ¥ per cultivated ha.

5.1.5   Own consumption of wheat and maize

Even those farm households with a high off-farm income reported to cultivate wheat for food security reasons. In total 92 per cent of farm households use their harvested wheat for own consumption and 36 per cent cultivate wheat only for own consumption. The average annual consumption of wheat per household member is 292 kg. Maize is used as human food for own consumption by 19 per cent of farm household and on average 129 kg are consumed annually per household member. Maize is used as livestock feed grain by 31 per cent of farm households and the average consumption is about 1 200 kg per household. The value of consumed wheat and maize is on average 440 ¥ per person taking the average wheat and maize price into account The average calculated production costs of this amount of wheat and maize which is used for own consumption is 205 ¥ per household member and therefore lower than the market price. The ratio between own consumption and selling of wheat and maize is discussed in chapter 5.3.1 and chapter 5.3.2. Furthermore, the share of harvested wheat which is sold (and not used for own consumption) is indicated as the variable *sold-harvest ratio*.

5.2   Income Generation of Farm Households

The development of the income level of rural household shows two fundamental tendencies. First, there is the income gap between urban residents and rural residents. The average net income per urban capita of about 8 000 ¥ is more than two times that of rural residents, which is about 3 000 ¥. Additionally, there are regional differences, e.g. rural residents in Shandong Province have about 50 per cent higher income than those in Henan Province. Further, urban residents in Beijing have about 13 000 ¥ per capita income. This is nearly two times the average per capita income of urban residents of the five NCP provinces (Annex Table 11).

Second, since in China the average cultivated land per capita is only about 0.10 ha the income from off-farm non agricultural activities becomes more and more important for rural households (LI, Y. 2001). According to official statistics for those provinces belonging to the NCP the average per capita income from agriculture is less than 1 000 ¥ and the average per capita income from off-farm activities is 1 830 ¥. The majority of rural labour engaged in off-farm activities is employed at Village and Township Enterprises and, therefore, these is the main source of off-farm income (Annex Table 11 and Annex Table 12).

The average household income at the survey sites is about 10 150 ¥ per year, this is about 2 000 ¥ per family member. The median is 7 280 ¥ annual income per farm household, while the lower quartile is 3 960 ¥ and the upper quartile amounts to 13 590 ¥ annual income per farm household. Figure 5 presents the cumulative distribution functions (CDF) of the household income at all surveyed counties.
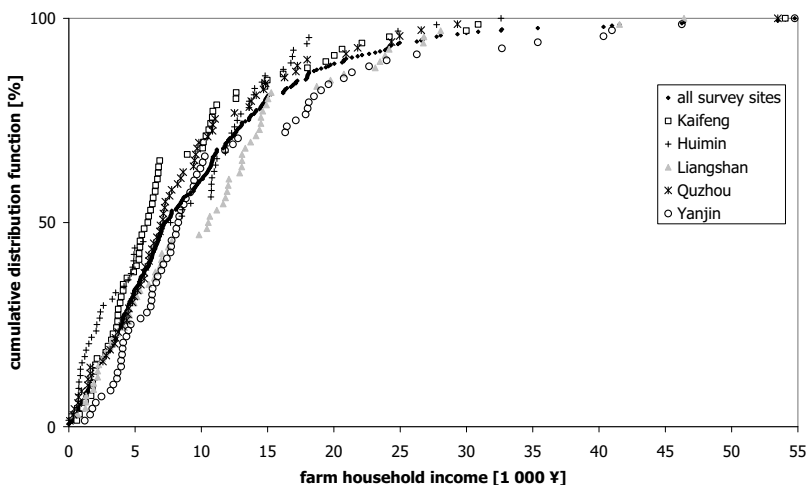
Figure 5   Cumulative distribution function of the farm household income

These cumulative distribution functions of the household income can be compared by applying the first-degree stochastic dominance criteria. Farm households in Huimin and Yanjin County have an above average income, while in Quzhou and Kaifeng it is below the average.

Farming results in an average farming net cash income of about 3 650 ¥ per year, this is 850 ¥ per family member. Additionally, there is an average annual net non-cash income of 895¥ per household from own consumption of wheat, maize, peanut and other crops as food, which is the difference between the production costs and the market value of those crops.[9] About one third of farm households uses maize as feed grain, the average net non-cash income of these households is 950 ¥ per year resulting in an average net non-cash income of 310 ¥ for all farm households. Therefore the average farming net non-cash income is 1 200 ¥ and the farming total net income is on average annually 4 850 ¥ per farm household. The average off-farm income of those 62 per cent of farm households actually having any kind of off-farm income amounts to 8 150 ¥ per year.[10] About 37 per cent of farmers report to have livestock net income, the average annual net income of those farm households is about 3 400 ¥ (Table 9).

Table 9   Structure of farm household income

	net cash income per household [¥ year^{-1}]	share of households having this kind of income
wheat net cash income	865	67% (1 300 ¥)
maize net cash income	650	61% (1 070 ¥)
peanut net cash income	840	21% (4 040 ¥)
cotton net cash income	1220	55% (2 220 ¥)
farming net cash income[1]	3 650	99% (3 750 ¥)
livestock net cash income	1 260	37% (3 400 ¥)
off-farm income	5 220	64% (8 150 ¥)
total income	10 150	

Note   [1] includes the net cash income of 75 ¥ of the not listed crops

As described, the majority of rural work force is working on the own fields, but off-farm income is the major cash income sources of the surveyed farm households at the survey sites in the North China Plain.[11] The average off-farm income is higher than the average farming net cash income, but more than half of the farm households do have an income share from farming of at least 50 per cent. These farm households are considered as *main income farming* farm households. These kind of farm households does have on average marginal more farmland and more net cash income from

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[9]   Soybean, garlic, onion, rapeseed, water melon, and tomatoes are summarised as other crops.
[10]   The income figures for farming are based on costs and revenue calculations of each crop, but since the figures for off-farm income are directly given by the interviewed farm household head these data might be over or under estimated.
[11]   The field survey focuses on the wheat and maize cultivation farm households, hence greenhouse farm household and pure livestock farm households are not considered.

farming than *minor income farming* farm households, which are characterised by an income share from farming of less than 50 per cent (Table 10).

Table 10   Differences on average income between full income farm households and part income farming farm households

	share of farm households [share]	farmland [ha]	household income [¥ year^{-1}]	farming net cash income [¥ year^{-1}]	share of farm households with off-farm income [share]	actual off-farm income [¥ year^{-1}]
main income farming[1]	54%	0.57	6 240	4 370	40%	3 160
minor income farming[2]	46%	0.48	14 630	2 840	92%	10 740

Note: [1] income share from farming is at least 50 per cent
          [2] income share from farming of less than 50 per cent

About 40 per cent of the *main income farming* farm households actually have off-farm income, but their average households income is less than half of that of *minor income farming* farm households. These farm households are characterised by an above average actual off-farm income, which leads to an above average household income. However, a small share of *minor income farming* farm households does have no off-farm income, but their income from livestock exceeds the income from farming. There is a local variation in the level of these income sources and differences in the share of farm households actually having this kind of income source (Table 11).

Table 11   Structure of farm household income at the survey sites

	total cash household income [¥ year^{-1}]	farming net income			livestock net cash income		off-farm net cash income	
		total [¥ year^{-1}]	cash[1] [¥ year^{-1}]	non-cash[2] [¥ year^{-1}]	[%][a]	[¥ year^{-1}][b]	[%][a]	[¥ year^{-1}][b]
TS #1, Liangshan	8 200	4 150	3 300	850	24	700	59	7 300
TS #2, Liangshan	11 650	2 400	1 400	1 000	34	1 200	81	11 600
TS #3, Huimin	11 550	4 800	3 750	1 050	53	3 500	78	7 600
TS #4, Huimin	14 450	4 800	3 850	1 000	44	8 650	75	8 700
TS #5, Kaifeng	12 000	6 300	4 650	1 650	58	4 900	48	9 000
TS #6, Kaifeng	5 900	3 650	2 250	1 400	15	2 700	52	6 100
TS #7, Quzhou	8 400	3 700	2 650	1 050	34	2 150	54	8 650
TS #8, Quzhou	6 900	3 650	2 900	750	18	1 800	59	5 900
TS #9, Yanjin	11 100	5 100	3 600	1 550	47	2 700	59	10 550
TS #10, Yanjin	12 000	9 800	8 200	1 600	47	2 150	56	4 600
all survey sites	10 190	4 850	3 650	1 200	37	3 400	64	8 150

Note: [1] average net cash income from selling, included in total household income
          [2] average net non-cash income from own consumption as food and feedgrain
          [a] this is the share of farmers actually having this kind of income source
          [b] this the average income of those farmer actually having this kind of income

Farm households at township #6 have an average income this is slightly more than half of the overall average and only half of the farm households have additional off-farm income. Farm households at township #2 gain an income above average due to a

high share of farm households with off-farm income sources, because the income from farming at this location reaches only half of the overall average (Table 11).

According to HUFFMAN (2001) there are tree types of farm households: only income from farming (*income type 1*), farming with partially local off-farm activities (*income type 2*), and at least one family member migrates (*income type 3*). Those 26 per cent of the farm households with income from migration have with 15 750 ¥ the highest average household income. About one third of farm households is without any off-farm income source and have only the average household income of 4 800 ¥ which is half of the overall average. This result underlines the influence of off-farm income towards the household income (Table 12).

Table 12   Income structure of defined *income types*

	share	total household income [¥ year^{-1}]	farming net income [¥ year^{-1}]	off-farm income [¥ year^{-1}]
exclusively farming income (income type 1)	36%	4 800	3 350[a]	
additional local off-farm income (income type 2)	38%	11 350	3 650[a]	6 400
additional income from migration (income type 3)	26%	15 750	4 000[a]	10 650

Source: farm household type definition adopted from (Huffman, W.E. 2001)

Note: [a] no significant difference in mean according to paired sample t-test

The average farming net non-cash income from own consumption of harvested crops as food and feed grain does not differ between these household income types, and there are no significant differences in farming net cash income. This result is confirmed by comparison of the calculated gross margin of each crop, there is no significant difference between these three income types.

Table 13 indicates the distribution of income type share at the surveyed townships. The townships #2, #3, and #4, which are located in Liangshan and Huimin are characterised by a low share of farm households with exclusively farming income (*income type 1*), while at the townships located in Kaifeng this share is above the overall average. This situation reflects the income level described in Table 11.

Table 13   Distribution of *income type* share at the survey sites

county	Liangshan		Huimin		Kaifeng		Quzhou		Yanjin	
township	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10
share income type 1 [%]	35[a]	16	22	22	52	48	43	38[a]	41[a]	44[a]
share income type 2 [%]	41[a]	50	53	50	18	30	23	41[a]	35[a]	38[a]
share income type 3 [%]	24[a]	34	25	28	30	21	34	21[a]	24[a]	18[a]

Note: [a] chi-square test: distribution does not differ significantly (p = 0.1) from overall distribution

Farm households of township #4 indicate the highest average income due to the low share of farm households belonging to *income type 1*. However, there are income type independent location specific effects. Township #10 shows a low share of farm households with migration as additional income source, but an above average in income. The extraordinary high income from farming explains this situation (Table 11).

5.2.1   Income Generation from Farming

Net income from farming can be divided into farming net cash income and farming net non-cash income from own consumption of harvested crops as food and feed. Table 14 presents the average net cash income and net non-cash income from usage as food or as feed considering all surveyed farm households, hence includes farm households who actually do not cultivate the considered crop. The main cash crop is cotton, but wheat still generates the highest total net income. Maize plays a major role as feed and shows similar net income values as peanuts. Other crops such as soybean, garlic, onion, rapeseed, and tomatoes are cultivated only locally. Less than one third of the surveyed farm households has one of these other crops. The average total net cash income of all crops is 3 650 ¥ per farm household, while the total net cash and non-cash income reaches on average 4 850 ¥ per farm household. The presented data indicate the average income per farm household, economic criteria such as gross margin per ha are shown in chapter 5.3.

Table 14   Average net cash income, net non-cash income from usage as food or feed of the major crops considering all farm households

	wheat	maize	peanut	cotton	other crops[1]	all crops
net cash income	865 ¥	650 ¥	840 ¥	1 220 ¥	75 ¥	3 650 ¥
net non-cash income from food	730 ¥	45 ¥	75 ¥		40 ¥	890 ¥
net non-cash income from feed		310 ¥				310 ¥
total net income	1 595 ¥	1 005 ¥	915 ¥	1 220 ¥	115 ¥	4 850 ¥

Note   [1] soybean, garlic, onion, rapeseed, watermelon, and tomatoes

Table 14 presents the average total net income of these crops, but the percentage of farm households, which actually cultivate und use the crop as food or as feed differs between these crops. Table 15 presents the share of farm households (all surveyed farm households are considered as 100 per cent) which actually cultivate these crops and the actual total net income generated from these crops. The share of farm households which actually cultivate wheat is 97 per cent and 82 per cent of farm households cultivate maize. Cotton is cultivated by 55 per cent of the surveyed farm households, while peanuts are cultivated by 23 per cent. Finally, the average sum of the annual farming net cash income and net non-cash income of wheat is 1 650 ¥ per wheat cultivating farm household.

Table 15   Average actual total net income of major crops considering only farm households actually cultivate the considered crops

	wheat	maize	peanut	cotton
cultivating farm households	322 (97%)	274 (82%)	77 (23%)	183 (55%)
actual total net income	1 650 ¥	1 220	3 950 ¥	2 220 ¥

Table 16 shows the usage of each crop and the share of farm households (all farm households which cultivate the crop are considered as 100 per cent) which actually sell or use the crop as food or as feed. Farm households use their crops in multiple ways,

hence the presented shares cannot be added up. About two third of wheat cultivating farm households sell wheat and use it for own consumption, while one third uses it as food only. In wheat, 69 per cent of wheat cultivating farm households sell wheat and have on average a net cash income of 1 300 ¥, this is 900 ¥ per farm household considering all wheat cultivating farm households. The average net non-cash income from own consumption per household is 730 ¥ considering all wheat cultivating farm households. However, 99 per cent use wheat as food and this percentage of farm households has an average actual net non-cash income of 740 ¥. The net cash income of wheat shows a wide variation from less than 500 ¥ to more than 2 000 ¥ between the surveyed counties (Annex Table 14). The average farming net cash income of those farm households actually selling maize reaches 1 070 ¥. Only a minority of farm households uses maize as food, but about two thirds of the maize cultivating farm households use maize as feed and reach an average net non-cash income of 950 ¥. Similar to wheat, these figures are converted into averages considering all maize cultivating farm households resulting in a total income of 1 220 ¥. The actual annual average net cash income per farm household of cotton amounts to 2 220 ¥, while the cultivation of peanuts reaches 3 950 ¥ average net cash and non-cash income per farm household (Table 15).

Table 16   Average net cash income and net non-cash income from usage as food or feed of the major crops

	wheat		maize		peanut		cotton	
	farms share	income	farms share	income	farms share	income	farms share	income
cash	222 (69%)	1 300 ¥	203 (74%)	1 070¥	69 (90%)	4 040 ¥	183 (100%)	2 220 ¥
food	320 (99%)	740 ¥	63 (23%)	240¥	31 (40%)	810 ¥		
feed			110 (40%)	950¥				

The average total net cash income of all crops is 3 650 ¥ per farm household. Taking into account the cropping pattern of cultivated crops as grouping variable for farm households four key cropping patterns with a share of more than ten per cent each are identified (Table 21, page 48). These cropping patterns show a wide variation in farming net cash income as well as in the share of farms with off-farm income. Table 17 shows the income characteristics of the major cropping pattern.

Table 17   Income structure of the most important cropping pattern

	farms	farming net cash income [¥ year^{-1}]	share of farms with off-farm income	total income [¥ year^{-1}]
wheat-maize	60	1 750	50%	6 390
wheat-maize -other	21	1 650	81%	11 360
wheat-maize -peanut	34	6 560	59%	12 140
wheat-maize -cotton	92	3 390	68%	9 810
wheat-maize -cotton-other	44	3 470	73%	12 640
all farms	344	3 650	64%	10 150

Note   other crops: soybean, garlic, onion, rapeseed, watermelon, grape, and tomatoes

Those 60 farm households (or 18 per cent) cultivating only wheat and maize gain an average farming net cash income of 1 750 ¥ which is less than half of the overall average net cash income from farming. Only half of these households have any kind of off-farm income source and their total household income of 6 430 ¥ is above average. By contrast farm households cultivating wheat, maize, and cotton have an average farming cash net income of 3 440 ¥. The cultivation of these three crops is the most common cultivation pattern. More information about cropping patterns and their characteristics are presented in chapter 5.3. Annex Table 13 shows all identified cropping patterns.

5.2.2   Off-farm Activities as Income Source for Rural Households

About two thirds of the surveyed farm households have some kind of off-farm income source and in this group on average 60 per cent of the household income is from off-farm activities. In general the off-farm income sources can be divided in tree different off-farm activities, own family business, employed job at mainly a rural village or township enterprise, and migration to usually urban areas to work mainly in industry or construction. Table 12 distinguishes only between local off-farm job (*income type 2*) and migration (*income type 3*). *Income type 2* includes family owned businesses, while *income type 3* consists of all combinations which include migration. Table 18 describes the off-farm income sources in more detail. It is uncommon for those farm households with off-farm income to have several off-farm income sources, less than 20 per cent have more than one off-farm income source. The average household income of these farms with two types of off-farm income amounts to about 20 000 ¥, which is nearly double that of the overall average farm household income. The income from family owned businesses shows a similar range than that of a local off-farm job.

Table 18   Income structure of farm households classified by income source

	income type	share[a]	local off-farm job income	migration income	family business income	total household income
local off-farm job only	2	35%[a]	4 610 ¥			9 760 ¥
migration only	3	32%[a]		8 980 ¥		13 830 ¥
family business only	2	14%[a]			5 490 ¥	8 920 ¥
local off-farm job, family business	2	11%[a]	7 240 ¥		6 080 ¥	19 620 ¥
local off-farm job, migration	3	5%[a]	8 510 ¥	10 530 ¥		26 260 ¥
migration, family business	3	3%[a]		7 450 ¥	5 550 ¥	18 420 ¥

Note: [a] share expresses the percentage of those farms with any kind of off-farm income source

Local details about the share of households actually having a certain off-farm income source and resulting average income are presented in annex table 15. There local averages of the total income share of the different off-farm income sources are shown.

5.3   Characteristics of Crop Cultivation

Wheat, maize, peanut, and cotton are the key crops of the North China Plain (Table 19). The five provinces belonging to the NCP own 26 per cent of the total arable land, but have nearly 60 per cent of the wheat cultivation area. For cotton, this share is even higher. Crops such as rapeseed, potatoes, or rice play only a minor role (Annex Table 16). Rice is cultivated in the Southern parts of Jiangsu and Anhui outside the NCP.

Table 19   Major cultivated crops in the North China Plain in 2003

	arable land [1 000 ha]	wheat [1 000 ha]	maize [1 000 ha]	peanuts [1 000 ha]	cotton [1 000 ha]
Hebei	6 880	2 190	2 490	490	580
Jiangsu	5 060	1 620	450	210	370
Anhui	5 970	2 010	630	270	390
Shandong	7 690	3 110	2 410	990	880
Henan	8110	4 800	2 390	960	930
NCP Provinces[1]	33 710	13 730	8 370	2 920	3 150
share to whole China	26%	57%	34%	60%	75%
PR China	130 039	23 900	24 600	4 900	4 200

Source: (NATIONAL BUREAU OF STATISTICS OF CHINA 2003), (ANHUI PROVINCE STATISTICAL BUREAU 2003), (HENAN PROVINCE STATISTICAL BUREAU 2003), (HEBEI PROVINCE STATISTICAL BUREAU 2003), (JIANGSU PROVINCE STATISTICAL BUREAU 2003), (SHANDONG PROVINCE STATISTICAL BUREAU 2003)

Note   [1] data for Hebei, Jiangsu, Anhui, Shandong and Henan, this includes those parts of these provinces which do not belong to the NCP and excludes the municipalities of Beijing and Tianjin

Table 20 lists the number of farm households cultivating each crop. The majority of farm households at all survey sites cultivates wheat and maize. Cotton is cultivated at nearly all survey sites, while peanuts play a major role at two surveyed townships. All other crops are only locally found, often only at one surveyed village. For this reason, these crops are summarized to other crops. According to the cultivation area, vegetables play an important role as well, but there are enormous regional differences and vegetables are often cultivated in a specialized greenhouse production system. Since the overall research focus of this research project is the wheat and maize cultivation system, greenhouse farms are not interviewed.

Based on a survey in Quzhou County in Hebei Province in 2001, CHEN et al. (2006) stated that food security is still the first priority to farm households. In their effort to maintain self-sufficiency in food production, farm households feel obliged to practice the wheat maize cropping system although it has a low economic benefit.

Winter wheat and summer maize are cultivated in rotation, while cotton is cultivated as one crop per year. The cultivation of peanuts is practiced in rotation with winter wheat or as one crop per year. At township level, not all farm household practice all crops, which are usually cultivated in this township. There exist several cropping

patterns at each township and some of these cropping patterns are practice at several townships.

Table 20   **Cultivated crops at the survey sites by number of farm households cultivating these crops**

county	Liangshan		Huimin		Kaifeng		Quzhou		Yanjin		all
township	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	farms
farm households [no.]	34	32	32	32	33	33	35	34	34	34	333
wheat [no.]	31	32	31	27	33	33	33	34	34	34	322
maize [no.]	23	31	30	26	13	28	32	31	30	30	274
peanuts [no.]	6				31				6	33	76
cotton [no.]	30	11	29	31		15	26	28	6	6	182
soybean [no.]	3	23							3		29
garlic [no.]				17							17
onion [no.]				14							14
rapeseed [no.]					5						5
watermelon [no.]	14			2	9						25
grape [no.]	11										11
tomatoes [no.]									6		6

As mentioned already, the pure wheat and maize cropping pattern is practiced by 62 out of 333 or 19 per cent of the surveyed farm households and it is the most common cropping pattern at two surveyed townships. However, at half of the surveyed townships it is not practiced at all (Table 21).

Table 21   **Cropping pattern at the survey sites**

county		Liangshan		Huimin		Kaifeng		Quzhou		Yanjin		all
township		#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	farms
	cotton -other	3		1	5			2				11
wheat	-peanut					10					4	14
wheat	-peanut -other					7	1					8
wheat	-cotton	1			1		5	2	3			12
wheat	-cotton-other	7	1	1		1						10
wheat	-other				1					3		4
wheat-maize		1	6	1		1	18	8	6	20	1	62
wheat-maize	-other	2	15	2						2		21
wheat-maize -peanut						8		1		2	23	34
wheat-maize -peanut-cotton										3	6	9
wheat-maize -peanut	-other	1				5				1		7
wheat-maize -peanut-cotton-other		5										5
wheat-maize	-cotton	4	3	21	6	1	9	22	25	1		92
wheat-maize	-cotton-other	10	7	6	19					2		44
number of farm households [no.]		34	32	32	32	33	33	35	34	34	34	333

Note   other crops: soybean, garlic, onion, rapeseed, watermelon, grape, and tomatoes

Usually only three different cropping patterns including one major pattern are practiced at township level. A few townships show four or even six different cropping patterns, but these cropping patterns differ marginally since all include cotton or peanut as the key common characteristic.

The most common cropping pattern of all survey sites is the wheat-maize-cotton cropping pattern, which is cultivated by 28 per cent of all farm households and is found in seven townships. In four townships, other crops extend this cropping pattern and this wheat-maize-cotton-other cropping pattern is practiced by 13 per cent of all farm households. Since peanuts are only cultivated in three townships the wheat-maize-peanut cropping pattern is dominating two of these townships. As mentioned already in Kaifeng County this cultivation pattern is modified by additional other crops and by cropping patterns without maize.

5.3.1   Cultivation of Wheat

Wheat is the staple food in north China and is cultivated by nearly all surveyed farm households. About two thirds of the harvested wheat are used for own consumption, but there are differences between the survey townships (Table 22).

Table 22   Wheat cultivation characteristics at the survey sites

county	Liangshan		Huimin		Kaifeng		Quzhou		Yanjin		all
township	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	farms
area [ha]	0.31	0.25	0.28	0.16	0.56	0.42	0.31	0.25	0.38	0.85	0.38
seed cost [¥ ha^{-1}]	270	420	600	500	470	670	600	560	400	460	490
fertilizer cost [¥ ha^{-1}]	1 780	1 790	2 290	2 170	1 790	1 890	1 780	2 430	1 540	1 310	1870
nitrogen input [kg ha^{-1}]	270	380	430	440	320	330	360	510	270	340	360
nitrogen price [¥ kg^{-1}]	7.34	5.03	5.49	5.37	6.64	6.38	5.73	5.50	6.52	3.75	5.77
yield nitrogen ratio [t t^{-1}]	32	20	15	21	19	23	21	17	33	20	22
irrigation cost [¥ ha^{-1}]	350	510	320	1 230	560	420	920	1 170	390	510	630
herbicide use[1] [%]	16	6	84	85	39	52	24	53	79	82	52
insecticide use [%]	74	91	97	93	100	97	64	79	97	91	88
insecticide cost [¥ ha^{-1}]	95	160	150	190	200	205	70	105	165	120	145
machine harvest[2] [%]	48	81	97	89	27	70	97	100	97	94	80
variable cost[3] [¥ ha^{-1}]	3 310	3 910	4 440	5 590	3 600	4 000	4 410	5 390	3 590	3 150	4 110
yield [t ha^{-1}]	4.53	5.65	5.60	6.66	4.77	6.80	5.55	5.81	6.56	5.25	5.73
wheat selling farms [%]	48	63	81	30	94	85	73	29	79	100	69
sold-harvest ratio[4] [%]	31	31	41	17	45	44	34	19	53	69	39
price [¥ kg^{-1}]	1.35	1.34	1.43	1.78	1.41	1.39	1.44	1.45	1.41	1.37	1.42
revenue[5] [¥ ha^{-1}]	6 540	8 000	7 930	9 690	6 760	9 620	7 860	8 230	9 300	7 430	8 120
gross margin[5] [¥ ha^{-1}]	3 230	4 090	3 490	4 090	3 160	5 630	3 450	2 840	5 710	4 280	4 010

Note: [1] average herbicides costs are 130 ¥ ha^{-1}
          [2] average costs of machine harvesting are 420 ¥ ha^{-1}
          [3] not all components of the variable costs are listed
          [4] sold-harvest ratio is the average share of the farm yield which is sold
          [5] calculated revenue and gross margin base on plot share taking ratio between total yield and sold yield into account in order to calculate area used for sold yield

For example, at the surveyed townships in Huimin and Yanjin most of farm households are selling wheat and about half of the yield is sold. While at the survey sites in Shandong Province less than 20 per cent of the wheat harvest is sold. This difference might be explained by the differences in family farmland between these townships (Table 7, page 37). On average about one third of farm households uses wheat only for own consumption and do not sell wheat.

Table 23 presents the components of the variable costs of wheat cultivation. These include the average costs, the share of farm households, and the actual average costs. The average costs of a certain activity considers all farm households cultivating this crop, but includes farm households actually not doing this kind of operation. However, especially if only a minority of farm households actually carry out certain operation, the resulting average costs do not provide useful data for comparing cultivation in different locations or of different crops. In this case, it is more interesting to know the share of farm households actually doing this activity and their average costs. Therefore, the share and the actual average costs are indicated as well.

Table 23   **Average costs of the components of variable costs, share of farms having this kind of costs, and average actual costs of these components in wheat cultivation**

	average costs considering all wheat cultivating farms [¥ ha^{-1}], (quartiles)[a]	share of farms actually having this kind of costs	average costs of farms actually having this costs [¥ ha^{-1}], (quartiles)[a]
seeds	490, (230; 680)[a]	79%	630, (400; 780)[a]
ploughing and sowing	260, (0; 470)[a]	57%	460, (370; 530)[a]
own machinery	320, (0; 560)[a]	65%	500, (230; 610)[a]
irrigation	630, (300; 900)[a]	98%	640, (315; 900)[a]
fertilizer	1 870, (1 210; 2 430)[a]	100%	1 870, (1 210; 2 430)[a]
herbicides	45, (0; 60)[a]	52%	85, (40; 110)[a]
insecticides	145, (55; 200)[a]	88%	165, (75; 215)[a]
machine harvesting	340, (150; 500)[a]	80%	420, (305; 525)[a]
variable costs[1]	4 110, (3 060; 4 930)[a]		

Note: [1] rounding errors lead to slight differences in the sum of the single components
          [a] quartiles interval of the lower or 25% and upper or 75% quartile

Farm households usually cultivate only one wheat variety, but a few farm households use two or three different varieties. The varieties Yumai-18 and Yumai-34 are the most common wheat varieties (Annex Table 17). The majority of farm households buy seeds, only a minority collects seeds from the own fields or gets the seeds from exchange with other farm households. The average seed costs are 490 ¥ per ha, but the average costs for seeds of those farm households (79 per cent) which actually buy seeds amounts to 630 ¥ per ha (Table 23).

Nearly all farmers use a tractor for ploughing and machine sowing. Usually farm households rent-in these machines together, hence only a single price for ploughing including sowing is available. More than half of the farm households rent-in these machinery and their average costs for sowing and ploughing amounts to 460 ¥ per ha

or 260 ¥ per ha considering all farm households. In case of tractor ownership, the total maintenance costs are allocated to each crop according to the cultivation area. The wheat share of these machinery costs is 320 ¥ per ha or 500 ¥ per ha, if considering only farm households owning machinery (Table 23).

Nearly all farm households use the furrow irrigation system. This means the fields are flooded by using pumps. The source of water depends on the location. In the survey sites located in Shandong Province surface water is available, while in the other counties farm households use mainly ground water. Farm households usually irrigate wheat two or three times per year, only a minority of farmers reported to irrigate wheat less than two times. Since water meters are uncommon, the information about the amount of water is a rough estimate. The irrigation cost calculations consider estimated pumping duration (usually one or two hours) and electricity or fuel costs per hour. In wheat cultivation, nearly all farm households irrigate and their average actual irrigation costs amount to about 640 ¥ per ha (Table 23).

All farm households apply fertilizer and the average fertilizer costs are about 1 870 ¥ per ha and the confidence interval is between 1 210 ¥ per ha at the lower quartile and 2 430 ¥ per ha at the upper quartile. Fertilizer costs cover half of the variable costs. The average nitrogen input is 360 kg per ha and the average nitrogen price amounts to 5.77 ¥ per kg of nitrogen. The application of nitrogen is discussed in chapter 7.

Most farm households apply insecticides and half of farm households use herbicides in wheat cultivation. In case of pesticide application, the actual average costs of herbicides amount to 85 ¥ per ha and insecticides to 165 ¥ per ha (Table 23). According to a survey in Shandong Province all farm households use insecticides, which are cheap and freely available and are applied at application rates that are two to three times higher than the recommended dosages (ZHEN, L., J.K. ROUTRAY et al. 2005). On average about 80 per cent of farms harvest wheat by using machinery, but there is a local variation. In most of the surveyed townships, all farm households use mechanical harvesting, but for example in township #5 in Kaifeng County less than one third of the farms uses mechanical harvesting (Table 22). The average actual costs of machine harvesting are 420 ¥ per ha. The resulting average variable costs at wheat cultivation are 4 120 ¥ per ha and the quartiles range from 3 060 to 4 930 ¥ per ha (Table 23). Table 24 presents the key economic figures for wheat including the lower and upper quartile. Further, the figures for maize, peanut, and cotton are shown to enable a direct comparison with wheat cultivation. The average wheat yield is 5.73 tons per ha. The quartiles show that half of the wheat cultivating farm households have a wheat yield between 4.69 tons and 6.43 tons per ha. There is a local variation in yield. The average at county level varies between 4.53 tons per ha at township #1 and 6.80 tons per ha at township #6 (Table 22).

The wheat price is on average 1.42 ¥ per kg and shows a low variation. As already mentioned, on average 39 per cent of the harvested wheat is sold. The actual revenue considers the ratio between total harvest and the amount of wheat sold, hence only farm households, which actually sell wheat. The actual revenue reaches an average of 8 350 ¥ per ha and it results in an average actual gross margin of 4 480 ¥ per ha. The the lower and the upper quartile show a range between 2 530 ¥ and 6 180 ¥ per ha.

Table 24   Key economic figures for cultivation of wheat

		wheat average (quartiles)	maize average	peanut average	cotton average
cultivation area	[ha]	0.38 (0.20; 047)	0.25	0.51	0.25
average yield	[t ha^{-1}]	5.73 (4.69; 6.43)	6.40	3.30	2.79
share of selling farms	[%]	69	74	90	100
sold-harvest ratio[1]	[%]	39	63	76	99
average crop price	[¥ kg^{-1}]	1.42 (1.38; 1.46)	1.10	3.08	4.43
actual revenue	[¥ ha^{-1}]	8 350 (6 590; 9 480)	7 060	10 560	12 640
calculated revenue	[¥ ha^{-1}]	8 120 (6 640; 9 110)	7 040	10 190	12 630
actual gross margin	[¥ ha^{-1}]	4 240 (2 530; 6 180)	4 680	8 290	9 060
calculated gross margin	[¥ ha^{-1}]	4 010 (2 280; 5 440)	4 660	8 050	9 050

Note: [1] share of total harvest that is sold

In order to include farm household cultivating exclusively for own consumption the calculated revenue and finally the calculated gross margin is calculated by taking individual yield and the average selling price into account. The values of the calculated gross margin are slightly lower than the values of the actual gross margins. This situation might indicate differences between cultivation of wheat for selling and exclusively own consumption. For this reason, the cultivation system of farm households, which cultivate wheat only for own consumption is compared with that of farm households selling wheat (Table 25).

Table 25   Comparison of characteristics of farms cultivating wheat exclusively use for own consumption and farm households selling wheat

		wheat cultivation exclusively for own consumption	wheat cultivation for selling and own consumption	all wheat farm households
farm households	[#]	100	222	322
family farmland	[ha]	0.42	0.58	0.53
wheat cultivation area	[ha]	0.23	0.45	0.38
long term wheat yield	[t ha^{-1}]	5.33[a]	5.35[a]	5.36
fertilizer costs	[¥ ha^{-1}]	2 180	1 730	1 870
relative fertilizer costs	[%]	106[a]	97[a]	100
nitrogen input	[kg ha^{-1}]	420	335	360
relative nitrogen input	[%]	108	96	100
nitrogen price	[¥ kg^{-1}]	5.70[a]	5.80[a]	5.77
variable costs	[¥ ha^{-1}]	4 730	3 840	4 110
relative yield	[%]	96	102	100
yield	[t ha^{-1}]	5.45[a]	5.86[a]	5.73

Note: [a] no significant difference in mean

In case of exclusively own consumption, farm households cultivate wheat on significantly less cultivation area of about 0.23 ha as compared to farm households selling wheat, which have an average cultivation area of 0.45 ha. The family farmland of farm households cultivating wheat exclusively for own consumption is below the

overall average. However, the average own consumption of wheat is 292 kg per household member. If the average household size of 3.6 persons and the average wheat yield of 5.73 tons per ha are considered, 0.18 ha are required to fulfil the wheat demand of an average farm household (Table 25).

On the one hand, the long term wheat yield shows no difference between wheat selling and not selling farm households. Hence, there is no difference in estimated plot quality. Further, there is no significant difference in the reported yield for 2004. On the other hand, since there are location related differences in wheat yield, the relative yield excluding the impact from the location considered. The relative yield indicates the yield as percentage of the village average yield. The farm households cultivating wheat exclusively for own consumption have on average a relative yield of 96 per cent, hence in general these farm households belong to farm households with lower yields inside a village. However, the importance of food security for those farm households cultivating wheat only for own consumption is indicated by the higher fertilizer costs and higher nitrogen input, both, in absolute as well as in relative figures (Table 25).

The survey results are compared with recommendations for German farmers, official statistics of NCP provinces, and two different recommendations for Chinese farm households in the NCP. The average weighted ratio between calculated revenue and fertilizer costs of the surveyed farm households amounts to 5.99 ¥ of revenue per unit fertilizer costs. These data are in line with the official statistics of the NCP provinces. CHEN (2003) suggested fertilizer application rates of 180 kg of nitrogen per ha excluding additional nitrogen input from manure and returning straw to field as optimised nitrogen input in case of a target yield of 6 tons per ha. These recommendations are similar to the recommendations for farm households in Bavaria, Germany (BAYRISCHE LANDESANSTALT FÜR LANDWIRTSCHAFT 2006). ZHEN et al. (2005) conducted a survey in Shandong Province and presents 210 to 255 kg of nitrogen per ha as recommendations from local agricultural experts. The author's survey results show a much higher average nitrogen input in wheat, which amounts to 360 kg of nitrogen per ha. The recommendations lead to a yield to nitrogen ratio of 33 kg (CHEN, X. 2003) or more than 20 kg (ZHEN, L., J.K. ROUTRAY et al. 2005) of wheat yield per kilogramme nitrogen, while considering the author's survey this figure reaches 22 kg of wheat yield. This figure is the weighted average of the individual ratios of each farm household. The ratio between yield and nitrogen input is the nitrogen use efficiency.

A farm survey in Shandong Province of ZHEN et al. (2005) identified that only six per cent of the farm households act on these recommendations with their average nitrogen input being 375 kg per ha which is similar to the results of the author's survey. However, only 13 per cent of the surveyed (of the author) farm households apply less than CHEN's (2003) recommendations of 180 kg of nitrogen per ha (Table 26).

Table 26   **Wheat cultivation characteristics of Germany, official Hebei Province statistics and recommendations for North China Plain**

		farm survey NCP[1]	German farmer[2]	official statistics[3]			Chen[4]	Zhen[5]
				Hebei	Henan	Shandong		
nitrogen input	[kg ha⁻¹]	360	160					180	210-255
yield nitrogen ratio	[kg kg⁻¹]	22ᵃ	39				33	25-21
fertilizer costs	[¥ ha⁻¹]	1 870	1 780	1 270	950	1 490		
revenue fertilizer ratio	[¥ ¥⁻¹]	5.99ᵃ	4.60	4.89	6.30	4.44		
seeds costs	[¥ ha⁻¹]	490	610	385	270	300		
irrigation costs	[¥ ha⁻¹]	630		565	150	355		
crop protection costs	[¥ ha⁻¹]	190	1 100	85	85	85		
harvesting costs	[¥ ha⁻¹]	340	1 120					
machinery costs	[¥ ha⁻¹]	320	1 160	820	555	670		
other costs	[¥ ha⁻¹]	270	0	1345	1 545	1 570		
variable costs	[¥ ha⁻¹]	4 120	5 770	4 470	3 555	4 470		
yield	[t ha⁻¹]	5.73	6.20	5.13	4.35	5.08	6.00	5.33
calculated revenue	[¥ ha⁻¹]	8 120	8 180	6 210	5 985	6 615		
calculated gross margin	[¥ ha⁻¹]	3 940	2 410	1 290	1 965	1 515		

Source: [1] IRTG SUSTAINABLE RESOURCE USE IN NORTH CHINA, FIELD SURVEY: SPRING 2005
            [2] recommendation of BAYERISCHE LANDESANSTALT FÜR LANDWIRTSCHAFT (2006), 1 € = 10 ¥
            [3] China Agricultural Statistics (NATIONAL DEVELOPMENT AND REFORM COMMISSION 2004)
            [4] recommendation considering target yield of 6 tons per ha (CHEN, X. 2003)
            [5] recommendation of Soil Survey Office Dezhou District, (ZHEN, L., J.K. ROUTRAY et al. 2005)

Note: ᵃ weighted average

In case of the recommendations by ZHEN et al. (2005) of 255 kg of nitrogen per ha this share is still one third. ZHEN et al. (2005) reported that farm households gain a net return in wheat of 1 110¥ per ha and a similar yield, 5.33 tons of wheat per ha.

5.3.2   Cultivation of Maize

The usage of maize is both, own consumption as food and especially animal feed grain as well as sales. The share of farm households cultivate maize exclusively for selling is 44 per cent, while in total 75 per cent of maize cultivating farm households sell maize. Table 27 presents the share of each maize usage pattern. In total, 40 per cent of the farm households use maize as feed grain and on average, the actual amount of maize that is feed to animals is 2.38 tons per household. This figure is slightly lower than the average sold amount of maize. The overall average cultivation area is 0.25 ha and shows some variation between the survey sites.

Nearly all farm households buy seeds from the extension service or seed dealers and the actual average seed costs of these farm households are 310 ¥ per ha. The variety Nongda-108 is cultivated by more than one third of farm households (Annex Table 18). Less than half of the farm households use a tractor for ploughing and machinery for sowing.

Table 27   Pattern of maize usage considering selling, own consumption as food, and own consumption as feed grain

	share	sold maize [ton per household]	used as food [ton per household]	used as feed grain [ton per household]
sold	44%	2.87		
sold food	13%	2.69	0.65	
sold feed grain	15%	2.47		1.81
sold food feed grain	3%	1.61	0.29	0.94
food	4%		1.26	
food feed grain	3%		0.47	3.04
feed grain	19%			2.95
all maize farmers		2.71	0.68	2.38

Similar to wheat, nearly all farm households apply fertilizer, but the actual average fertilizer costs of 955 ¥ per ha are about half of the figures in wheat cultivation. The average nitrogen input is 220 kg per ha and the average nitrogen price amounts to 4.61 ¥ per kg of nitrogen (Table 28).

Table 28   Average costs of the components of variable costs, share of farms having this kind of costs, and average actual costs of these components in maize cultivation

	average costs considering all maize cultivating farms [¥ ha^{-1}], (quartiles)[a]	share of farms actually having this kind of costs	average costs of farms actually having this costs [¥ ha^{-1}], (quartiles)[a]
seeds	310 (190; 390)[a]	96%	320 (205; 395)[a]
ploughing and sowing	110 (0; 120)[a]	41%	275 (105; 390)[a]
own machinery	320 (0; 460)[a]	63%	500 (225; 605)[a]
fertilizer	930 (515; 1 150)[a]	97%	955 (540; 1 200)[a]
irrigation	350 (90; 475)[a]	80%	435 (205; 600)[a]
herbicides	95 (0; 150)[a]	73%	135 (60; 150)[a]
insecticides	140 (45; 150)[a]	88%	160 (80; 180)[a]
threshing	70 (0; 100)[a]	65%	110 (60; 120)[a]
machine harvesting	15	3%	400 (330; 450)[a]
variable costs[1]	2 380 (1 700; 2 850)[a]		

Note: [1] rounding errors lead to slight differences to the sum of the single components
         [a] quartiles interval of the lower or 25% and upper or 75% quartile

The costs for irrigation are lower as well, but as mentioned already, these figures are rough estimates. The majority of farm households apply herbicides and insecticides in maize cultivation. The actual average costs in case of application of herbicides are 135 ¥ per ha and 160 ¥ per ha for insecticides. Two thirds of farm households have threshing costs and these actual average costs are 110 ¥ per ha, this figure considers the individual yield. Nearly no farm household uses machinery for harvesting (Table 28).

The average variable cost of 2 380 ¥ per ha shows a variation between 1 700 ¥ and 2 850 ¥ per ha as lower and upper quartile. The variation of maize yield at township level shows a similar pattern as that of wheat yield (Table 29).

Table 29   Maize cultivation characteristics at the survey sites

county	Liangshan		Huimin		Kaifeng		Quzhou		Yanjin		all
township	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	farms
area [ha]	0.18	0.18	0.28	0.17	0.19	0.32	0.28	0.25	0.32	0.26	0.25
seed cost [¥ ha^{-1}]	260	270	320	290	370	320	270	340	330	300	310
fertilizer cost [¥ ha^{-1}]	850	740	1 340	1 400	900	720	730	600	850	1 220	930
nitrogen input [kg ha^{-1}]	150	160	240	280	240	190	180	140	240	380	220
nitrogen price [¥ kg^{-1}]	6.06	4.79	6.34	5.16	3.90	3.86	4.27	4.27	3.84	3.57	4.60
yield nitrogen ratio [t t^{-1}]	40	40	35	37	26	37	42	49	37	29	38
irrigation cost [¥ ha^{-1}]	140	240	90	270	310	320	610	750	220	440	350
herbicide use[1] [%]	39	19	97	92	46	50	84	97	83	97	73
insecticide use [%]	70	90	100	100	92	89	72	81	90	93	88
insecticide cost [¥ ha^{-1}]	115	185	145	185	225	135	75	110	175	115	140
threshing costs [¥ ha^{-1}]	40	105	60	110	55	20	55	65	120	80	70
variable cost [¥ ha^{-1}]	1 930	1 910	2 580	2 950	2 580	2 150	2 390	2 430	2 380	2 550	2 380
yield [t ha^{-1}]	4.30	5.49	7.01	8.07	4.80	6.50	5.93	6.56	7.09	7.00	6.40
maize selling farms [%]	74	87	77	42	38	89	75	87	80	63	74
sold-harvest ratio [%]	67	72	52	40	29	79	64	77	61	54	63
price [¥ kg^{-1}]	1.14	1.10	1.15	1.13	1.00	1.06	1.12	1.05	1.09	1.11	1.10
revenue [¥ ha^{-1}]	4 760	6 030	7 870	8 870	5 280	7 150	6 520	7 210	7 800	7 700	7 040
gross margin [¥ ha^{-1}]	2 830	4 120	5 290	5 920	2 700	5 000	4 130	4 780	5 420	5 150	4 660

Note: [1] average herbicide costs are 130 ¥ ha^{-1}
           [2] not all components of the variable costs are listed

The average yield in the surveyed farm households and the single evaluated components of the variable costs are higher than the official data for the provinces of Hebei, Shandong, and Henan. However, the average variable costs of the author's survey are lower than the official variable costs, but there is no information available which other components the official data consider. In most locations with higher wheat yield a higher maize yield is found as well. The average maize yield of 6.40 tons per ha varies between 4.30 tons and 8.07 tons per ha as township average. The quartile interval of the overall average yield shows a similar range. The average crop price of maize is 1.10 ¥ per kg. This result enables a calculated return of 7 040 ¥ per ha and a calculated gross margin of 4 660 ¥ per ha. By contrast to wheat, there are no differences between the actual and the calculated gross margin. The actual gross margin considers exclusively maize selling farm households, while the calculated gross margin uses the average maize price and all maize farm households (Table 30).

Table 30   Key economic figures for cultivation of maize

		wheat average	maize average, (quartiles)[a]	peanut average	cotton average
cultivation area	[ha]	0.38	0.25 (0.13; 0.33)	0.51	0.25
average yield	[t ha^{-1}]	5.73	6.40, (5.0; 7.5)[a]	3.30	2.79
share of selling farms	[%]	69	74	90	100
sold-harvest ratio[1]	[%]	39	63	76	99
average crop price	[¥ kg^{-1}]	1.42	1.10, (1.06; 1.14)[a]	3.08	4.43
actual revenue	[¥ ha^{-1}]	8 350	7 060, (5 610; 8 290)[a]	10 560	12 640
calculated revenue	[¥ ha^{-1}]	8 120	7 040, (5 500; 8 250)[a]	10 190	12 630
actual gross margin	[¥ ha^{-1}]	4 240	4 680, (3 140; 5 820)[a]	8 290	9 060
calculated gross margin	[¥ ha^{-1}]	4 010	4 660, (3 200; 5 770)[a]	8 050	9 050

Note: [1] share of total harvest that is sold
          [a] quartiles interval of the lower or 25% and upper or 75% quartile

As already discussed in the wheat section, the survey results are compared with maize cultivation recommendations for German farmers, official statistics for NCP province, and recommendations for Chinese farmers in the NCP (Table 29).

Table 31   Maize cultivation characteristics of Germany, official Hebei Province statistics and recommendations for North China Plain

		farm survey NCP[1]	German farmer[2]	official statistics[3]			Chen[4]	Zhen[5]
				Hebei	Henan	Shandong		
nitrogen input	[kg ha^{-1}]	220	200				180	165-210
yield nitrogen ratio	[kg kg^{-1}]	38[a]	45				33	37-29
fertilizer costs	[¥ ha^{-1}]	930	2 000	730	685	670		
revenue fertilizer ratio	[¥ ¥$^{-1}$]	10.64[a]	5.48	8.88	7.69	10.82		
seeds costs	[¥ ha^{-1}]	310	1 550	222	295	320		
irrigation costs	[¥ ha^{-1}]	350		278	115	175		
crop protection costs	[¥ ha^{-1}]	235	690	90	90	115		
harvesting costs	[¥ ha^{-1}]	15	1 380					
machinery costs	[¥ ha^{-1}]	320	1 170	263	95	205		
other costs	[¥ ha^{-1}]	180		1 515	2 200	2 025		
variable costs	[¥ ha^{-1}]	2 380	6 790	3 210	3 480	3 510		
yield	[t ha^{-1}]	6.40	8.99	5.70	4.28	6.09	6.00	6.05
calculated revenue	[¥ ha^{-1}]	7 040	10 960	6 480	5 265	7 250	6 600	6 650
calculated gross margin	[¥ ha^{-1}]	4 660	4 170	2 835	1 335	3 120		

Source: [1] IRTG SUSTAINABLE RESOURCE USE IN NORTH CHINA, FIELD SURVEY: SPRING 2005
          [2] recommendation of BAYERISCHE LANDESANSTALT FÜR LANDWIRTSCHAFT (2006), 1 € = 10 ¥
          [3] China Agricultural Statistics (NATIONAL DEVELOPMENT AND REFORM COMMISSION 2004)
          [4] recommendation considering target yield of 6 tons (CHEN, X. 2003)
          [5] recommendation of Soil Survey Office Dezhou District, (ZHEN, L., J.K. ROUTRAY et al. 2005)
Note: [a] weighted average

The average nitrogen input at the survey sites of the author is just slightly higher than the recommendations of CHEN (2003) as well as of ZHEN et al. (2005), but due to

the high nitrogen input in wheat cultivation there is still an over sufficient nitrogen content in the soil and available for maize. The nitrogen use efficiency indicated by the ratio between yield and nitrogen input at the survey sites shows an average value of 38 kg of maize yield per kg of nitrogen input.

ZHEN et al. (2005) reported from a survey in Shandong Province that farm households gain a net return of 2 100 ¥ per ha. The reported yields are similar to the results of the IRTG survey, 6.05 tons of maize per ha.

5.3.3   Cultivation of Peanuts

Cultivation of peanuts has a local distribution. It is cultivated at five surveyed townships, but only in township #5 and #10 peanuts are cultivated by nearly all farm households. More than 80 per cent of the peanut cultivating farm households are located in these two townships, which are both located in the counties of Kaifeng and Yanjin in Henan Province. These townships are characterized by above average cultivated land per farm household and therefore the average peanut cultivation area is more than 0.5 ha per farm household (Annex Table 19). Only 18 per cent of the peanut cultivating farms buy peanut seeds, in this case the average seed costs are with about 1 540 ¥ per ha more than double those of cotton and wheat. Ploughing by using a tractor and mechanical sowing is practised by nearly no farm household. However, the average costs for maintenance of the own tractor amounts to 320 ¥ per ha. The resulting average variable costs are 2 130 ¥ per ha (Table 32).

Table 32   Average costs of the components of variable costs, share of farms having this kind of costs, and average actual costs of these components in peanut cultivation

	average costs considering all peanuts cultivating farms [¥ ha^{-1}], (quartiles)[a]	share of farms actually having this kind of costs	average costs of farms actually having this costs [¥ ha^{-1}], (quartiles)
seeds	280	18%	1 540 (1 100; 1 935)[a]
ploughing and sowing	20	3%	815 (790; 840)[a]
own machinery	320 (130; 450)[a]	87%	360 (150; 460)[a]
fertilizer	740 (405; 900)[a]	83%	890 (530; 985)[a]
irrigation	490 (220; 600)[a]	87%	565 (300; 750)[a]
herbicides	100 (0; 150)[a]	58%	175 (75; 200)[a]
insecticides	145 (0; 190)[a]	70%	210 (90; 295)[a]
plastic cover	25 (0; 40)[a]	35%	65 (35; 90)[a]
variable costs[1]	2 130 (1 300; 2 900)[a]		

Note: [1] rounding errors lead to slight differences to the sum of the single components
           [a] lower or 25-% and upper or 75-% quartile

In peanut cultivation, 17 per cent of farm households reported not to apply fertilizer. The average costs of fertilizer of those farm households actually applying fertilizer is 890 ¥ per ha. The average nitrogen input is 135 kg per ha and the average nitrogen price amounts to 6.36 ¥ per kg of nitrogen. About one third of the farm

households uses plastic to cover the soil. For harvesting neither external labour nor machines are used. The average yield is 3.30 tons per ha (Table 33).

Table 33   Key economic figures for cultivation of peanuts

		wheat average	maize average	peanut average, (quartiles)[a]	cotton average
cultivation area	[ha]	0.38	0.25	0.51 (0.33; 0.67)	0.25
average yield	[t ha-1]	5.73	6.40	3.30 (2.61; 3.75)[a]	2.79
share of selling farms	[%]	69	74	90	100
sold-harvest ratio[1]	[%]	39	63	76	99
average crop price	[¥ kg-1]	1.42	1.10	3.08 (2.80; 3.04)[a]	4.43
actual revenue	[¥ ha-1]	8 350	7 060	10 560 (7 370; 12 120)[a]	12 640
calculated revenue	[¥ ha-1]	8 120	7 040	10 180 (8 040; 11 560)[a]	12 630
actual gross margin	[¥ ha-1]	4 240	4 680	8 430 (5 100; 9 750)[a]	9 060
calculated gross margin	[¥ ha-1]	4 010	4 660	8 050 (6 030; 9 430)[a]	9 050

Note: [1] share of total harvest that is sold
               [a] lower or 25% and upper or 75% quartile

The average price of 3.1 ¥ per kg enables a calculated revenue of 10 560 ¥ per ha and a calculated gross margin of 8 290 ¥ per ha (Table 33). These figures are in line with official statistics of Hebei and Shandong Province (Annex Table 20).

5.3.4   Cultivation of Cotton

At all survey sites cotton is cultivated. The average cultivation area is at the same level as maize, about 0.25 ha per household. The average expenditure for seeds are about 730 ¥ per ha, but there is a high variation in the price of the used seeds. [12] In spite of the fact that most farm household cultivate BT-cotton about 75 per cent of them apply insecticides.[13] PEMSL et al. (2005) conducted a field survey in Shandong Province and found out that nearly all cotton cultivating farm households cultivate BT-cotton. The average insecticide costs reach 1 005 ¥ per ha. Less than half of the cotton cultivating farm households reported to have ploughing and sowing costs. In this case, the figures are similar to that in wheat.

Nearly all farm households apply fertilizer and the average fertilizer costs are about 1 230 ¥ per ha, considering all cotton cultivating farm households. The average nitrogen input is 180 kg per ha and the average nitrogen price amounts to 8.41 ¥ per kg of nitrogen. The average irrigation costs of about 200 ¥ per ha are lower than those of maize. In cotton cultivation it is common to cover the soil with plastic resulting in average costs of 155 ¥ per ha. Nearly all farm households harvest by hand and use only family labour (Table 34).

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[12]   The average seed price is 40 ¥ kg-1, but prices between 5 and 100 ¥ kg-1 are found at the survey.

[13]   BT-crops are genetically engineered to carry a gene from the soil bacterium *Bacillus thuringiensis.* This gene encodes for a toxin that is lethal for certain insects. The modified BT-crops also express this toxin and are resistant against some pests.

Table 34   Average costs of the components of variable costs, share of farms having this kind of costs, and average actual costs of these components in cotton cultivation

	average costs considering all cotton cultivating farms [¥ ha^{-1}], (quartiles)[a]	share of farms actually having this kind of costs	average costs of farms actually having this costs [¥ ha^{-1}], (quartiles)[a]
seeds	730 (360; 940)[a]	93%	785 (385; 985)[a]
ploughing and sowing	175 (0; 300)[a]	41%	435 (300; 490)[a]
own machinery	280 (0; 405)[a]	58%	490 (210; 620)[a]
fertilizer	1 230 (545; 1 720)[a]	91%	1 345 (700; 1 815)[a]
irrigation	200 (0; 315)[a]	70%	285 (150; 365)[a]
herbicides	60 (0; 90)[a]	53%	115 (55; 150)[a]
insecticides	750 (25; 1 250)[a]	75%	1 005 (440; 1 500)[a]
plastic cover	155 (5; 190)[a]	87%	180 (70; 205)[a]
machine harvesting	15	3%	400 (330; 450)[a]
variable costs[1]	3 590 (2 320; 4 520)		

Note: [1] rounding errors lead to slight differences to the sum of the single components
           [a] lower or 25% and upper or 75% quartile

The resulting variable costs are on average 3 590 ¥ per ha, but there is a local variation especially due to variation in fertilizer expenditure (Annex Table 21). The average yield is 2.79 tons per ha, but at those survey sites with a high share of cotton cultivating farm households the average is above 3.00 tons per ha. The average calculated returns are 12 640 ¥ per ha and the corresponding calculated gross margin reaches 9 060 ¥ per ha (Table 35).

Table 35   Key economic figures for cultivation of cotton

		wheat average	maize average	peanut average	cotton average, (quartiles)
cultivation area	[ha]	0.38	0.25	0.51	0.25 (0.13; 0.33)
average yield	[t ha^{-1}]	5.73	6.40	3.30	2.79, (2.08; 3.28)[a]
share of selling farms	[%]	69	74	90	100
sold-harvest ratio[1]	[%]	39	63	76	99
average crop price	[¥ kg^{-1}]	1.42	1.10	3.08	4.53, (4.20; 4.80)[a]
actual revenue	[¥ ha^{-1}]	8 350	7 060	10 560	12 640, (9 170; 15 600)[a]
calculated revenue	[¥ ha^{-1}]	8 120	7 040	10 190	12 630, (9 410; 14 860)[a]
actual gross margin	[¥ ha^{-1}]	4 240	4 680	8 430	9 060, (5 910; 11 400)[a]
calculated gross margin	[¥ ha^{-1}]	4 010	4 660	8 050	9 050, (6 210; 11 380)[a]

Note: [1] share of total harvest that is sold
           [a] lower or 25-% and upper or 75-% quartile

The official statistics present a yield that is only about one third of the survey average (Annex Table 22). The official seed costs and pesticide costs are lower than the survey results, but the fertilizer expenditure are at the same level. The presented total costs are higher than the presented components and more than double than the survey average. The official revenue is higher than the survey average, but the

presented net profit for the provinces of Hebei and Shandong is at the same level than the survey results.

ZHEN et al. (2005) reported from a survey in Shandong Province that farm households gain a net return in cotton of 5 340 ¥ per ha. The reported yields are similar to the results of the IRTG survey and amount to 3.06 tons of cotton per ha. The differences between this net return and the gross margin of IRTG survey might result from different calculations of the net return and the gross margin. PEMSL (2005) did a detailed investigation about pesticide application in cotton based on a survey in Shandong Province, which shows an average yield of 3.8 tons per ha, fertilizer costs of about 2 000 ¥ per ha and an average gross margin of about 15 000 ¥ per ha. As described, the IRTG survey results show an average nitrogen input of 180 kg per ha in cotton cultivation. ZHEN et al. (2005) reported that the surveyed farm households apply on average 360 kg of nitrogen per ha, while CHEN et al. (2006) reported an average nitrogen input in cotton of 177 kg per ha based in survey, which was conducted in Quzhou County, Hebei Province in 2000. There is no clear explanation for this difference in nitrogen application rates in cotton. However, 30 per cent of the surveyed farm households show nitrogen application rates less than 100 kg per ha, while the remaining 70 per cent apply on average 240 kg of nitrogen per ha.

5.4   Major nitrogen fertilizer

The 340 surveyed farm households apply in total 810 tons of fertilizer at 1 847 single applications. The resulting total nitrogen input is 72 tons considering the nitrogen contents of each fertilizer, which are presented in Table 36.

Table 36   Characteristics of applied fertilizer

		fertilizer type	nitrogen content	usage share
有机肥 (manure)	自家的农家肥	manure from own livestock	1%	6 %
	商品有机肥	commercial manure	1%	2 %
氮肥 (nitrogen fertilizer)	碳铵	ammonium carbonate	17%	16 %
	尿素	urea (carbamide)	46%	44 %
	硝酸铵	ammonium nitrate	35%	< 1 %
	其他	other nitrogen fertilizer	16%	1 %
磷肥 (phosphorous fertilizer)	普钙	ordinary superphosphate	0%	1 %
	重钙	coarse whiting	0%	< 1%
	钙镁磷肥	fused calcium magnesium phosphate	0%	2 %
	其他	other phosphorous fertilizer	0%	4 %
钾肥 (potassium fertilizer)	氯化钾(国产)	potassium chloride (domestic)	0%	1 %
	其他	other potassium fertilizer	0%	< 1 %
复合肥 (compound fertilizer)	磷酸一铵	monoammonium orthophosphate	11%	< 1 %
	磷酸二铵(国产)	diammonium phosphate (domestic)	17%	5 %
	国产复合肥(低)	domestic composite fertilizer (low)	10%	1 %
	国产复合肥(中)	domestic composite fertilizer (medium)	13%	8 %
	国产复合肥(高)	domestic composite fertilizer (high)	15%	1 %
	进口复合肥	imported composite fertilizer	16%	1 %
	其他	other compound fertilizer	15%	3 %
		all other not classified fertilizer	15%	< 1 %

Table 37 presents the nitrogen input distribution of the most common fertilizer and crops expressed as share of the total amount of nitrogen applied. The most common fertilizer is urea, 43 per cent of all fertilizer applications are urea and 51 per cent of the applied nitrogen originates from urea. The nitrogen content of urea is 46 per cent and in average 350 kg fertilizer or 160 kg nitrogen are applied at each single urea application. Ammonium carbonate covers 27 per cent of applied nitrogen. About seven per cent of the applied nitrogen originates from own or bought manure. As already mentioned, manure is mainly applied in wheat cultivation. Domestic medium composite fertilizer, imported and domestic diammonium phosphate fertilizer cover about 10 per cent of the nitrogen input. Together, the discussed fertilizers cover about 95 per cent of the total nitrogen input. In total 59 per cent of the total amount of nitrogen is applied in wheat, while the share of maize amounts to 20 per cent. The corresponding share of peanut and cotton is 8 and 11 per cent (Table 37).

Table 37 **Nitrogen distribution for most common fertilizer by crops expressed as percentage of the applied 72 tons of nitrogen**

	total [%]	wheat [%]	maize [%]	peanut [%]	cotton [%]
domestic medium composite fertilizer, 13% N	4.5	2.5	0.5	0.7	0.8
imported diammonium phosphate, 18% N	2.0	0.9	0.1	0.1	0.7
domestic diammonium phosphate, 17% N	3.2	2.0	0.4	0.1	0.5
urea (carbamide), 46% N	50.8	27.6	10.0	6.0	5.6
ammonium carbonate, 17% N	27.5	17.4	8.6	0.3	1.2
bought manure, 1% N	1.2	0.9	0	0.3	0
own manure, 1% N	5.7	5.1	0.3	0	0.3
all fertilizer	100.0	59.0	20.4	7.7	10.8

Ammonium carbonate and urea are a cheap nitrogen source. Their nitrogen price is less than 4 ¥ per kg nitrogen, while nitrogen from diammonium phosphate and composite fertilizer costs more than 13 ¥ per kg of nitrogen respectively (Table 38).

Table 38 **Price of the applied fertilizer and its price of nitrogen**

	average fertilizer price [¥ kg^{-1}]	average nitrogen price [¥ kg^{-1} N]
domestic medium composite fertilizer, 13% N	2.05	15.77
imported diammonium phosphate, 18% N	2.43	13.50
domestic diammonium phosphate, 17% N	2.28	13.41
urea (carbamide), 46% N	1.76	3.83
ammonium carbonate, 17% N	0.58	3.41
bought manure, 1% N	0.09	9.00

Table 39 shows the distribution of applied nitrogen amount for each crop. Urea and ammonium carbonate are the key nitrogen sources in wheat cultivation. The share of nitrogen, which is applied in wheat and originated from the application of urea amounts to 47 per cent. In case of ammonium carbonate this figure is 30 per cent.

Table 39 **Nitrogen distribution of most common fertilizer for wheat, maize, peanut, and cotton expressed as share of applied nitrogen**

	wheat [%]	maize [%]	peanut [%]	cotton [%]
domestic medium composite fertilizer, 13% N	4.2	2.4	9.5	7.2
imported diammonium phosphate, 18% N	1.6	0.6	0.7	6.7
domestic diammonium phosphate, 17% N	3.5	1.9	1.3	4.6
urea (carbamide), 46% N	46.8	49.1	77.7	52.0
ammonium carbonate,17% N	29.5	42.4	3.3	11.1
bought manure, 1% N	1.5		3.2	0.1
own manure, 1% N	8.7	1.4		2.4
sum of all other fertilizer	4.2	2.2	4.3	15.9
all fertilizer	100.0	100.0	100.0	100.0

The share of own and bought manure amounts to 10 per cent. In maize the most common fertilizers are urea and ammonium carbonate. Together these fertilizers cover 93 per cent of the nitrogen input in maize. In peanut 78 per cent of the nitrogen input is originated from urea and domestic medium composite fertilizer covers nearly 10 per cent. More than half of the nitrogen input in cotton originated from urea. Further, several mineral fertilizers such as composite fertilizer or diammonium phosphate are used as nitrogen source in cotton (Table 39).

6 Efficiency Analyses of the Agricultural System

In this chapter several efficiency analyses are presented which were carried out in order to identify inefficiencies in the agricultural production system prevalent in the North China Plain. Farm household income structure and income level of farm households are being investigated in order to find interactions between farm household structure and income generation structure. This analysis is expanded to an analysis of the impact of farm household and income structure related factors to the nitrogen application level. The extent by which nitrogen price and nitrogen input are related is considered as well. The analysis was broadened to the impact of named factors on crop yields and rounded out by a sensitivity analysis exploring the influence of nitrogen price, nitrogen input and crop yield to gross margin. All these findings were entered into an optimum calculation of nitrogen application.

6.1 Analysis of Farm Household Income

6.1.1 Logistic Regression Analysis of Farm Income Source Structure

As described in the previous sections, rural households differ in terms of income sources and income level. Hence the question arises which characteristics lead to a high probability that a rural household has an additional income source from off-farm activities or has only farming as income source. In other words, the overall question sounds just simple, why do one third of farm families have no off-farm income source while two thirds do?

Income form livestock is regarded as additional farm income besides farming, hence for this research question it is not taken into account. The surveyed townships differ in terms of income structure of farm households, but at all survey sites farm households with additional off-farm income were found. These survey results lead to the assumption that certain farm household structure related factors exist which result in a higher probability that a household has off-farm income sources. There is no doubt, off-farm income sources must be available and a farm family must have labour surplus who is willing and able to work off-farm. As already described, off-farm income sources seem to be available at all locations and a typical farm household has sufficient labour surplus due to an average family farmland to family labour force ratio of 0.24 ha per family labour (Table 7, page 37).

Additionally, the farm households are categorised according to their income share from farming. The term *main income farming* indicates that the income share from farming exceeds 50 per cent, while in case of *minor income farming* the income share from farming is lower than 50 per cent. As expected, the majority (60 per cent) of farm households with off-farm activities have off-farm income as the major income source, but 40 per cent do not. Their major income source is farming. For this reason, factors leading to farming as major income source are analysed, too. Beside the income structure, the structure of family labour is analysed in order to find out which factors increase the probability that at least one family member is working part-time

off-farm (*labour type 4*) or full-time off-farm (*income type 5*) as compared to farm households which have neither *labour type 4* nor *labour type 5* on farm.

The binary logistic regression is a suitable tool to predict and to explain a binary variable, hence the presence of absence of a certain characteristic based on values of a set of predictor variables are referred to as covariates. Table 40 presents the dependent variables of the regression models of this chapter.

Table 40   Dependent variables of logistic regression models for the analysis of income structure

dependent variable encoding: 1	n	dependent variable encoding: 0	n
income type 1	121	income type 2&3	212
type 4 available: off-farm and farm work	101	labour type 4&5 not available	156
type 5 available: only off-farm work	96	labour type 4&5 not available	237
main income farming (income share ≥50%)	161	minor income farming (income share <50%)	161

In total, eleven covariates are pre-selected for each model to indicate the farm household characteristics (Annex Table 23). The covariate category family labour characteristics consists of family size, number of family work force, household head age, and the highest family education. Farmland as absolute and relative value and the pure wheat-maize cropping pattern as dichotomous variable characterise the cultivation system.[14] Further, the average long term wheat yield at the plots of each farm household are included.[15] The village average family farmland and wheat yield is considered in order to include location related characteristics.

The logistic regression models with dependent variables *income type 1* and the aggregation of *income type 2* and *income type 3* consist of eight covariates, while the main income farming model bases on seven covariates. The -2 Log likelihood ratio tests as well as the pseudo r^2 of Cox & Snell and that of Nagelkerke show sufficient significance for all models. The probability of *income type 1* increases with larger family size, lower family work force, less education and older household head. Hence, an unfavourable family structure might be mainly responsible that a farm household does not have off-farm income. The opposing effect of the family size and family work force appears confusing, because there is a significant positive correlation between these variables. An explanation might be that a larger family size does not lead to higher number of family work force due to age of the family members.

None of the location indicating variables is included. The pure wheat and maize cropping pattern seems to be connected with no off-farm activities. Further, more farmland decreases the probability of off-farm income, but only at lower levels of relative farmland. This might be explained as follows: These farm households are located in a village of higher level of farmland, hence these farm households have higher levels of farmland, but inside the village, these households have less relative

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[14]   The relative farmland is the cultivated area as percentage of the village average farmland.
[15]   The interviewed farmer were asked to estimate the long term wheat yield on their plots in order to evaluate the plot quality.

farmland. Since the covariate local average farmland is not included, the described effect should not be overestimated (Table 41).

Table 41   Analysis of the probability of *income type 1* and *main income farming* using binary logistic regression

dependent variable encoding: 1		income type 1	main income farming
dependent variable encoding: 0		income type 2&3	minor income farming
-2 Log likelihood ratio test [-2LL$_0$; -2LL$_M$]		341; 452[***]	377; 456[***]
Cox & Snell r^2; Nagelkerke r^2		0.279; 0.373	0.193; 257
	covariate	ß	ß
family size [per.]	V$_{001}$	0.490[***]	0.395[***]
family work force [LU]	V$_{005}$	-1.306[**]	-0.825[***]
highest family education [1-4]	V$_{004}$	-0.285[*]	-0.377[**]
household head age [years]	V$_{003}$	0.046[***]	
pure wheat-maize pattern [1,0]	V$_{041}$	0.728[**]	0.759[**]
farmland [ha]	V$_{014}$	2.948[***]	4.236[***]
relative farmland [%]	V$_{016}$	-0.019[***]	-0.015[***]
rent-in farmland [1,0]	V$_{020}$	-0.983[*]	
village average wheat yield [t ha^{-1}]	V$_{076}$		-0.210[**]

Note   [*] significant at p<0.10; [**] significant at p<0.05; [***] significant at p<0.01

Summarized, the structure of the family labour, hence the availability of a family member who can work off-farm seems to be an important factor beside the general availability of off-farm jobs, which is not considered due to lack of data.

The logistic regression model analyses the income share from farming and shows quite similar results in terms of family structure as the *income type 1* models. The indicated family structure increases the probability of no off-farm income activities. In combination with the positive effect of family farmland it increases the probability that the income share form farming exceeds 50 per cent (*main income farming*). Table 42 presents the logistic models analysing the probability of *labour type 4* (temporary off-farm job) and *labour type 5* (permanent off-farm job) availability. The *labour type 4* model shows a low model fit, while the *labour type 5* model shows a high model fit. A certain family structure indicated by low family size, high family work force and a younger household head increases the probability that at least one family member works permanently off-farm (*labour type 5*). Further, the cultivation of cash crops (not the pure wheat and maize cropping pattern) shows a positive effect. In addition, one location specific covariate is included. A low local average family farmland increases the probability of permanent off-farm jobs. The covariate long term wheat yield is included in both models, but with different direction. In case of *labour type 5* a lower long term wheat yield increases the probability of a permanent off-farm activity, while a higher long term wheat yield increases the probability of a temporary off-farm job. A lower long term wheat yield might force farm households to search for permanent non-farming income sources to gain a sufficient household income. Farmers, who work temporary off-farm and on-farm might be more active and better informed. For this reason, these farm households might have higher yields. Further, rent-in *of additional*

farmland is connected with the availability of *labour type 4* on farm. Temporary off-farm activities seems to be a favourable farm household characteristic for successful faming, but this effect should not be overestimated, since the logistic regression model shows a low model fit.

Table 42   Analysis of the probability of *labour type 4* and *labour type 5* on farm using binary logistic regression

dependent variable encoding: 1		labour type 4 on farm	labour type 5 on farm
dependent variable encoding: 0		neither labour type 4 nor type 5 on farm	neither labour type 4 nor type 5 on farm
-2 Log likelihood ratio test [-2LL$_0$; -2LL$_M$]		375; 452[***]	273; 446[***]
Cox & Snell R^2; Nagelkerke R^2		0.083; 0.111	0.417; 0.555
	covariate	ß	ß
family size [per.]	V$_{001}$		-0.585[***]
family work force [LU]	V$_{005}$		1.814[***]
household head age [years]	V$_{003}$	-0.032[***]	
pure wheat-maize pattern [1,0]	V$_{041}$		-1.613[**]
rent-in farmland [1,0]	V$_{020}$	0.864[**]	
long term wheat yield [t ha^{-1}]	V$_{021}$	0.200[**]	-0.283[**]
village average farmland [ha]	V$_{015}$		-4.500[***]

Note   [*] significant at p<0.10; [**] significant at p<0.05; [***] significant at p<0.01

SOMWARU et al. (2001) found similar results as the *income type 1* model, more *family farmland* lead to a lower probability of off-farm income activities. They found that farm households with less than 0.07 ha only 29 per cent are engaged exclusively in farm work, while in household with more than 2 ha this share is 72 per cent.

DE BRAUW (2001) already expected that human capital levels, household characteristics or attributes of villages would have a significant effects as to whether or not people have opportunities to work in off-farm labour markets. Several authors identified that social networks are very important for the migration of rural labour. According to a survey form 1994 more than half of the migrated rural labour obtained their jobs through introductions by relatives or neighbours (SATO, H. 2003). And ZHAO (2001) found positive effects of migration networks measured by the number of early migrants form the same village on the probability of migration. Further, CHEN et al. (2003) found positive effects of migrant networks measured by proportion of households with migration experience. WANG et al. (2000) even stated that the labour market in the construction sub sector requires neither education nor skill to perform the unskilled construction job, as in other spheres in Chinese societies it is helpful to have some human connections or "guanxi" in Chinese language.

6.1.2   Logistic Regression Analysis of Farm Income Level

Off-farm income in particular as well as above average farmland lead to an above average income, but there might be other farm households structure related factors connected with the income level. For this reason, two logistic regression model consider as dependent variable whether a farm household belongs to the one third

of farm households that has a household income of less than 4 950 ¥ (*low household income*) and whether a farm household belongs to the one third of farm households that has a household income of more than 11 050 ¥ (*high household income*).

Most of the pre-selected covariates of the previous model in chapter 6.1.1 are preselected variables in this model as well (Annex Table 24). In addition to the covariates, which indicate farm family and farming system, the income level model considers the occupation of family members as dichotomous covariate. Occupation means, whether at least one family member is regarded as *labour type 4* (temporary off-farm job) or at least one *labour type 5* (working exclusively off-farm) is on farm. Furthermore, the village average household income is included as covariate, which indicates the location conditions. Table 43 presents the covariates towards the probability of *low household income* and *high household income*.

Table 43   Analysis of the probability of *low household income* and *high household income* using binary logistic regression

dependent variable encoding: 1		low household income (< 4 950 ¥)	high household income (> 11 050 ¥)
dependent variable encoding: 0		income ≥ 4 950 ¥	income ≤ 11 050 ¥
-2 Log likelihood ratio test [$-2LL_0$; $-2LL_M$]		250; 447[***]	315; 445[***]
Cox & Snell r^2; Nagelkerke r^2		0.451; 0.602	0.369; 0.492
	covariate	ß	ß
family work force [LU]	V_{005}	-0.435[**]	
household head age [a]	V_{003}	0.047[***]	-0.024[*]
labour type 4 on farm [1,0]	V_{010}	-1.878[***]	1.516[***]
labour type 5 on farm [1,0]	V_{012}	-3.188[***]	2.569[***]
farmland [ha]	V_{014}	-2.530[***]	8.003[***]
relative farmland [%]	V_{016}		-0.034[**]
long term wheat yield [t ha^{-1}]	V_{021}		0.438[***]
village average farmland [ha]	V_{015}		-5.271[***]
village average wheat yield [t ha^{-1}]	V_{076}	0.473[***]	-0.593[***]
village average household income [1000 ¥]	V_{031}	-0.158[***]	0.185[***]

Note   [*] significant at p<0.10; [**] significant at p<0.05; [***] significant at p<0.01

As expected, family members on farms, who are working temporary or permanently off-farm increase the probability of *high household income*. An older household head increases the probability of low income, but education shows no significant influence. A high village average wheat yield increases the probability of *low household income* and decreases the probability of *high household income.* Areas of lower village average wheat yield and less village average farmland show a higher share of farm households with additional off-farm income due to the lower income from farming. This situation results in higher household income. In areas with more favourable farming conditions as well as higher yields less farm households are forced to search for additional income sources. Furthermore, the pure income from farming usually leads to a relative low household income. However, the variables farmland and long term wheat yield increase the probability for high income.

6.2   Fertilizer Application Level Analysis

As described in the literature review, the agricultural production in the NCP is characterised by high levels and wide variation of fertilizer application. This situation rises the question, whether there is a correlation in terms of nitrogen application level between the cultivated crops. Fertilizer costs in wheat cultivation show a positive correlation with those in maize cultivation indicated as direct costs as well as percentage of local average. In other way, farm households having fertilizer costs in wheat which are above the local average do have above local average fertilizer costs in maize as well. Further, there is a significant positive correlation in fertilizer costs between wheat and cotton as well as between maize and cotton. In terms of nitrogen input, there is a positive correlation between wheat and cotton in direct costs as well as relative costs and between wheat and cotton in direct fertilizer costs, but there is no significant correlation between wheat and maize (Table 44).

Table 44   Correlation of fertilizer costs and nitrogen application level

	fertilizer costs				nitrogen input			
	wheat	maize	peanut	cotton	wheat	maize	peanut	cotton
wheat		0.134*	X	0.155*		X	X	0.239**
maize	0.134*		X	0.454**	X		X	0.366**
peanut	X	X		X	X	X		X
cotton	X	0.270**	X		0.162*	X	X	

Note: upper cells on right hand side: correlation coefficient of application level
         cells below on left hand side: correlation coefficient of percentage of village average
         X not significant; * significant at $p<0.05$; ** significant at $p<0.01$

Figure 6 presents the distribution of nitrogen input at the survey sites. The histogramme on the left hand side shows the distribution of nitrogen input to all farm crops and on the right hand side the wheat nitrogen input. The term all farm crops considers the average but weighted nitrogen input in the major cultivated croups.[16]
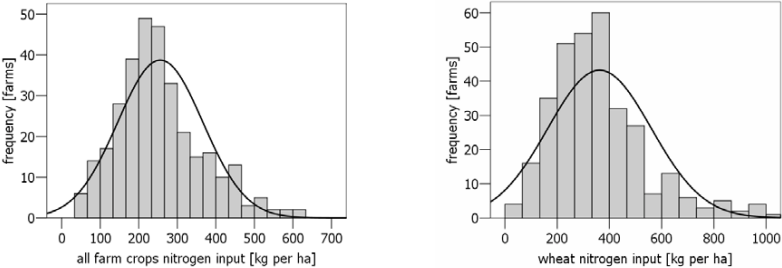
Figure 6   Histogramme of nitrogen input all farm crops and wheat nitrogen input including normal distribution for comparison

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[16]   Sum of the nitrogen input for all farm plots of wheat, maize, peanut, and cotton is divided by the sum of the cultivation area of wheat, maize, peanut, and cotton.

For comparison, the normal distribution curve is included. The variation of nitrogen input to all farm crops is close to the normal distribution. The range varies between 180 kg of nitrogen per ha (lower or 25% quartile) and 310 kg of nitrogen per ha (upper or 75% quartile). In wheat nitrogen input the quartiles indicate a range between 230 to 440 kg of nitrogen per ha. Further, Ju et al. (2004) found out that the average wheat nitrogen input at the NCP is about 370 kg of nitrogen per ha and shows a range between 173 kg and 754 kg of nitrogen per ha.

As mentioned already, a farm household survey conducted in Shandong Province by ZHEN et al. (2005) identified that only about 6 per cent of the surveyed farm households apply according to the recommendations for balanced input use. If farm households do not follow the recommendations that consider the crop demand, this leads to the question, which factors other than the crop demand influences the fertilizer application behaviour. In the other way, is there any kind of pattern or are there common characteristics of farm households with high nitrogen application level.

There is no doubt, that fertilizer costs correlate strongly with nitrogen input, but there is a variation in the nitrogen price. Nitrogen input reflects to the agronomic point of view, while the fertilizer costs might be more useful to analyse the intention or attitude of the decision maker who applies the fertilizer. For this reason, nitrogen input as well as fertilizer cost are analysed, but in different ways.

6.2.1   Logistic Regression Analysis of Nitrogen Input

The nitrogen input is analysed by logistic regression models. In the first step, factors are identified which lead to a high probability of high nitrogen input all farm crops. Then logistic regression models analyse nitrogen application in wheat, maize and cotton. The pre-selected independent variables in these nitrogen models are listed in annex table 25. These are characteristics of the family work force, income structure, farmland, and cultivation system indicators such as manure application, cropping pattern, and degree of own consumption. In addition, the average nitrogen price is considered. Further, the village average nitrogen input is included to summarize location specific characteristics.

Table 45 presents the covariates of the logistic regression models. All models include the covariate nitrogen price, the probability of higher nitrogen input decreases with a higher nitrogen price. Further, an estimated lower long term wheat yield shows a negative effect. This leads to the assumption that these farm households try to compensate the lower wheat yield potential of their plots by higher nitrogen application levels. The relative farm household income (percentage of village average income) shows a negative coefficient. The covariates indicating the income in absolute values are not included. Hence, the income effect on nitrogen application cannot be clearly discussed.

Table 45   **Analysis of nitrogen input using binary logistic regression with stepwise backward (likelihood ratio) method**

		farm crops N application	wheat N application	maize N application	cotton N application
dependent variable encoding	1	≥237 kg N ha^{-1}	≥325 kg N ha^{-1}	≥175 kg N ha^{-1}	≥160 kg N ha^{-1}
dependent variable encoding	0	<237 kg N ha^{-1}	<325 kg N ha^{-1}	<175 kg N ha^{-1}	<160 kg N ha^{-1}
-2 Log likelihood [-2LL$_0$; -2LL$_M$]		397; 447***	374; 446***	320; 359***	176; 232***
Cox & Snell r^2; Nagelkerke r^2		0.223; 0.297	0.268; 0.358	0.257; 0.342	0.396; 0.528
covariate		ß	ß	ß	ß
labour type 4 on farm [1,0]	V$_{010}$				0.960**
relative income [%]	V$_{032}$	-0.003*		-0.004**	-0.006**
full-farming income [1,0]	V$_{038}$		0.481*		
farmland [ha]	V$_{014}$		-1.851**		1.422*
relative farmland [%]	V$_{016}$		0.012**		
long term wheat yield [t ha^{-1}]	V$_{021}$	-0.254**	-0.257**	-0.239**	
manure usage [1,0]	V$_{042}$		1.039***		
nitrogen price [¥ kg^{-1}]		-0.440***	-0.259***	-0.273***	-0.293***
sold-harvest ratio [%]		n/a	-0.012**		n/a
village average nitrogen input [kg ha^{-1}]		0.016***	0.007***	0.014***	0.011***

Note: * significant at p<0.10; ** significant at p<0.05; *** significant at p<0.01

As discussed already, farm households with a higher wheat own consumption share or a lower *sold-harvest ratio* tend to apply higher nitrogen rates in wheat cultivation. Further, application of manure leads to higher nitrogen input. This effect might interfere with the price effect, or farm households underestimate the nitrogen content of manure. The location summarizing covariate village average nitrogen input is included in all models.

6.2.2   Analysis of the Nitrogen Price

As the logistic regression already indicated, there is a negative relationship between level nitrogen input and nitrogen price. In other words, farm households which apply more expensive nitrogen apply less nitrogen per ha. The average nitrogen price at all farm crops amounts to 5.67 ¥ per kg (Table 46).

Table 46   **Average nitrogen price and range of lower and upper at all farm crops, in wheat, in maize, and in cotton**

	all farm crops	wheat	maize	cotton
average nitrogen price [¥ kg^{-1}]	5.67	5.77	4.61	8.41
lower and upper quartiles of nitrogen price [¥ kg^{-1}]	4.07; 6.64	3.79; 7.06	3.04; 4.35	4.35; 11.43

As already indicated in Table 38 (page 63), the ratio between fertilizer price and nitrogen content of the major fertilizer is indicated by the variable nitrogen price and it

shows a broad variation. Furthermore, the individual nitrogen price indicates composition of the applied fertilizer of a farm household. Hence, the nitrogen price can be considered as an indicator for the fertilizer selection of the farm household. For further analysis, the weighted average nitrogen price of all crops is plotted against the nitrogen input considering the aggregated average of all crops (Figure 7).
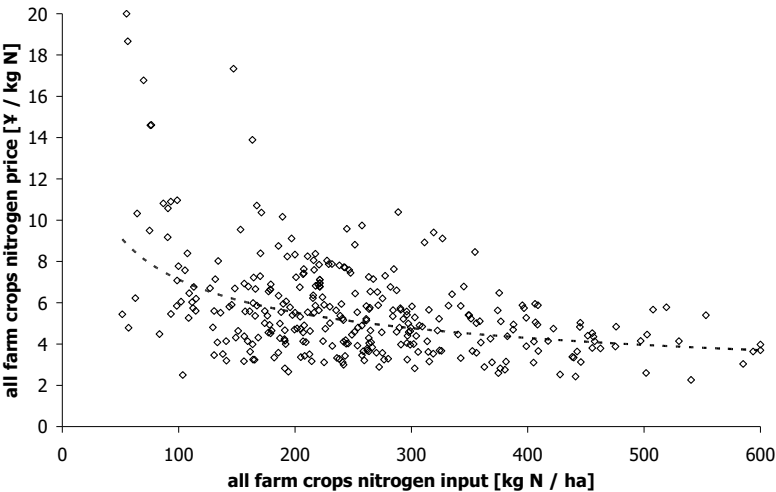
Figure 7   **Scatter plot of the relationship between *nitrogen input all farm crops* and *nitrogen price all farm crops* as well as an estimated power function describing this relationship**

The power function shows a suitable shape to describe the relationship between nitrogen input and nitrogen price. It considers the ratio between low nitrogen input and high nitrogen prices as well as high nitrogen input level, but the effects at the borders should not be overestimated. For this reason, an applicable range for the estimated power functions in wheat, maize, and cotton is given (Table 47).

Table 47   **Power functions describing the relationship between nitrogen input (N) and nitrogen price (Q)**

	all farm crops	wheat	maize	cotton
model fit [r^2]	0.21	0.15	0.09	0.24
multiplier d [$P(N) = d\,N^f$]	38.3	31.2	12.5	39.6
power f [$P(N) = d\,N^f$]	-0.3651	-0.3129	-0.2124	0.3384
applicable nitrogen input (N) range	50 - 500	50 - 700	100 - 400	80 - 400
corresponding nitrogen price (Q) range	9.2 - 4.0	9.2 - 4.0	4.7 - 3.5	9.0 - 5.2

Note: * significant at p<0.10; ** significant at p<0.05; *** significant at p<0.01

The relationship between nitrogen input and nitrogen price in wheat (Annex Figure 1), maize (Annex Figure 2), and cotton (Annex Figure 3) shows a similar

relationship as that of the weighted average of all crops. The impact of the nitrogen price on the nitrogen input is considered at the simulation scenarios in chapter 8.2.

6.2.3   Analysis of Fertilizer Costs

The nitrogen application level shows no interaction with off-farm activities. However, the calculated nitrogen input is more or less a agronomic variable, while the fertilizer costs or the amount of money which is spend for fertilizer might be more suitable to describe the farmer's interests in fertilising. Usually off-farm activities affect the farm household in two ways. It increases the cash income and reduces the family work force available for farm work. As already discussed in chapter 2.1.4 (page 8), this might lead to increased or decreased fertilizer costs. Further, there might be no impact on fertilizer application characteristics.

For this reason, the farm households are grouped in fully homogenous groups according to fertilizer costs and a set of pre-selected dichotomous income structure related factors. The median of fertilizer costs all farm crops amounts to 1 230 ¥ per ha and is considered as basis of the dichotomous variable fertilizer costs: at least 1 230 ¥ per ha as fertilizer costs for all farm crops (*high fertilizer costs*) or below. The pre-selected income related dichotomous variables are described as follows. The variable *low household income* considers whether the farm household belongs to the one third of farm households, which has a household income of less than 4 950 ¥. In case of *high household income*, the limit is more than 11 050 ¥. An income share from farming of above 50 per cent fulfils the demand of the variable *main income farming*. Finally, the degree off farm work is considered by the variable *high farming work force ratio*, which indicates a farming work force ratio of more than 85 per cent.

These binary variables enable to cluster the farm households. The group size can be used as indicator for a relation ship between fertilizer costs and the characteristics in terms of income level, income source, and labour use. Cluster of the same income structure, but differences in fertilizer costs are considered as double cluster. Table 48 presents the major double cluster including the share of farm households belonging to cluster of high fertilizer costs and low fertilizer costs. The largest double cluster is characterised by *low household income*, which is originated mainly from farming and the family work force is mainly working on-farm, hence these are farm household with no or minor off-farm activities. This double cluster consists of two clusters of nearly equal size, one is characterised by high fertilizer costs, the other one by low fertilizer costs. Hence, farm households that are characterised by a low household income can have both, high fertilizer costs as well as low fertilizer costs.

The second largest double cluster is characterised by *high household income* from off-farm activities and shows a difference in size between the two fertilizer costs groups. There are 59 per cent of these farm households, which have below median fertilizer costs. This tendency should not be overestimated, because still 41 per cent of the farm households have *high fertilizer costs* and the following double cluster shows an opposing effect. The following double cluster is characterised by medium household income. Farm households have neither low nor high household income, income from

off-farm activities is the major income source of this group as well. In terms of fertilizer costs, the cluster of high fertilizer costs is larger than that of low fertilizer costs.

Table 48   Fertilizer costs cluster

farms [no.]	fertilizer costs >1230¥	income <4950¥	income >11050¥	faming income share >50%	farming work force ratio >85%
39 (51%)	+	+	-	+	+
37 (49%)	-	+	-	+	+
27 (41%)	+	-	+	-	-
39 (59%)	-	-	+	-	-
23 (56%)	+	-	-	-	-
18 (44%)	-	-	-	-	-
16 (47%)	+	-	-	+	+
18 (53%)	-	-	-	+	+
12 (57%)	+	-	-	+	-
9 (43%)	-	-	-	+	-

Note: 95 farm households in 14 clusters (with less than 10 elements) are not listed
            8 possible cluster do not contain any farm households

Similar to the first double cluster, the double clusters, which are characterised by farming as the major income source show only marginal differences in fertilizer costs. Summarized, low income farm households do not have higher fertilizer costs, but their costs do also not decrease.

6.3   Analysis of yield

The crop production theory explains that the natural conditions of soil and climate, hence water, nutrients, radiation, and temperature influence yield. Beside these natural conditions the cultivation system or the decisions of the farmer and so his farming operations influences the yield of the cultivated crop. There is no doubt that the nitrogen supply from natural sources and especially the one from mineral fertilizer are the major factors which influence the crop yield level.

First, the question arises, whether or not there is a correlation between the yields of the crops cultivated by a farm household. Both, the actual yield as well as the relative yield are considered. The relative yield expressed as percentage of the average yield at village level excludes possible location related effects. There is a positive significant correlation between wheat and maize as well as wheat and peanut in yield considering actual yield as well as relative yield. In other way, a farm household which harvests high yields in wheat, usually has high yields in maize and peanut as well (Table 49).

Table 49   Correlation of actual yield as well as relative yield of each cultivated crop to other cultivated crops

	wheat	maize	peanut	cotton
wheat		0.409[**]	0.388[**]	X
maize	0.278[**]		X	X
peanut	0.308[**]	X		X
cotton	X	X	X	

Note: upper cells on right hand side: correlation coefficient of application level
         cells below on left hand side: correlation coefficient of percentage of village share
         X not significant; [*] significant at $p<0.05$; [**] significant at $p<0.01$

The distribution of the yield is the second question. The average wheat yield is 5.73 tons per ha and the quartiles range from 4.69 to 6.43 tons per ha. The wheat yield histogrammes show a distribution close to the normal distribution, but about 20 per cent of the farms report a wheat yield of 6.00 to 6.50 tons per ha (Figure 6).
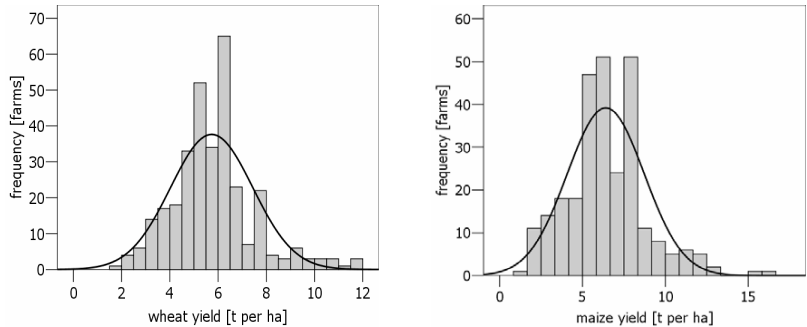
Figure 8   Histogramme of wheat yield and maize yield including normal distribution for comparison

The average maize yield at the survey sites amounts to 6.40 tons per ha and the quartiles range from 5.00 to 7.50 tons per ha. Similar to wheat, the maize yield, peanuts yield, and cotton yield histogrammes show a distribution close to the normal distribution (Annex Figure 4). Summarized there is a broad variation in yield.

Several staff member of the County Agricultural Bureaus at the survey sites reported that in the NCP the location compared to the cultivation system has a strong influence towards the yield level. However, the NCP is not a homogenous cultivation area, hence differences in soil quality and microclimate might lead to differences in yield. For this reason, farm households have been asked to estimate the expected wheat yield in a normal year of each plot. This variable long term wheat yield can be used as indicator for plot quality for cultivation. Median and average at village level of the long term wheat yield of each plot vary between 4.0 tons and 6.0 tons of wheat per ha and show differences inside a village, but there are significant differences between most surveyed villages. The yield at each village is indicated as a box plot, which shows the median, quartiles, and extreme values (Figure 9).
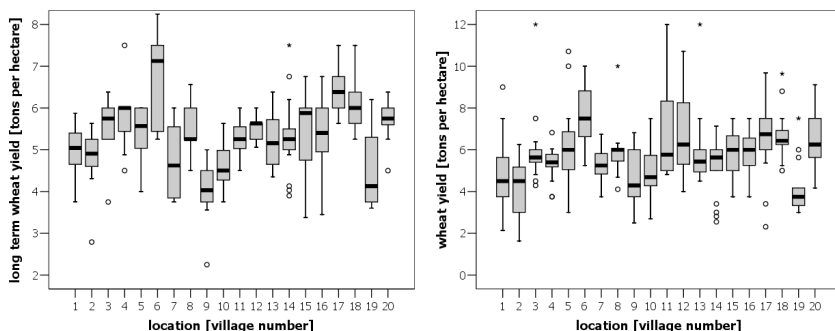
Legend: ° outlier: are cases with values between 1.5 and 3 box lengths from the upper or lower
           edge of the box. The box length is the interquartile range.
         * extreme cases: are cases with values more than 3 box lengths from the upper or lower
           edge of the box. The box length is the interquartile range.
         location: the names and the administrative affiliation of the villages are presented in Table 2

**Figure 9   Average estimated long term wheat yield and surveyed wheat yield
                at village level**

The reported yield in wheat (Figure 9), maize, and cotton (Annex Figure 5) for 2004 show similar confirm the results of the long term wheat yield, there is a strong local variation in yield. These figures clearly indicate the differences in yield between villages, in some cases villages located in the same township show differences in yield.

Since off-farm activities play a major role in rural China, its interrelations to the farming system are considered. Indeed, farm households without off-farm income do have a significantly lower average yield than farm households with a local off-farm job (*income type 2*), while there is no difference in mean to *income type 3* , which stands for income from migration (Table 50).

Table 50   **Average wheat yield and distribution of high and low wheat yield between the defined income types**

	income type 1	income type 2	income type 3	all
average wheat yield [t ha^{-1}]	5.58^a	5.96^a	5.63	5.77
share: low wheat yield	61%^{b,c}	42%^{b}, 44%^{c}	58%^{b}, 55%^{c}	53%^{b,c}
share: high wheat yield	39%^{b,c}	58%^{b}, 56%^{c}	42%^{b}, 45%^{c}	47%^{b,c}

Note ^{a} significant difference in mean between these two groups, but no significant difference in means of each group to the third group
^{b} yield: low yield < 5.63 t ha^{-1}; high yield ≥ 5.63 t ha^{-1}
^{c} relative yield: low relative yield < 100%; high relative yield ≥ 100%

Farm households without off-farm income do have a higher share of below average wheat yield in absolute and relative figures, while farm households of *income type 2* (local off-farm job) do have a higher share of above average yield as well as relative yield of wheat. The distribution of farm households of *income type 3* is similar to the overall distribution (Table 50). Especially in terms of poverty alleviation, the effects on the low yield groups are more important than the overall average. For this reason, the distribution of the dichotomous variables above and below the average yield are considered as well as cumulative distribution function (CDF) of wheat yield (Figure 10).
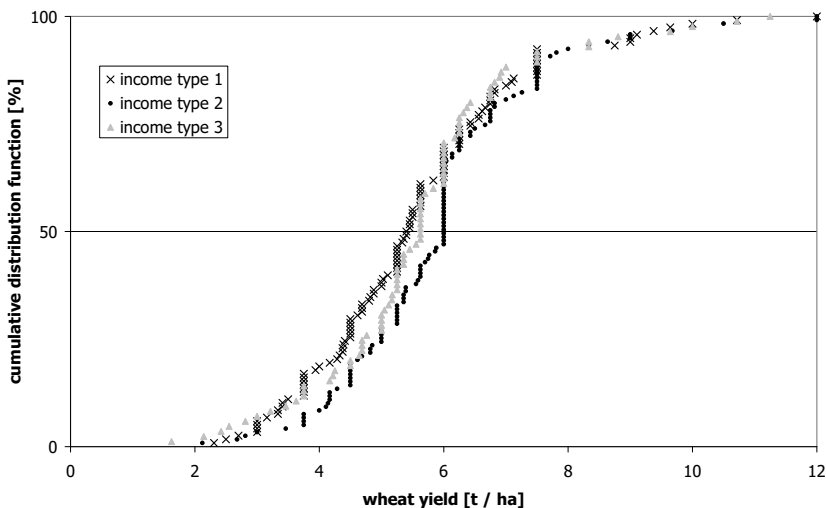
Figure 10   **Cumulative distribution function of wheat yield at income type 1, income type 2, and income type 3**

The cumulative distribution function (CDF) of wheat yield of each income type confirms these results, especially in the yield range between 4 to 6 tons per ha (Figure 10). There is a similar tendency in maize and cotton, but there is no significant difference in mean of yield between the income types (Annex Table 26). Yield of wheat, maize and cotton is analysed in three different models. Peanuts are excluded

due to their low number of cases. First, the relationship between nitrogen input and yield is detail. Finally, a binary logistic regression model analyses the impact of farm characteristics towards yield level.

6.3.1   Analysis of Impact Factors on Yield

A survey and field experiment conducted by EMTERD et al. (2004) found that only five per cent of farm households have obtained higher yield since 1993, despite increasing nitrogen fertilizer application. No correlation between nitrogen fertilizer applied and the wheat and maize yields was found in that 1998 survey. JU et al. (2006) analysed wheat and maize cultivation systems in Shandong Province and found no significant correlations between yield and nitrogen application as well. The described literature review leads to the question, whether this non-relationship between nitrogen input and yield can be confirmed by the IRTG survey. For this reason, the impact of nitrogen to yield is analysed in the following chapters in details.

First, a quadratic yield function is estimated (Equation 2, page 18). In addition, the relation is estimated by a linear function with limitation which is also known as Liebig function. The Liebig function estimates the optimum nitrogen input level and considers a linear relationship up to that nitrogen level. The least square method is used to estimate the related coefficients. The yield at the optimum nitrogen level is considered as maximum yield level (Equation 3, page 18). Table 51 presents the estimated coefficients of the quadratic and Liebig function with limitation in wheat, maize, and cotton. In wheat, the yield function looks like a constant of about 5.8 tons per ha (Figure 11). It shows an insufficient model fit and an agronomic unrealistic shape (negative linear term and positive quadratic term).

Table 51   Estimated quadratic yield function and Liebig function of wheat, maize, and cotton

	wheat [coefficients]		maize [coefficients]		cotton [coefficients]	
	quadratic	Liebig	quadratic	Liebig	quadratic	Liebig
model ft [r²]	<0.01	<0.01	0.07	0.07	0.05	0.06
constant [t ha^{-1}]	5.8727	5.8538	5.4449	5.4961	2.3376	2.2780
nitrogen input [kg ha^{-1}]	-0.0005	-0.0004	0.0044	0.0039	0.0046	0.0042
yield at limitation [t ha^{-1}]	n/a	5.8227	n/a	9.030	n/a	3.0131
nitrogen input at limitation [kg ha^{-1}]	n/a	90	n/a	900	n/a	175
square of nitrogen input	1.3 10^{-7}	n/a	-6.1 10^{-7}	n/a	-7.4 10^{-6}	n/a

The model fit in maize and cotton is quite low. In maize, the quadratic and the Liebig function show a similar shape. The functions increase from 5.5 tons of maize per ha and show a maximum which is far beyond a realistic nitrogen input (Figure 12). The functions, which estimate the relationship between nitrogen input and yield in cotton show a shape, which is similar to the agronomic expectation (Figure 13). The yield function analysis provides no clear relationship between nitrogen input and yield.
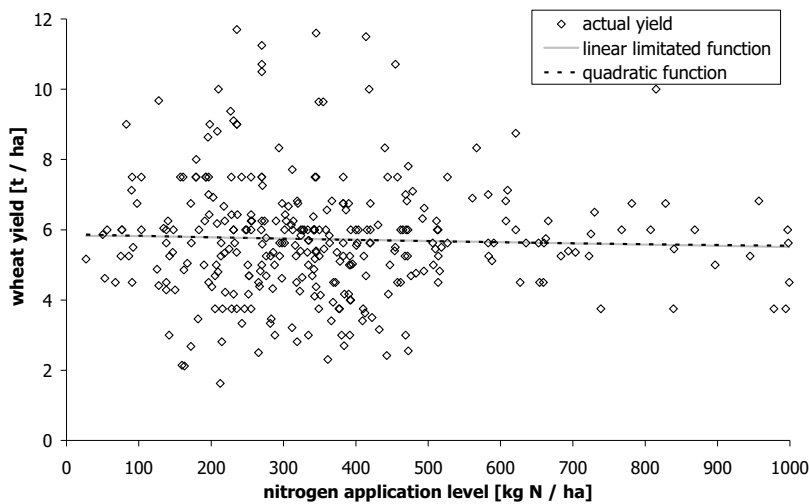
Figure 11   Scatter plot of the relationship between nitrogen input and yield in wheat as well as estimated yield functions

These results might lead the assumption that due to the long term high nitrogen inputs the crop demand in nitrogen is fulfilled and a short term reduction in nitrogen supply or even no fertilizer application will not have a significant effect on the actual yield. However, the available data does not allow a clear answer on this assumption.
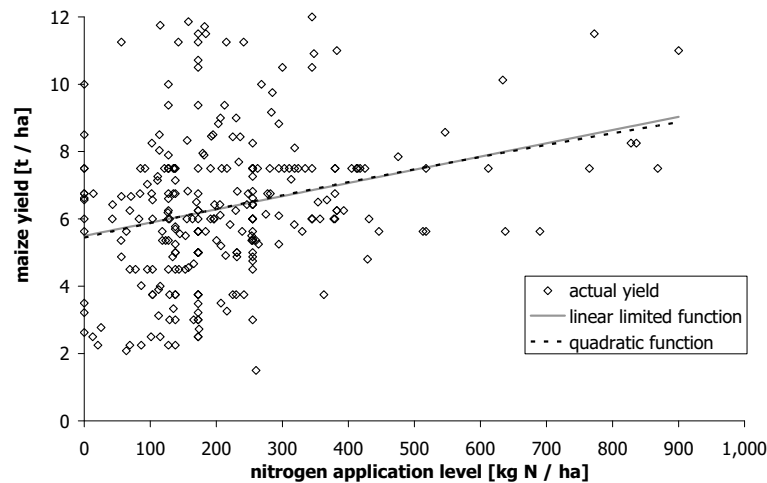
Figure 12   Scatter plot of the relationship between nitrogen input and yield in maize as well as estimated yield functions

Usually, the degree of labour input for farming is assumed to have an impact on the cultivation success. The variable farmland to farming work force ratio is included as additional independent variable. This ratio indicates the amount of work force available for farm work in labour units (LU) to the cultivated farmland. There is no doubt that this variable does not stand for the quality or actual quantity of farm work. Therefore, its impact on the cultivation success should not be overestimated (Table 52).

Table 52   Estimated relationship between yield and selected factors of wheat, maize, and cotton

	wheat [coefficient]		**maize** [coefficient]		**cotton** [coefficient]	
	excluding location	including location	excluding location	including location	excluding location	including location
model ft [r²]	0.05	0.18	0.09	0.17	0.07	0.08
constant	7.5804	1.0652	6.2463	-1.4488	3.0223	2.2219
nitrogen input [kg ha^{-1}]	-0.0010	-0.0005	0.0042	0.0030	0.0036	0.0033
square of nitrogen input	$4.7\ 10^{-7}$	$1.0\ 10^{-7}$	$5.1\ 10^{-8}$	$1.4\ 10^{-6}$	$-5.0\ 10^{6}$	$-4.8\ 10^{-6}$
farmland work force ratio [ha LU^{-1}]	-10.526	-5.1016	-4.6910	1.2289	-4.7479	-4.2494
square farmland work force ratio	13.406	7.0937	5.0979	-1.8179	7.4576	6.8493
village average long term wheat yield [t ha^{-1}]	n/a	1.0399	n/a	1.218	n/a	0.1396

Note   LU stands for labour unit and it is described in Table 3

The model fit of all models increases marginally, but it is still insufficient. The survey data do not provide a clear relationship between these input factors and yield.
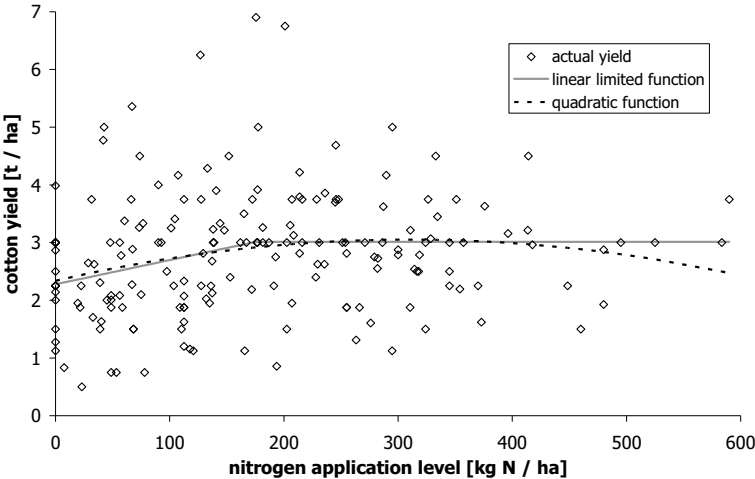
Figure 13   Scatter plot of the relationship between nitrogen input and yield in cotton as well as estimated yield functions

As already described in figure 9, there is a broad variation in average yield between the survey sites. The location related cultivation conditions might play a major role on the individual crop yield. The estimated long term wheat yield is regarded as an indicator for the quality of the farm plots for the cultivation of field crops. It summarizes the impact of all location specific input factors, but it does not provide any detailed information about the characteristics of these impact factors. However, the estimated long term wheat yield is definitely influenced by the nitrogen application rates and the labour input (multi-collinearity). In spite of described problems the variables long term wheat yield is included as linear input variable. The model fit in wheat and maize increases to an acceptable value, but as described these models do not fulfil the demand of avoiding multi-collinearity (Table 52). However, the available data do not allow an analysis of the impact of location specific characteristics on the yield, but the consideration of the variable long term wheat yield provides an indication that location specific factors have an impact on the individual crop yield.

The yield function analysis indicates that there is no clear relationship between nitrogen input and yield, while the village average yield shows the strongest influence to the yield. For this reason, local quadratic yield functions for each village are estimated for wheat (Table 53), maize (Table 54), and cotton (Table 55).

Table 53   Estimated yield functions of wheat at village level

village	survey results		estimated yield functions					
	average yield	average nitrogen input	quadratic function			model fit	maximum yield	nitrogen input at maximum yield
no.	[t ha^{-1}]	[kg ha^{-1}]	aN	bN^2	c	r^2	[t ha^{-1}]	[kg ha^{-1}]
#5	6.19	405	0.0318	-3.3 10^{-5}	-0.73	0.15	6.9	478
#16	5.87	430	0.0048	-5.8 10^{-6}	5.20	0.20	6.2	419
#19	4.07	410	0.0089	-4.3 10^{-6}	1.39	0.33	5.9	1 023

Note   only applicable production functions are listed

However, since it is expected that farm households focus on the maximum yield, the maximum yield and the corresponding nitrogen input are estimated and discussed. The economic optimum of nitrogen application is discussed in chapter 6.5.

Half of the local quadratic yield functions in wheat show a sufficient model fit, but seven functions show an agronomic unrealistic shape with a negative linear and positive quadratic term. Three local yield functions show an applicable shape in wheat. Their estimated maximum yield amounts values between 5.9 to 6.9 tons per ha and the corresponding nitrogen input exceeds 400 kg of nitrogen per ha (Table 53).

The local average nitrogen inputs of the surveyed farm households show similar values as the estimated nitrogen inputs at the maximum yield. In total, four applicable local production functions are estimated for maize. The calculated maximum yields and the corresponding nitrogen inputs show similar values as the averages of the surveyed farm households in the considered villages (Table 54).

Table 54   Estimated yield functions of maize at village level

village	survey results		estimated yield functions					
	average yield	average nitrogen input	quadratic function			model fit	maximum yield	nitrogen input at maximum yield
no.	[t ha^{-1}]	[kg ha^{-1}]	aN	bN^2	c	r^2	[t ha^{-1}]	[kg ha^{-1}]
#6	9.63	210	0.0335	-7.7 10^{-5}	7.01	0.15	10.7	218
#12	7.44	205	0.1159	-3.5 10^{-4}	-1.37	0.13	8.3	168
#16	6.31	135	0.0270	-5.6 10^{-5}	3.95	0.21	7.2	239
#17	6.64	225	0.0360	-7.0 10^{-5}	2.67	0.23	7.3	256

Note   only applicable production functions are listed

In cotton, six applicable local production functions are found. In most of the villages, the average surveyed yield and nitrogen input in cotton are lower than the calculated maximum yield and the corresponding nitrogen input. Summarised, the estimated local production function show a broad variation in shape, which results in a broad range of calculated maximum yield and corresponding nitrogen input (Table 55).

Table 55   Estimated yield functions of cotton at village level

village	survey results		estimated yield functions					
	average yield	average nitrogen input	quadratic function			model fit	maximum yield	nitrogen input at maximum yield
no.	[t ha^{-1}]	[kg ha^{-1}]	aN	bN^2	c	r^2	[t ha^{-1}]	[kg ha^{-1}]
#2	2.21	80	0.0071	-2.7 10^{-5}	2.04	0.16	2.5	131
#4	2.76	110	0.0093	-1.7 10^{-5}	1.72	0.15	3.0	276
#6	3.38	240	0.0072	-1.6 10^{-5}	2.83	0.10	3.6	225
#13	3.03	140	0.0078	-1.2 10^{-5}	2.46	0.18	3.7	329
#14	3.61	110	0.0120	-2.4 10^{-4}	3.03	0.16	4.5	246
#15	2.34	220	0.0089	-2.3 10^{-5}	2.58	0.10	3.4	194

Note   only villages with at least 10 cotton farms and a model fit of more than 0.10 are presented

The results indicate that there is no common yield function of each crop for all farm households. Even inside the villages are huge differences in the shape the individual production functions for wheat, maize and cotton. As described, there are location specific input factors on the crop yield. Furthermore, the heterogeneous nitrogen yield relationships of the individual farm households at the same survey site indicate that there are further impact factor on crop yield beside the nitrogen input. The survey data do not provide sufficient information to identify and to quantify the impact of these factors. As mentioned in the introduction, due to a weak data basis, the factor irrigation is excluded, but it would be too ambitious to discuss whether or not the availability and quality of irrigation water would be a major impact factor on the crop yield. Summarised, the survey data do not provide sufficient data for yield function based modelling approaches.

6.3.2   Analysis of the Relative Yield and Relative Nitrogen Input

As already described, the location seems to play a major role in yield level influencing factors. The relationship between the nitrogen input and relative wheat yield is analysed in order to exclude possible location related effects, but higher nitrogen input does not clearly lead to an above average yield (Annex Figure 6). Further a linear and a quadratic non-linear regression is estimated, but both regression models show an insufficient model fit. The assumption that farm households applying nitrogen above or blow the local average gain an above average wheat yield cannot be confirmed.

There is the question whether or not, farm households, which apply nitrogen above the local average nitrogen, gain yields of above the local average. The scatter plot shows no relationship between relative nitrogen input and relative yield (Annex Figure 7). This relationship can be divided into four groups (Annex Table 27). The adjusted shares in wheat show similar values. Hence, about half the farm households actually follow the assumption that above (below) average nitrogen application leads to above (below) yield, but the other half show two different relationships. About one fourth of the farm households applies above average nitrogen and harvests below average yield, the same share applies below average nitrogen and has above average yields. In maize and cotton the situation is similar.

6.3.3   Estimation of the production function of the aggregated wheat and maize cultivation

The cultivation of winter wheat and summer maize is the characterizing cropping system of the NCP. Therefore, the cultivation input and output can be aggregated to evaluate the entire cultivation system. In order to avoid interference with other cultivated crops, only those 60 farm households cultivating the pure wheat and maize pattern are considered. A quadratic yield function as well as a Liebig function analyse the relationship between the aggregated nitrogen input and the aggregated yield (Annex Figure 8). The visualised estimated quadratic production function shows realistic agronomic shape, but neither the quadratic nor the Liebig function show a sufficient model fit (Annex Table 28).

6.3.4   Estimation of a Production Function Based on a Location Independent Production Function

An location independent single factor quadratic production function of the major grain crops is estimated by KRAYL (1993). This concept bases on various field experiments in Europe. It considers the maximum yield and the corresponding nitrogen input and presents a corresponding single factor production function. KAZENWADEL (1999) modified this concept in order to consider the optimum nitrogen input and the corresponding yield. This modification requires the crop and nitrogen price. The concept base on crop cultivation in Europe, but optimum nitrogen application and expected yield for wheat and maize based on recommendations for

the NCP by ZHEN et al. (2005) are considered to estimate the coefficients of a single factor quadratic production function (Equation 11 and Equation 12).

$$Y = 0.021N - 3.9 \times 10^{-5} N^2 + 2.50$$

Y = yield [t ha^{-1}]
N = nitrogen input [kg ha^{-1}]

Equation 11   Wheat production function based on the concept of Krayl

The wheat cultivation recommendations of 220 kg of nitrogen to harvest 5.3 tons of wheat per ha can be regarded as realistic values or even lower or upper boundaries. For example, CHEN (2003) found out at an experimental site in Beijing Municipality that nitrogen levels of 100 kg are sufficient for wheat yields of 5 to 6 tons per ha.

$$Y = 0.028N - 6.8 \times 10^{-5} N^2 + 3.04$$

Y = yield [t ha^{-1}]
N = nitrogen input [kg ha^{-1}]

Equation 12   Maize production function based on the concept of Krayl

Figure 14 shows the production function based on the concept of KRAYL (1993) and recommendations of ZHEN et al. (2005).
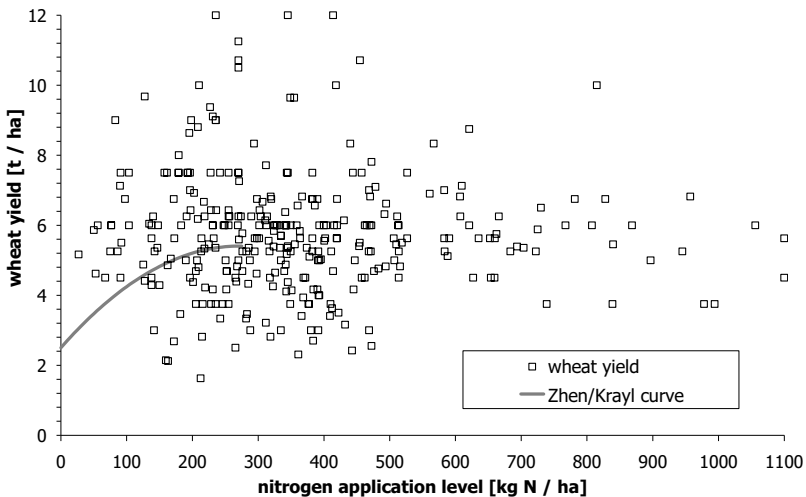
Figure 14   Estimated wheat production function based on the concept of Krayl

However, if the yield of the quartile interval (4.7 to 6.4 tons per ha) and nitrogen application levels beyond 500 kg of nitrogen per ha are regarded as outlier this production function shows an acceptable shape. The production function approach of KRAYL (1993) is only specified to indicate the relationship between nitrogen input and yield up to the nitrogen input at maximum yield. For this reason, the production function based in the concept of KRAYL (1993) might be a suitable instrument to

describe the relationship between nitrogen input and yield (for the wheat cultivation at the survey sites), if nitrogen inputs beyond its maximum lead to a constant yield.

The estimated production function of maize considering the concept of KRAYL (1993) and recommendations of ZHEN et al. (2005) might fit the survey results if possible outlier and survey errors are excluded. Similar to wheat the production function is limited to the nitrogen input at maximum yield (Figure 15).
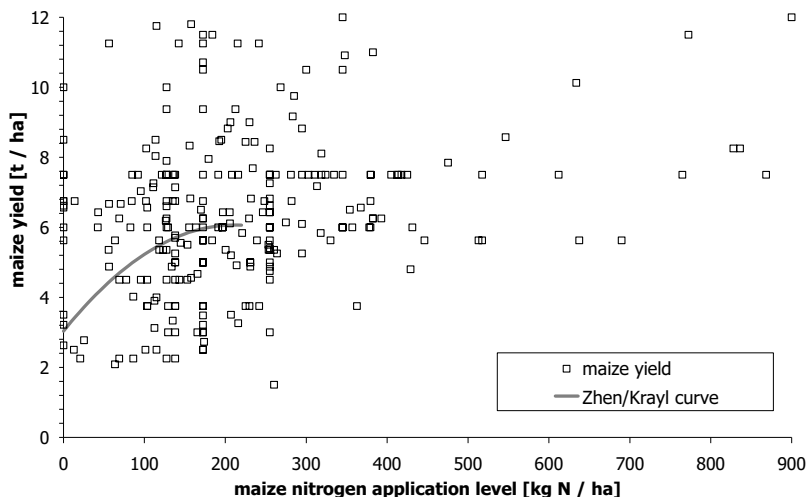
Figure 15   Estimated maize production function based on the concept of Krayl

Table 56 presents the considered recommended nitrogen input, the nitrogen price, and the crop price. The calculated maximum yield and the corresponding nitrogen input are listed as well.

Table 56   Estimated maximum yield and nitrogen input in wheat and maize considering a production function based on the concept of Krayl and survey results as wells recommendations of Zhen for comparison

	wheat	maize
model fit [r²]	<0.01	<0.01
survey results: nitrogen price [¥ kg^{-1}]	5.77	4.51
survey results: crop price [¥ kg^{-1}]	1.42	1.09
ZHEN et al. (2005): recommended nitrogen input [kg ha^{-1}]	220	180
ZHEN et al. (2005): yield at recommended nitrogen input [t ha^{-1}]	5.33	6.05
production function based on the concept of KRAYL (1993): nitrogen input at yield maximum [kg ha^{-1}]	272	211
production function based on the concept of KRAYL (1993): maximum yield [kg ha^{-1}]	5.4	6.1
survey results: actual average nitrogen input [kg ha^{-1}]	360	220
survey results: actual average yield [t ha^{-1}]	5.7	6.4

Further, the model fit of the estimated production function is calculated, but without an acceptable value. In case of wheat the recommended nitrogen input (220 kg per ha) and even the nitrogen input (272 kg per ha) at maximum yield are below the reported actual nitrogen input (360 kg per ha), while the maximum yield is slightly lower than reported actual yield. In maize, the situation is similar, but the actual average nitrogen input is marginally higher than the nitrogen input at yield maximum.

6.3.5 Logistic Regression Analysis of Yield

The yield of wheat, maize, and cotton show some variations between farm households inside a village. One the one hand, the cultivation operations of the individual farm households influences the individual yield level, but on the other hand, other characteristics of the farm household might effect the quantity and the quality of these cultivation operations. Farm household and cultivation characteristics do not influence the yield level directly, but certain characteristics might lead to a higher probability of high yield or low yield. The median yield of wheat, maize, and cotton is used to divide the farm households into a high and a low yield group, each. The binary logistic regression analyses the odds ratio of group membership.

The following covariates are pre-selected for the binary logistic regression with the stepwise backward (likelihood ratio) method (Annex Table 29). The family labour is characterised by the covariate highest family education and by the occupation of family members. Occupation means, whether at least one family member is regarded as *labour type 4* (off-farm job including working on own farm when needed) or at least one *labour type 5* (working exclusively off-farm) is on farm. The ratio between cultivated land and family work force, which are actually doing farm work is considered as covariate farmland farming work force ratio. This covariate indicates the degree of labour input in farming. Further, the income structure of the farm household is considered. The kind of off-farm income source is excluded, only whether or not a farm households does have off-farm income indicated as *income type 1*. Instead of the value of the total household income, two dichotomous covariates are included. This are whether or not the farm household belongs to the one third of farm households, which has an income of less than 4 950 ¥ (*low household income*) or to the one third of farm households that has an income of more than 11 050 ¥ (*high household income*). Additionally, the relative household income is included, which is the individual household income expressed as percentage of the village average income. The farm size is characterised by the variables farmland as well as the relative farmland. The application of manure and whether or not the farm household cultivates the pure wheat and maize cropping pattern are considered as dichotomous covariates to characterise the cultivation system. Table 57 presents the logistic regression models of wheat, maize and cotton yield. There is one eye-catching result in wheat and cotton. The cultivation area shows a highly significant negative effect. Hence, there seems to be an opposite scale effect. This might lead to the assumption that a higher labour input per cultivation area results in a higher yield, but there is no significant difference in mean of farmland to farming work force ratio between the high and low yield in wheat and in cotton.

Table 57   **Analysis of the probability of high yield using binary logistic regression**

		wheat yield	maize yield	cotton yield
dependent variable encoding 1		≥ 5.63 t ha^{-1}	≥ 6.15 t ha^{-1}	≥ 2.85 t ha^{-1}
dependent variable encoding 0		< 5.63 t ha^{-1}	< 6.15 t ha^{-1}	< 2.85 t ha^{-1}
-2 Log likelihood [-2LL$_0$; -2LL$_M$]		403; 447***	337; 380***	210; 254***
Cox & Snell r^2; Nagelkerke r^2		0.131; 0.175	0.077; 0.103	0.180; 0.240
covariate		ß	ß	ß
labour type 4 on farm [1,0]	V$_{010}$	0.497**	0.383*	
low household income [1,0]	V$_{030}$	-0.927***	-1.169***	
high household income [1,0]	V$_{029}$	0.782***		0.913*
relative household income [%]	V$_{032}$			0.006**
farmland farming work force ratio [ha LU^{-1}]	V$_{019}$			-2.796*
pure wheat-maize pattern [1,0]	V$_{041}$	1.308***		
cultivation area [ha]		-2.087***		-3.735***

Note: * significant at p<0.10; ** significant at p<0.05; *** significant at p<0.01

However, a lower household income might be caused by lower crop yields. Hence, farm households belonging to the one third of farm households that have an income of less than 4 950 ¥ (*low household income*) have a lower probability to harvest a wheat yield of more than 5.63 tons per ha. The probability of high yield increases if the farm household belongs to the one third of farm households that has an income of more than 11 050 ¥ (*high household income*). Since this level of income is usually gained from off-farm activities, this effect might indicate that there are farm household with off-farm income, which practice farming more successful. The covariate *labour type 4* indicates a family member, who is working temporary off-farm, but on farm when needed. As expected from the presented yield data at the different income types (Table 50, page 78), in wheat and in maize this covariate shows a positive effect. This leads to the assumption that family members having temporary local off-farm jobs might be more active and well informed. This might lead to farming that is more successful. In wheat, the cultivation of the pure wheat and maize cropping pattern increases the probability of high wheat yield. This relationship might lead to the assumption that higher wheat yields reduce the pressure to cultivate cash crops.

6.4   Analysis of Gross Margin

In economic terms, the gross margin characterises the economic success of crop cultivation. The calculated gross margin is the individual yield multiplied by the average crop price (in order to include farm households without selling their harvested crops) minus the individual variable costs. The key share of the variable costs is fertilizer costs. Similar to the nitrogen use efficiency the gross margin indicates the efficiency of the nitrogen input to yield ratio, but additionally it takes the factor price and product price into account. On the one hand, there is no doubt that yield and nitrogen input strongly influence the resulting gross margin. On the other hand, there might be other factors or common characteristics of more as well as less successful farm households in crop cultivation.

First, a possible correlation between the cultivated crops is analysed. Similar to the yield analysis, there is a positive significant correlation between wheat and maize as well as wheat and peanut in yield and potential gross margin considering direct value as well as relative value. In other words, farm households with a higher gross margin in wheat usually obtain a higher gross margin in maize and peanuts (Table 58).

Table 58   **Correlation of actual gross margin as well as relative gross margin of each cultivated crop to other cultivated crops**

	wheat	maize	peanut	cotton
wheat		0.364[**]	0.391[**]	X
maize	0.242[**]		X	X
peanut	0.237[*]	X		X
cotton	X	X	X	

Note: upper cells on right hand side: correlation coefficient of application level
cells below on left hand side: correlation coefficient of percentage of village share
X not significant; [*] significant at $p<0.05$; [**] significant at $p<0.01$

The results of these correlation analyses indicate that there are relationship between the cultivated crops. Therefore, certain characteristics of the farm household might lead to these similarities in cultivation system between the cultivated crops.

6.4.1   Gross margin and farm households characteristics

On the one hand, QUAN and LIU (2002) stated that local Township Enterprises (TVE) often absorb young and skilled farmers with higher income than farming, leaving the old and women at home, which may lead to decrease of productivity and income. DE BRAUW (2001) stated that when migrants leave the village the farm households' stock of family labour falls, leading to a decrease in farming income. On the other hand, the survey data and finally the regression model results do not show any relationship between income structure indicated by the income type and the potential gross margin. The income structure, hence off-farm activities seem to be without any clear influence as Table 12 (chapter 5.2) already indicates. There is no difference in farming net cash income between farm households with additional off-

farm income sources and farm households with income exclusively from farming. Further, the average calculated gross margin of each crop shows no significant difference between these three income types. Similar to the analysis of yield, a logistic regression model is conducted in order to identify farm household characteristics, which increase or decrease the probability of above average gross margins. None of the logistic regression models shows a sufficient model fit.

6.4.2   Sensitivity Analysis of Impact Factors on Gross Margin

There is still the question, how do its key factors influence the gross margin. The key factors are yield and fertilizer costs, but due to the variation in nitrogen price, the fertilizer costs are split into its components, the nitrogen input and the nitrogen price. A linear regression model estimates the impact of yield, nitrogen input, and nitrogen price on the calculated gross margin in wheat, maize and cotton. A constant crop price is taken into account due to the high share of own consumption, therefore the crops price is excluded from the regression model. All models show a high model fit and the nitrogen input as well as the nitrogen price show a negative relationship to the calculated gross margin (Table 59).

Table 59   Estimated multiple linear regression model of gross margin

	wheat	maize	cotton
model ft [r²]	0.84	0.91	0.93
constant [¥ ha⁻¹]	-205.3	-395.2**	-657
nitrogen input [kg ha⁻¹]	-5.306***	-4.639***	-6.626***
nitrogen price [¥ kg⁻¹]	-205.9***	-174.9***	-114.3***
yield [¥ ha⁻¹]	1 277***	1 077***	4 229***

An elasticity analysis shows that the gross margin at all crops is inelastic towards changes in nitrogen input and nitrogen price (Table 60).

Table 60   Estimated elasticity of yield (Y), nitrogen input (N) and nitrogen price (Q) to gross margin (G)

	wheat	maize	cotton
factor	elasticity	elasticity	elasticity
nitrogen input [$\eta_{G/N}$]	-0.47 (-4.7%)[a]	-0.21 (-2.1%)[a]	-0.13 (-1.3)[a]
nitrogen price [$\eta_{G/Q}$]	-0.29 (-2.9%)[a]	-0.17 (-1.7%)[a]	-0.11 (-1.1%)[a]
yield [$\eta_{G/Y}$]	1.84 (+18.4%)[a]	1.52 (+15.2%)[a]	1.31 (13.1%)[a]

Note   [a] percentage of gross margin change if factor is increased by 10 per cent

For example, an increased nitrogen price of 10 per cent decrease the gross margin in wheat by 2.9 per cent, while in maize and cotton it is less than 2 per cent. A modified nitrogen price does not have a huge impact on the gross margin.

6.5   Analysis of Optimum Nitrogen Input and Nitrogen Price

As described already in the previous chapter, the gross margin depends on the yield and the fertilizer costs, or its components, nitrogen input and nitrogen price. The crop price and the variable costs excluding the fertilizer costs are considered as constants, based on the survey data (Equation 5, page 20). Table 61 presents the average crop price and the average other variable costs (variable costs excluding fertilizer costs) in wheat and in maize. These constants are considered at the following gross margin calculations.

Table 61   Average crop price and variables costs excluding fertilizer costs

	wheat	maize	cotton
crop price [¥ t^{-1}]	1 440	1 100	4 530
other variable costs (variable costs excluding fertilizer costs) [¥ ha^{-1}]	2 250	1 450	2 360

Usually a fixed nitrogen price is considered, but as indicated in chapter 6.2.2 the indicator nitrogen price can be described as a power function of nitrogen input (Table 47, page 73). The nitrogen price is the ratio between fertilizer costs and nitrogen input and it stands for composition of the applied fertiliser. As described in chapter 6.3.1 (Table 51, page 79) the survey results do not show a clear relationship, but from the overall agronomic point of view, a quadratic function describes the influence of nitrogen input to yield. As indicated already, the estimated wheat production function shows an agronomic impossible shape. For this reason, the production function based on the concept of KRAYL (1993) is selected as an applicable instrument to indicate the relationship between nitrogen input and yield for wheat cultivation (chapter 6.3.4, page 84). These relationships allow it to indicate the nitrogen input as a function of yield, nitrogen price, and fertilizer costs (Equation 13).

$$Y(N) = aN + bN^2 + c \iff N(Y) = -\frac{a}{b} \pm \sqrt{\frac{Y}{b} + \frac{a^2}{4b^2} - \frac{c}{b}}$$

$$Q(N) = dN^f \iff N(Q) = \left(1/d\right)^{\frac{1}{f}} Q^{\left(\frac{1}{f}\right)}$$

$$F(N) = N * dN^f \iff N(F) = \left(1/d\right)^{\frac{1}{f+1}} F^{\left(\frac{1}{f+1}\right)}$$

a, b, c = coefficients of the estimated yield function
d, f = coefficients of the estimated nitrogen price function
Y = yield [t ha^{-1}]
N = nitrogen input [kg ha^{-1}]
Q = nitrogen price [¥ kg^{-1}]
F = fertilizer costs [¥ ha^{-1}]

Equation 13   Yield (Y), nitrogen price (Q), and fertilizer costs (F) as function to nitrogen input (N)

In the next step, these functions of equation 13 are set in equation 5 (page 20) in order to express gross margin as a function of nitrogen input as shown in equation 14. Finally, the root of the first derivative of each function can be used to determine the economic optimum of nitrogen input. The equation, which indicates nitrogen input as a function to nitrogen price and fertilizer costs allows it to calculate the economic optimum of nitrogen price and fertilizer costs based on the nitrogen input optimum.

$$G(N) = (aN + bN^2 + c) * P - N * dN^f - O$$

$$G'(N) = 0 = 2Pb * N - (f + 1)d * N^f + Pa$$

a, b, c = coefficients of the estimated yield function
d, f = coefficients of the estimated nitrogen price function
G = gross margin [¥ ha^{-1}]
N = nitrogen input [kg ha^{-1}]
P = crop price (constant) [¥ kg^{-1}]: wheat 1 440, maize 1 100, cotton 4 530
O = other variable costs (constant) [¥ ha^{-1}]: wheat 2 250, maize 1 450, cotton 2 360

Equation 14   Gross margin (G) as function of nitrogen input (N) including its first derivative

The gross margin indicates the economic optimum. For the ecological point of view an equalised nitrogen balance without environmental pollution from nitrogen overuse as it is described in the introduction. For this reason, the gross margin is replaced by the nitrogen balance. Detailed environmental parameters such as nitrogen soil content, natural inflow and natural outflow must be considered in order to estimate an optimum nitrogen balance, but since these data are not available, the range between the equilibrium and a surplus of 50 kg of nitrogen per ha is considered as substitution optimum or acceptable maximum nitrogen balance. This determination of an ecological optimum nitrogen balance is based on SCHLEEF and KLEINHANß (1994), who indicated that 100 kg per ha of annual nitrogen surplus could be regarded as a baseline for nitrate leaching into groundwater on a regional scale. Equation 15 presents the nitrogen balance as function of nitrogen input, which considers the nitrogen input from fertilizer and returned straw and as nitrogen output the nitrogen content of the harvested crop. CHEN (2003) reported for the NCP that the nitrogen content of a whole wheat plant is 30 kg of nitrogen per ton of grain yield and for wheat straw the content is only 4 kg of nitrogen per ton of grain yield. In maize, the nitrogen content per ton of grain yield sums up to 25 kg of nitrogen for the whole plant and 5 kg of nitrogen for the straw only. LIN et al. (1999) estimated the nitrogen content for peanuts with 21 kg of nitrogen per ton of yield.[17] The nitrogen content per ton of cotton yield amounts to 48 kg (LIN, K., Y. XIANG et al. 1999).[18] The average nitrogen input in wheat from returned maize straw is 10 kg of nitrogen per ha. The average amount of nitrogen

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[17]   A kernel yield of 3.78 tons per ha has a nitrogen content of 52 kg of nitrogen. The corresponding stem yield is 20 tons and nitrogen content is 10 kg of nitrogen. In total, the whole crop contains 78 kg of nitrogen per 3.78 tons of kernel yield or 21 kg of nitrogen per ton of yield.

[18]   A unginned seeds yield of 2.85 tons per ha has a nitrogen content of 79 kg of nitrogen. The stem yield is 12.58 tons and nitrogen content is 47 kg of nitrogen. The whole crop contains 137 kg of nitrogen per 2.85 tons of unginned seeds yield or 48 kg of nitrogen per ton yield.

from returned wheat straw to maize is 9 kg per ha and in peanuts as well as cotton it is 6 kg of nitrogen per ha. The nitrogen balance and nitrogen use efficiency is discussed in chapter 7.1 in more detail.

$$B = N + S - Y * C$$

$$B(N) = A = N + S - \left(aN + bN^2 + c\right) * C$$

A = accepted maximum nitrogen balance: 50 kg ha^{-1}
B = nitrogen balance [kg ha^{-1}]
Y = yield [t ha^{-1}]
N = nitrogen input [kg ha^{-1}]
S = nitrogen input from straw left on the field (constant) [kg N ha^{-1}]: wheat 10, maize 9, cotton 6
C = nitrogen content of crop (constant) [kg N t^{-1} yield]: wheat 30, maize 25, cotton 48
a, b, c = coefficients of the yield function

Equation 15   Nitrogen balance (B) as function of nitrogen input (N)

As described, the calculation of the optimum nitrogen input in order to maximise the gross margin is based on equation 14. The nitrogen input allows the calculation of price, fertilizer costs, gross margin, nitrogen balance, and yield. In wheat, the optimum nitrogen input is equal to the nitrogen input at the maximum yield of the considered wheat production function based on the concept of KRAYL (1993). At this point the nitrogen input is 272 kg per ha, which results in a nitrogen surplus of 110 kg per ha. The maximum gross margin reaches 4 057 ¥ per ha (Table 62).

Table 62   Optimum nitrogen input, nitrogen price, and fertilizer costs to maximize gross margin and calculated nitrogen balance

	wheat (Krayl[1])	maize (Krayl[1])	cotton (survey[2])
optimum: nitrogen input [kg ha^{-1}]	272	211	252
optimum: nitrogen price [¥ kg^{-1}]	5.4	4.0	6.1
optimum: fertilizer costs [¥ ha^{-1}]	1 469	853	1 535
maximum: gross margin [¥ ha^{-1}]	4 057	4 407	9801
nitrogen balance at optimum [kg ha^{-1}]	110	29	107
yield at optimum [t ha^{-1}]	5.4	6.1	3.02
survey results: average nitrogen input [kg ha^{-1}]	360	220	180
survey results: average calculated gross margin [¥ ha^{-1}]	4 010	4 660	9 050
recommended nitrogen input[3] [kg ha^{-1}]	220	180	200

Note: [1] considering the production function based on the concept of KRAYL (1993)
           [2] considering the production function based on the survey data
           [3] recommendations by ZHEN et al. (2005)

For comparison, the average calculated gross margin at the survey sites shows a similar value. In maize, the initially estimated production function results in an increasing gross margin with increasing nitrogen input. Therefore, the theoretical nitrogen optimum is beyond the applicable range of the nitrogen input function. Similar to wheat, the concept of KRAYL (1993) shows an applicable production function for maize and the optimum nitrogen input (211 kg per ha) is equal to the nitrogen input at

the maximum yield (6.1 tons per ha). The maximum gross margin amounts to 4 407 ¥ per ha and the nitrogen surplus is 29 kg per ha. The maximum gross margin in cotton amounts to 9 801 ¥ per ha at a nitrogen input of 252 kg per ha. The corresponding yield is 3.02 tons per ha, the nitrogen balance shows a surplus of 107 kg of nitrogen per ha, the nitrogen price is 6.1 ¥ per kg of nitrogen, and the fertilizer cost amounts to 1 535 ¥ per ha. The calculated optimum nitrogen inputs in wheat, maize and cotton are higher than the recommended nitrogen application rates of ZHEN et al. (2005), but in wheat and maize still lower than the average of the surveyed farm households. As already discussed, the average nitrogen input in cotton at the survey sites is lower than the recommendations and average nitrogen input in cotton presented by ZHEN et al. (2005). These results lead to the statement that the present nitrogen application rates in wheat and maize are not at the economic optimum, but the difference is less than expected. In another words, there might be a high share of farm households, which actually apply nitrogen at the economic optimum. The economic optimum does not take the nitrogen balance and its environmental impacts into account. In order to consider the environmental impacts of nitrogen application, table 63 presents the gross margin, yield and nitrogen input for the equilibrium of nitrogen balance and for a nitrogen surplus of 50 kg of nitrogen per ha.

Table 63   Nitrogen input, nitrogen price, fertilizer costs, gross margin and yield at nitrogen equilibrium and at nitrogen surplus of 50 kg per ha

	wheat (Krayl[1])		maize (Krayl[1])		cotton (survey[2])	
nitrogen balance [kg ha^{-1}]	0	50	0	50	0	50
nitrogen input [kg ha^{-1}]	140	205	145	200	135	190
nitrogen price [¥ kg^{-1}]	6.6	5.9	4.4	4.1	7.5	6.7
fertilizer costs [¥ ha^{-1}]	930	1 210	630	820	1 019	1 280
gross margin [¥ ha^{-1}]	3 560	3 980	4 260	4 390	9 410	9 690
yield [t ha^{-1}]	4.7	5.2	5.8	6.1	2.8	2.9

Note: [1] considering the production function based on the concept of KRAYL (1993)
              [2] considering the production function based on the survey data

This range can be regarded as the environmental correspondent to the maximised gross margin. A nitrogen surplus of 50 kg is considered as target value for an optimum nitrogen input estimation. A target nitrogen surplus of 50 kg in wheat cultivation would require a nitrogen input of 205 kg per ha and it might reduces the gross margin by less then 2 per cent, while the calculated yield decrease by 13 per cent. In maize and in cotton the results are similar. These results describe the environmental optimum nitrogen input. This leads to the question, whether or not the economic and the environmental optimum can be combined. A shifted nitrogen price to nitrogen input function modifies the fertilizer costs and gross margin without changes in nitrogen input, which results in a modified economic optimum nitrogen input.

Table 64 presents the required nitrogen price shift for a common optimum nitrogen input and the resulting maximum gross margin. A common nitrogen optimum in wheat requires a nitrogen price shift of 3.0 ¥ per kg, at an average nitrogen price of 5.77 ¥ per kg of nitrogen. In this case, a nitrogen input of 205 kg per ha is the environmental

optimum, the nitrogen balance shows a surplus of 50 kg per ha, and it is the economic optimum. The maximum gross margin amounts to 3 365 ¥ per ha. This is a reduction of gross margin by 17 per cent. In maize, the economic optimum results already in an equalised nitrogen balance. In cotton, the common optimum requires a nitrogen price shift of 3.3 ¥ per kg, but the resulting calculated gross margin is equal to the average surveyed gross margin.

Table 64   Optimum nitrogen input at nitrogen equilibrium and at nitrogen surplus of 50 kg per ha due to nitrogen price modification

	wheat (Krayl[1])		maize (Krayl[1])		cotton (survey[2])	
nitrogen balance [kg ha^{-1}]	0	50	0	50	0	50
increased nitrogen price [¥ kg^{-1}]	+9.5	+3.0	+5.5	0	+6.5	+3.3
nitrogen input [kg ha^{-1}]	140	205	145	200	135	190
gross margin [¥ ha^{-1}]	2 225	3 365	3 470	4 390	8 525	9 060

Note: [1] considering the production function based on the concept of KRAYL (1993)
               [2] considering the production function based on the survey data

The nitrogen input recommendations of ZHEN et al. (2005) are below the actual optimum nitrogen input. However, these results lead to the statement that the present nitrogen price must be increased in order to move the recommendations to the economic optimum. In wheat and in maize the nitrogen price requires a shift by 1.6 ¥ and in cotton by 2.7 ¥ per kg of nitrogen to achieve this target. The corresponding nitrogen balances in these cases would show accepted figures (Table 65).

Table 65   Nitrogen price modification for an optimum nitrogen input equal to the nitrogen input recommendations of Zhen

	wheat (Krayl[1])	maize (Krayl[1])	cotton (survey[2])
nitrogen input recommendation [kg ha^{-1}]	**220**	**180**	**200**
increased nitrogen price [¥ kg^{-1}]	+1.6	+1.6	+2.7
nitrogen balance [kg ha^{-1}]	65	35	60
gross margin [¥ ha^{-1}]	3 365	4 110	9 180

Note: [1] considering the production function based on the concept of KRAYL (1993)
               [2] considering the production function based on the survey data

Summarized, high nitrogen price modifications are required to gain a sufficient impact. Nitrogen price changes show only a low impact on gross margin.

7 Analysis of Nitrogen Use

This chapter focuses on the nitrogen application level and estimates the resulting nitrogen balance. As indicated from the previous chapters, a broad variation in nitrogen balance is estimated. For this reason, farm households are grouped according to their nitrogen balance. In the next step, logistic regression models analyse which factors increases the probability of heavy nitrogen surplus and which increases the probability of equalised nitrogen balance. In addition, a cluster analysis inside the nitrogen balance group of the highest nitrogen surplus illustrates possible parallel opposing effects. Finally, easy observable variables are analysed in order to allow an easy applicable identification of farm households, which show a high probability of nitrogen overuse.

7.1 Analysis of Nitrogen Balance

7.1.1 Estimation of Nitrogen Balance

As mentioned already, in wheat cultivation both the fertilizer costs of 1 870 ¥ per ha and the resulting nitrogen input of 360 kg of nitrogen per ha are about twice the values of maize (220 kg of nitrogen per ha), peanuts (135 kg of nitrogen per ha) and cotton (180 kg of nitrogen per ha). The nitrogen input in wheat cultivation includes manure. It is applied by 25 per cent of the surveyed farm households and the average nitrogen input from manure application is 140 kg of nitrogen per ha. The fertilizer costs for all farm crops are on average 1 340 ¥ per ha and the corresponding nitrogen input all farm crops is on average about 255 kg of nitrogen per ha.[19] A farm survey conducted in Hebei and Shandong by CHEN (2003) found similar results. Average nitrogen input from mineral fertilizer in wheat is 270 kg per ha and in maize 200 kg of nitrogen per ha. The application of manure or maize straw left on the field results in an additional supply of about 90 kg of nitrogen per ha.

For a better understanding of this situation, different ratios are presented. In wheat cultivation, the fertilizer costs in absolute values are already higher than in cultivation of the other crops, but the ratio between fertilizer costs and potential revenue underlines the extraordinary position of wheat. In maize, peanut and cotton about 120 ¥ are spend per 1 000 ¥ of revenue, but in wheat this value exceeds 250 ¥ per 1 000 ¥ of revenue (Table 66). A ratio between grain yield and nitrogen takes factor and product prices out of account. Hence, it is a suitable indicator to compare the nitrogen application level of a certain crop, but at different locations with different prices. This ratio is the nitrogen use efficiency. In the NCP, on average 22 kg of wheat are harvested per kg of nitrogen input, while in Germany this ratio is nearly double (Table 26, page 54). The presented averages are means, but due to outliers the corresponding medians are lower, in case of wheat the median amounts to 17 kg of

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[19] Sum of the fertilizer costs of nitrogen input for all farm plots of wheat, maize, peanut, and cotton divided by sum of the cultivation area of wheat, maize, peanut, and cotton. Due to differences in cultivation period, only farms with winter wheat are taken into account.

wheat per kg of nitrogen input. In maize, peanut, and cotton the difference between means and medians are similar. The nitrogen balance from agricultural activities is calculated by nitrogen inputs from fertilizer application including manure minus the nitrogen content of the harvested crop. Natural nitrogen inflows and outflows are not taken into account.[20] Ju et al. (2006) analysed the nitrogen balance of the wheat and maize cultivation system in the NCP and accounted the nitrogen input from irrigation water on less than 5 kg of nitrogen per ha and from wet deposition on less than 20 kg of nitrogen per ha. The estimation of the nitrogen content of the harvested crops is described already in equation 15 (page 93). Taking these estimates and the average yield into account the resulting average losses by harvesting are in wheat 170 kg of nitrogen per ha, in maize 160 kg per ha, in peanut 70 kg of nitrogen per ha, and in cotton 135 kg of nitrogen per ha (Table 66).

Table 66   Nitrogen input and output by farming activities

	wheat	maize	peanut	cotton
nitrogen input				
fertilizer costs [¥ ha^{-1}]	1 870 (950)[a]	930 (670)[a]	740 (600)[a]	1 230 (850)[a]
nitrogen input [kg ha^{-1}]	360 (200)[a]	220 (160)[a]	135 (105)[a]	180 (135)[a]
fertilizer costs revenue ratio [¥ 1 000 ¥$^{-1}$]	255 (159)[a]	140 (93)[a]	80 (60)[a]	110 (88)[a]
nitrogen use efficiency [kg kg^{-1}]	22[b]/17[c] (20)[a]	38[b]/29[c] (27)[a]	29[b]/24[c],(21)[a]	24[b]/16[c] (24)[a]
nitrogen from returned straw [kg ha^{-1}]	10	9	6	6
nitrogen losses				
nitrogen content of crop [kg ha^{-1}]	170	160	70	135

Note: [a] standard deviation
             [b] mean
             [c] median

In wheat and in maize cultivation about 45 per cent of farm households return the straw back to the fields. In this case, this straw is regarded as nitrogen input for the next cultivated crop. Therefore, maize straw has to be taken into account in wheat nitrogen balance and wheat straw in those of maize, peanut, and cotton. The average nitrogen content of wheat straw returned to the field is 25 kg of nitrogen per ha. In maize this average is 33 kg of nitrogen per ha. The average nitrogen input in wheat from returned maize straw is 10 kg of nitrogen per ha. This figure considers the share of wheat and maize cultivating farm households which return the maize straw to the wheat plots (39 per cent), and the average amount of nitrogen returned to the plot in case of returning maize straw, which is 26 kg of nitrogen per ha. The average amount of nitrogen from returned wheat straw to maize is 9 kg per ha and in peanuts as well as cotton it is 6 kg of nitrogen per ha.[21] There is a broad variation in frequency of returning wheat and maize straw to the field between the surveyed townships. In

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[20]   Natural inflows are wet and dry deposition, nitrogen fixation, and sedimentation. Natural outflows are leaching, gaseous losses, and soil erosion.

[21]   These data are a theoretical approach and consider an equal distribution of the wheat straw to all plots of the farm household. The nitrogen input from wheat straw differs between maize, peanut, and cotton due to differences in probability to return wheat straw and to cultivate a certain crop.

Quzhou and Yanjin County most of the farm households return wheat and maize straw to the field, while in Liangshan County nearly no farm household returns it (Table 68).

The average calculated nitrogen balance shows a nitrogen surplus at all crops. The average surplus in maize, peanut, and cotton is below 100 kg of nitrogen per ha, while in wheat it reaches 200 kg of nitrogen per ha. The added and weighted nitrogen balance of all farm crops amounts to 115 kg of nitrogen per ha (Table 67). Similar to the nitrogen input and yield the nitrogen balance shows a broad variation, as shown in figure 16.

Table 67   **Estimated average nitrogen balance and nitrogen surplus ratio as well as share of farm households belonging to a certain range of nitrogen balance**

	all farm crops	wheat	maize	peanut	cotton
average nitrogen surplus [kg ha^{-1}]	115 (113)[a]	200 (205)[a]	65 (155)[a]	75 (105)[a]	50 (135)[a]
farms with a nitrogen deficit	15%	14%	32%	25%	42%
farms with N surplus up to 75 kg ha^{-1}	25%	12%	26%	29%	23%
farms with N surplus75 to 150 kg ha^{-1}	27%	18%	23%	27%	11%
farms with N surplus higher 150 kg ha^{-1}	33%	56%	18%	19%	24%
average nitrogen surplus ratio[1] [%]	85 (85)[a]	136 (200)[a]	50 (96)[a]	112 (155)[a]	50 (123)[a]

Note: [a] standard deviation
          [1] ratio of nitrogen surplus and nitrogen content of harvested crop

The nitrogen balance shows a wide range for the weighted average at all crops. The high share of farms of both extreme, farms with a nitrogen deficit and farms with a nitrogen surplus exceeding 150 kg of nitrogen per ha indicates this.
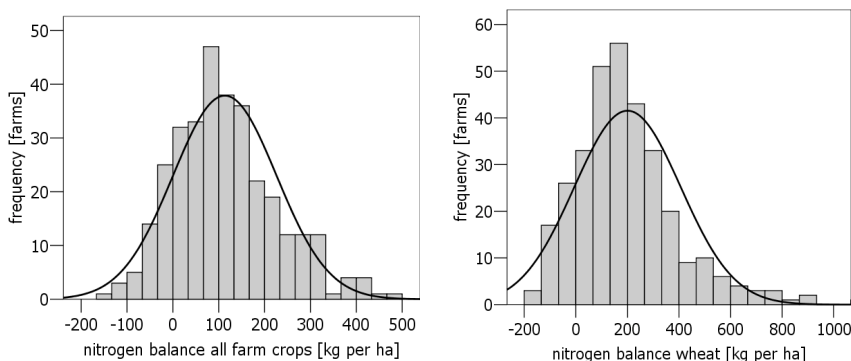
Figure 16   **Histogramme of nitrogen balances for all farm crops and wheat nitrogen balance including normal distribution for comparison**

Additionally, these data underline the high nitrogen surplus in wheat. More than half of the farms have a nitrogen surplus of more than 150 kg of nitrogen per ha, while in maize, peanut, and cotton it is about 20 per cent. On the other hand, about one third of the farm households have a nitrogen deficit in maize, peanut, and cotton. In wheat,

it is only 14 per cent. The high variation in the nitrogen balances leads to the assumption that farm households at the survey locations differ strongly in fertilizer application habits.

A indicator for the level of nitrogen overuse is the *nitrogen surplus ratio*. It is the nitrogen balance as percentage of the nitrogen demand, which is the nitrogen content of the harvested crop. For considering wheat, the average nitrogen surplus is 200 kg of nitrogen per ha and the average nitrogen content of the harvested wheat is 170 kg of nitrogen per ha. Hence, the *nitrogen surplus ratio* amounts in this case to 117 per cent. The average *nitrogen surplus ratio* for wheat of all farm households is 136 per cent. In maize, it amounts to 50 per cent, in peanuts to 112 per cent, and in cotton to 50 per cent. The *nitrogen surplus ratio* for all farm crops amounts to 85 per cent (Table 67).

As already mentioned there is a strong variation between the surveyed townships. Table 68 shows the nitrogen input, the resulting nitrogen surplus, and the *nitrogen surplus ratio* of each crop and of all farm crops.

Table 68 **Estimated nitrogen input, nitrogen balance, and nitrogen surplus ratio at the different survey sites**

county	all	Liangshan		Huimin		Kaifeng		Quzhou		Yanjin	
township		#1	#2	#3	#4	#5	#6	#7	#8	#9	#10
wheat N input [kg ha^{-1}]	360	270	380	430	440	320	330	360	510	270	340
maize N input [kg ha^{-1}]	220	150	160	240	280	240	190	180	140	240	380
peanut N input [kg ha^{-1}]	145					105					190
cotton N input [kg ha^{-1}]	180	75	155	250	250		130	120	185		
all crops N input [kg ha^{-1}]	260	165	270	310	300	220	250	240	280	250	275
return wheat straw [%]	46	3	9	32	48	0	67	82	88	82	38
return maize straw [%]	46	4	10	3	31	0	86	53	68	90	83
wheat: maize straw[1] [%]	39	3	9	3	30	0	73	52	62	58	61
maize: wheat straw[2] [%]	49	4	10	30	46	0	75	78	87	83	37
peanut: wheat straw[2] [%]	25					0					39
cotton: wheat straw[2] [%]	44	0	9	28	39		47	77	86		
wheat N surplus [kg ha^{-1}]	200	135	215	270	215	175	145	210	360	100	190
maize N surplus [kg ha^{-1}]	65	40	20	65	85	120	40	50	-15	85	215
peanut N surplus [kg ha^{-1}]	75					35					130
cotton N surplus [kg ha^{-1}]	50	-25	30	95	100		75	-25	45		
all crops N surplus [kg ha^{-1}]	115	50	125	150	125	110	95	100	130	90	155
wheat N surplus ratio [%]	136	133	135	168	118	133	90	140	230	65	146
maize N surplus ratio [%]	50	37	16	41	53	110	50	44	-10	60	133
peanut N surplus ratio [%]	112					74					177
cotton N surplus ratio [%]	50	-18	36	73	87		130	-11	33		
all crops N surplus ratio [%]	85	53	87	94	81	106	75	71	84	60	132

Note: [1] share of farms cultivating wheat on plots with straw from the previous maize cultivation
         [2] share of farms cultivating maize, peanuts or cotton on plots with straw from the previous wheat cultivation

Further, a high local variation is found, e.g. in Liangshan County, nearly no farm household returns straw, while in Quzhou more than 80 per cent of farm households return wheat straw back to the fields.

7.1.2   Clustering of Farm Households Concerning their Nitrogen Balance

The previous section has shown that wheat cultivation is in general characterized by nitrogen overuse. Therefore, it offers the most promising potential for nitrogen overuse reduction. In order to identify and compare farm households with suitable nitrogen applications and those wasting nitrogen by excessive applications, the overall fertilizer application behaviour for all farm crops as well as the specific situation in wheat cultivation are taken into consideration.

There are three farm types in terms of nitrogen balance: *equalised nitrogen balance*, *slight nitrogen surplus*, and *heavy nitrogen surplus*. Only farm households with wheat cultivation are taken into account. This research approach focuses on the identification of factors leading to nitrogen proper use as well as nitrogen overuse. Both, nitrogen surplus in absolute figures and nitrogen surplus ratio as percentage are suitable characteristics for the nitrogen application level.

For grouping, only one characteristic must exceed or remain under a certain level at both wheat cultivation and at all farm crops, each. This manual grouping method is selected in order to take these determined levels of nitrogen use into account, while a clustering routine such as the k-means cluster analysis would minimise the distance inside a group and maximise it between the groups. The according boundaries in wheat are above 200 kg nitrogen surplus per ha or more than 150 per cent nitrogen surplus ratio and the respective boundaries for all crops are a nitrogen surplus of more than 150 kg per ha or a nitrogen surplus ratio exceeding 100 per cent. Table 69 shows the amount of farms fulfilling each criterion, in total 103 farm households belong to *heavy nitrogen surplus* group which is considered as *nitrogen surplus type 3*.

Table 69   Determination of farms with a heavy nitrogen surplus

	number of farms	share of farms
wheat: farms with nitrogen surplus exceeding 200 kg ha^{-1}	136	42%
wheat: farms with nitrogen surplus ratio of more than 150%	112	35%
all farm crops: farms with nitrogen surplus exceeding 150 kg ha^{-1}	105	33%
all farm crops: farms with nitrogen overuse of ratio more than 100%	121	38%

A study by SCHLEEF and KLEINHANß (1994) indicated that 100 kg per ha of annual nitrogen surplus could be regarded as a baseline for nitrate leaching into ground or surface water on a regional scale. For this reason, farm households with an equalised nitrogen balance (*nitrogen surplus type 1*) are characterised as follows. A nitrogen surplus of less than 100 kg of nitrogen per ha or a *nitrogen surplus ratio* of less than 50 per cent in wheat and a nitrogen surplus of less than 50 kg of nitrogen per ha or a *nitrogen surplus ratio* of less than 25 per cent at farm level. Table 70 shows the

amount of farms fulfilling each criterion, in total 78 farm households belong to *equalised nitrogen balance* group.

Table 70   Determination of farms with an equalised nitrogen balance

	number of farms	share of farms
wheat: farms with nitrogen surplus less than 100 kg ha^{-1}	103	32%
wheat: farms with nitrogen surplus ratio of less than 50%	92	29%
all farm crops: farms with nitrogen surplus less than 50 kg ha^{-1}	100	31%
all farm crops: farms with nitrogen overuse of ratio more than 25%	90	27%

Table 71 shows the nitrogen use characteristics for wheat, maize, peanut, and cotton of each nitrogen balance type. Except in peanut, the nitrogen characteristics of maize and cotton fulfil clearly the characteristics according their farm type affiliation. The largest groups consist on 141 farm households that show neither an equalised nitrogen balance nor a heavy nitrogen surplus (*nitrogen surplus type 2*). The group size distribution itself underlines the level of overall nitrogen overuse at the survey sites, in total one third of the farm households belongs to the heavy nitrogen surplus group.

Table 71   Nitrogen balance characteristics of farm households according to the identified nitrogen balance types

	all wheat farms	nitrogen balance type 1	nitrogen balance type 2	nitrogen balance type 3
number of farms	322	78 (24%)	141 (44%)	103 (32%)
nitrogen surplus all farm crops [kg ha^{-1}]	113	-15	95	235
nitrogen surplus ratio all farm crops [%]	85	-8	67	179
wheat: nitrogen surplus [kg ha^{-1}]	201	-14	172	402
wheat nitrogen surplus ratio [%]	136	-3	106	282
maize: number of farms	272	65 (24%)	124 (46%)	83 (31%)
maize: nitrogen surplus [kg ha^{-1}]	68	3	65	123
maize: nitrogen surplus ratio [%]	51	6	52	83
peanut: number of farms	77	14 (18%)	39 (51%)	24 (31%)
peanut: nitrogen surplus [kg ha^{-1}]	73	51	81	72
peanut: nitrogen surplus ratio [%]	112	63	121	124
cotton: number of farms	172	36 (21%)	82 (48%)	54 (31%)
cotton: nitrogen surplus [kg ha^{-1}]	48	-40	47	110
cotton: nitrogen surplus ratio [%]	49	-21	50	94

The group size distribution for each crop is similar to the overall distribution of the nitrogen balance types, about 30 per cent of farms belonging to *nitrogen balance type 3* and 20 per cent to *nitrogen balance type 1*. There are no differences between the nitrogen balance types and the cultivation of a certain crop. At each crop, all types of nitrogen balance are found in the same distribution.

The nitrogen use efficiency considers the amount of yield per applied kg of nitrogen and explains the nitrogen balance types. Farm households belonging to *nitrogen balance type 1* harvest on average 45 kg of wheat per kg of nitrogen, while at *nitrogen balance type 3* this ratio reaches only 10 kg of wheat per kg of nitrogen (Table 72).

Table 72   Average nitrogen use efficiency (ratio of yield to nitrogen input) of each crop at each nitrogen balance type

	nitrogen balance type 1	nitrogen balance type 2	nitrogen balance type 3
wheat: nitrogen use efficiency [kg kg^{-1}]	45	18	10
maize: nitrogen use efficiency [kg kg^{-1}]	60	37	26
peanut: nitrogen use efficiency [kg kg^{-1}]	30	31	25
cotton: nitrogen use efficiency [kg kg^{-1}]	37	24	18

In total, the farm households belonging to *nitrogen balance type 3* cultivate on 55.4 ha, which is 32 per cent of the total farmland. The overall cultivation area of all farm crops of these farm households amounts to 89.6 ha or 33 per cent. Hence, the distribution of the overall farmland does not differ from distribution of the nitrogen balance types. As indicated already, the nitrogen balance types differ in nitrogen consumption and resulting nitrogen balance. Farm households belonging to *nitrogen balance type 3* consume nearly half of the total nitrogen and are responsible for about two thirds of the overall nitrogen surplus, while their share of overall net income of all farm crops reaches 26 per cent (Table 73). The overall net income base on the calculated gross margin and the cultivation area, but this calculation does not consider own consumption. For this reason, these presented data differs from the net cash income data presented in chapter 5.

Table 73   Overall farm household characteristics

	nitrogen balance type 1 (24%)	nitrogen balance type 2 (44%)	nitrogen balance type 3 (32%)	all wheat farms
family farmland [ha]	38.0 (22%)	78.5 (46%)	55.4 (32%)	171.9
cultivation area [ha]	54.7 (20%)	128.0 (47%)	89.6 (33%)	272.4
net cash income[1] [1000 ¥]	382.7 (26%)	710.3 (48%)	394.0 (26%)	1 487
farm nitrogen input [kg]	8 460 (12%)	29 840 (43%)	31 390 (45%)	69 690
farm nitrogen surplus [kg]	-452 (-1%)	12 831 (39%)	20 618 (62%)	32 997

Note   [1] the overall net cash income does not consider own consumption and differs from the surveyed net cash income

The overall data in wheat explain the differences between the nitrogen balance types. Farm households belonging to *nitrogen balance type 1* and *nitrogen balance type 3* produce about 180 tons of wheat, each. *Nitrogen balance type 1* farm household consume about 4.5 tons of nitrogen, while *nitrogen balance type 3* farm households apply more than four times of the amount of nitrogen. As a result, the two thirds of the overall nitrogen surplus in wheat are originated from farm households belonging to *nitrogen balance type 3* (Table 74).

Table 74   Overall wheat cultivation characteristics

	nitrogen balance type 1 (24%)	nitrogen balance type 2 (44%)	nitrogen balance type 3 (32%)	all wheat farms
wheat cultivation area [ha]	26.3 (21%)	55.1 (45%)	41.4 (34%)	122.8
wheat production [t]	176.7 (26%)	303.6 (45%)	196.4 (29%)	676.8
wheat net income[1] [1000 ¥]	166.8 (34%)	232.7 (47%)	95.9 (19%)	495.5
wheat nitrogen input [kg]	4 560 (11%)	16 737 (39%)	21 377 (50%)	42 675
wheat nitrogen surplus [kg]	-437 (-1.9%)	8 242 (35%)	15 762 (67%)	23 566

Note   [1] the overall net cash income do not considers own consumption and differ from the surveyed net cash income

In terms of overall nitrogen surplus, maize cultivation (Table 75) and cotton cultivation (Table 76) show similar results as wheat cultivation.

Table 75   Overall maize cultivation characteristics

	nitrogen balance type 1 (24%)	nitrogen balance type 2 (44%)	nitrogen balance type 3 (32%)	all wheat farms
maize cultivating farms	65 (24%)	124 (46%)	83 (31%)	272
maize cultivation area [ha]	15.6 (23%)	33.2 (49%)	19.1 (28%)	67.9
maize production [t]	106.1 (25%)	209.1 (49%)	113.8 (27%)	429.0
maize net income[1] [1000 ¥]	82.7 (26%)	157.1 (49%)	79.3 (25%)	319.1
maize nitrogen input [kg]	2 537 (18%)	7 221 (49%)	4 858 (34%)	14 516
maize nitrogen surplus [kg]	70 (2%)	2 256 (50%)	2 190 (48%)	4 516

Note   [1] the overall net cash income do not considers own consumption and differ from the surveyed net cash income

The overall nitrogen input as well as nitrogen surplus clearly indicate the outstanding position of wheat cultivation. More than two thirds of the nitrogen surplus is originated from wheat cultivation.

Table 76   Overall cotton cultivation characteristics

	nitrogen balance type 1 (24%)	nitrogen balance type 2 (44%)	nitrogen balance type 3 (32%)	all wheat farms
cotton cultivating farms	36 (21%)	82 (48%)	54 (31%)	172
cotton cultivation area [ha]	7.7 (18%)	21.4 (50%)	13.4 (32%)	42.4
cotton production [t]	23.6 (21%)	55.0 (49%)	33.8 (30%)	112.4
cotton net income[1] [1000 ¥]	82.7 (23%)	180.0 (49%)	103.6 (28%)	366.3
cotton nitrogen input [kg]	689 (10%)	3 452 (48%)	3 004 (42%)	7 144
cotton nitrogen surplus [kg]	-384 (-19%)	951 (47%)	1 461 (72%)	2 028

Note   [1] the overall net cash income do not considers own consumption and differ from the surveyed net cash income

7.2   Analysis of Impact Factors on Nitrogen Balance

7.2.1   Farm Household Characteristics of the Nitrogen Balance Types

By definition, the nitrogen balance types differ in nitrogen application level and fertilizer costs, but there are further differences in farm household and cultivation characteristics. Beside means of variables the distribution of dichotomous variables are compared with that of the nitrogen balance types among all farm households. There is a special focus on the characteristics of farm households belonging to *nitrogen balance type 1* and *nitrogen balance type* 3.

Both groups do not distinguish in all kind of characteristics. There are no differences in mean in farm family size, education level, and in farmland per family member as well as per farming labour between the nitrogen balance types. In case of family farmland, there is a significant difference between *nitrogen balance type 1* and *nitrogen balance type 2*, but no difference considering *nitrogen balance type 3*. The farm size seems to be without any influence towards the nitrogen use behaviour. The proportion of farm households having an own tractor does not differ to the overall distribution. The situation is similar considering the availability family members that are classified as *labour type 4* (working off-farm and on farm when needed) and *labour type 5* (working exclusively off-farm). Furthermore, the distribution of the share of farm households counted as *main income farming* or *minor income farming* show no difference between the nitrogen balance types. However, each nitrogen balance type is not fully homogenous, but there are similarities.

In terms of farm household characteristics, there are these significant effects. Farm households belonging to *nitrogen balance type 3* have on average a lower farm household income in absolute as well as in relative figures and have a lower farming net cash income. For this reason, there is no significant difference in income share from farming between the three nitrogen balance types (Table 77).

Table 77   Farm characteristics at each nitrogen balance type

		nitrogen balance type 1	nitrogen balance type 2	nitrogen balance type 3
farming work force ratio [%]	V_{008}	78[a]	80	82[a]
farmland [ha]	V_{014}	0.49[a]	0.56[a]	0.54
household income [¥]	V_{028}	11 040[b]	10 610[b]	8 610
relative household income [%]	V_{032}	107.4[b]	106.4[b]	87.0
off-farm income [¥]	V_{039}	6 020[b]	5 750[b]	3 980
farming net cash income [¥]	V_{034}	3 820[b]	3 870[b]	3 200
farming non-cash income [¥]	V_{035}	1 450[b]	1 310[b]	960
long term wheat yield [t ha^{-1}]	V_{021}	5.56[c]	5.38[c]	5.18[c]

Note: [a] significant difference in mean between these two groups, but no significant difference in means of each group to the third group
[b] no significant difference in mean between these two groups, but significant difference in means of each group to the third group
[c] all groups differ in means significantly from each other

Further, the higher farming work force ratio of *nitrogen balance type 3* farm households indicates that a higher share of family work force is doing farm work, but as mentioned the farming income is lower than that of *nitrogen balance type 1.* The long term wheat yield, which can be used as indicator for soil and climate conditions shows low, but significant differences between each nitrogen balance type. This might indicate that farm households belonging to *nitrogen balance type 1* have better cultivation conditions, but it could as well be an indicator that farm households of the *nitrogen balance types 2* and *nitrogen balance types 3* apply fertilizer already beyond the yield maximum. Table 78 compares the distribution of the nitrogen balance type as share of farm households with selected characteristics. The distribution of *income type 2* (farming and local off-farm job) shows a high proportion at *nitrogen balance type 1*, while the proportion of *income type 1* (only farming) and *income type 3* (farming and migration) differs not significantly from the overall proportion. In addition, *nitrogen balance type 1* and *nitrogen balance type 2* show a higher off-farm income than farm households of *nitrogen balance type 3*. Manure application shows a more clear relationship. Only 10 per cent of farm households using manure belonging to *nitrogen balance type 1*, but the share of households belonging to this nitrogen use group is 24 per cent. The share of farm households which cultivate wheat only for own consumption shows a similar effect. As described already (Table 25, page 52), farm households selling wheat apply higher nitrogen rates than those farm households cultivating wheat for own consumption only.

Table 78   Differences between nitrogen use types indicated by the share of farm households characterised by a dichotomous criteria

	nitrogen balance type 1	nitrogen balance type 2	nitrogen balance type 3
share of farm households	24%	44%	32%
share: income type 2	31%	38%	31%
share: manure usage in wheat	11%	39%	49%
share: no wheat selling, only own consumption	18%	43%	39%

Note   [a] chi-square: proportion does not differ significantly (p = 0.1) from overall proportion

Table 79 shows this distribution of the nitrogen balance types considering the cropping pattern.

Table 79   Share of the most important cropping pattern at each nitrogen balance type

		nitrogen balance type 1 [share]	nitrogen balance type 2 [share]	nitrogen balance type 3 [share]
cropping patter	farms	24%	44%	32%
pattern without cotton or peanut	87	35%[a]	33%[a]	32%[a]
cotton or peanut based pattern	235	20%[a]	48%[a]	32%[a]

Note: [a] chi-square: distribution does not differ significantly (p = 0.1) from overall proportion

The cropping pattern is divided into two aggregates of cropping patterns, one group does exclude the key cash crops peanut and cotton, while the other group aggregated

all cropping patterns which includes peanut or cotton. The cash crop based cropping pattern shows a high share at the *nitrogen balance type 2*, while the group excluding peanut or cotton shows a higher share at *nitrogen balance type 1*. There is no difference in the share of *nitrogen balance type 3* between the two groups and the overall share, hence the cultivation of cash crops such as peanut or cotton is connected with heavy nitrogen overuse in the same way as the cultivation of the pure wheat and maize cropping pattern.

The *nitrogen balance type 3* farm households show a lower wheat and maize yield in absolute figures as well as in location independent relative figures. These farm households have on average only 90 per cent of the village average wheat yield at village level and in maize it is 96 per cent (Table 82 and Table 83). The relationship between yield and fertilizer application level is economically represented by the gross margin. The comparisons of average calculated gross margin of each crop indicate clearly that proper nitrogen use is connected with a higher potential gross margin. Nitrogen overuse does not only show negative environmental impacts (see chapter 2.1.2), it reduces farm level economic benefits as well (Table 80).

Table 80   Average gross margin of each crop at each nitrogen balance type

	nitrogen balance type 1	nitrogen balance type 2	nitrogen balance type 3
wheat [¥ ha^{-1}]	6 080	4 060	2 360
maize [¥ ha^{-1}]	5 360	4 590	4 210
peanuts [¥ ha^{-1}]	9 860	7 830	7 360
cotton [¥ ha^{-1}]	10 620	9 040	7 850
all farm crops [¥ ha^{-1}]	6 520	5 510	4 280

Table 82 presents the major cultivation criteria as weighted average for all farm crops. It shows clearly the differences between the nitrogen balances types in terms of fertilizer costs, nitrogen efficiency, and nitrogen price.

Table 81   Major cultivation criteria as weighted average for all farm crops at each nitrogen balance type

	nitrogen balance type 1	nitrogen balance type 2	nitrogen balance type 3
fertilizer costs [¥ ha^{-1}]	975	1 300	1 660
nitrogen input [kg ha^{-1}]	150	235	365
nitrogen use efficiency [kg kg^{-1}]	43	22	13
nitrogen price [¥ kg^{-1}]	6.99	5.64	4.72
nitrogen balance [kg ha^{-1}]	-15	95	235

The total wheat production per family member living on the farm households does not differ significantly between the nitrogen balance types. The overall consumption averages at about 600 kg of wheat per person. In spite of this result, farm households of *nitrogen balance type 3* have a higher share of wheat that is used for own

consumption and show therefore lower sold-harvest ratio than farm households belonging to *nitrogen balance type 1* (Table 82).

Table 82   Wheat cultivation characteristics at each nitrogen balance type

		nitrogen balance type 1	nitrogen balance type 2	nitrogen balance type 3
fertilizer costs [¥ ha^{-1}]	V_{055}	1 205	1 860	2 390
nitrogen price [¥ kg^{-1}]	V_{061}	7.34	5.75	4.61
nitrogen input [kg ha^{-1}]	V_{058}	175	330	545
relative nitrogen input [%]	V_{060}	54.9	94.0	142.6
variable costs [¥ kg^{-1}]	V_{066}	3 460	4 050	4 700
sold-harvest ratio [%]	V_{071}	46[a]	40	34[a]
yield [t ha^{-1}]	V_{067}	6.73	5.73	4.98
relative yield [%]	V_{069}	113	100	90
relative calculated gross margin [%]	V_{076}	138.5	104.8	65.0

Note: [a] significant difference in mean between these two groups, but no significant difference in means of each group to the third group

The presented results are in line with the fertilizer costs and nitrogen input models, as already indicated in chapter 5.3.1. Farm households using wheat exclusively for own consumption apply more nitrogen and have higher fertilizer costs in wheat cultivation. The average *sold-harvest ratio* at each nitrogen balance type (Table 77) and the distribution of farm households which use wheat only for own consumption (Table 78) confirms these finding. Similar to the results of fertilizer costs and nitrogen input analysis (chapter 6.2) farm households belonging to *nitrogen balance type 3* have a lower average nitrogen price indicating the ratio between fertilizer costs and nitrogen input. In general, maize cultivation shows similar results, but the differences between the nitrogen balance types are lower (Table 83).

Table 83   Maize cultivation characteristics at each nitrogen balance type

		nitrogen balance type 1	nitrogen balance type 2	nitrogen balance type 3
fertilizer costs [¥ ha^{-1}]	V_{090}	790[b]	915[b]	1 070
nitrogen price [¥ kg^{-1}]	V_{096}	5.16[a]	4.54	4.27[a]
nitrogen input [kg ha^{-1}]	V_{093}	170	215	255
relative nitrogen input [%]	V_{095}	85.1	93.6	120.1
yield [t ha^{-1}]	V_{102}	6.98	6.31[b]	6.07[b]
relative yield [%]	V_{104}	109.9	97.3[b]	95.9[b]
relative calculated gross margin [%]	V_{111}	114.7	96.8[b]	93.1[b]

Note: [a] significant difference in mean between these two groups, but no significant difference in means of each group to the third group
[b] no significant difference in mean between these two groups, but significant difference in means of each group to the third group
[c] all groups differ in means significantly from each other

There are differences in fertilizer application as well as in yield between the survey sites. The share of farm households belonging to one of the regarded nitrogen balance types differs between the surveyed townships. Except in township #4, the proportion

of nitrogen types at all townships differs significantly from the overall proportion. Township #1 and #6 show a low share of *nitrogen balance type 3* farm households due to a low local average nitrogen input (township #1) or due to an above average high wheat yield, see township #6 (Table 84).

Table 84   **Share of farm households belonging to each nitrogen balance type as well as to the classification group of above or below average nitrogen use at each survey site**

county	Liangshan		Huimin		Kaifeng		Quzhou		Yanjin		all
township	1	2	3	4	5	6	7	8	9	10	farms
number of farm households [#]	31	36	31	27	33	33	33	34	34	34	333
share *N balance type 1* [%]	42	22	6	30ª	15	36	33	15	29	15	24
share *N balance type 2* [%]	35	33	55	37ª	52	36	36	53	50	47	44
share *N balance type 3* [%]	23	44	39	33ª	33	27	30	32	21	38	32

Note   ª chi-square test: proportion does not differ significantly (p = 0.1) from overall proportion

Township #3 is characterised by an extremely low share of *nitrogen balance type 1* farm households, which is caused by the high local average nitrogen input at average yield levels. Township #5 shows a similar situation in terms of nitrogen balance types, but the reason might be the below average wheat yields.

7.2.2   Logistic Regression Analysis of Nitrogen Balance Type Membership

There is still the question, which factors lead to a high probability that a farm household applies fertilizer at an adequate or at an excessive level. Therefore, the probabilities of *nitrogen balance type 1* or *nitrogen balance type 3* group membership are analysed by considering three logistic regression models. The stepwise backward method removes covariates of less significant influence by applying the likelihood ratio analysis. The proximate cluster analysis indicates homogenous subgroups inside each nitrogen balance type in order to include factors with ambiguous effects.

In case of *nitrogen balance type 1* the key model encodes farm households of *nitrogen balance type 1* (n = 78) as dependent variable 1 and all remaining 244 farm households are encoded as dependent variable 0. The key model of *nitrogen balance type 3* encodes farm households of *nitrogen balance type 3* (n = 103) as dependent variable 1 and all remaining 219 farm households as dependent variable 0. In addition, only *nitrogen balance type 3* and *nitrogen balance type 2* are considered as dependent variables. Further, farm households of *nitrogen balance type 3* are excluded in order to focus on factors leading to *nitrogen balance type 2* in case of *nitrogen balance type 1* as reference system (Table 85). The pre-selected covariates of these four models characterises the farm structure in terms of family labour, income, available land, and the wheat farming system (Annex Table 32). The family size, total family labour force, and the highest family education are pre-selected covariates to characterise the family labour. Further, *labour type 4* (temporary off-farm) as well as *labour type 5*

(permanent off-farm) are considered as dichotomous covariate, whether or not at least one family member belongs to these category. The absolute and the relative farmland are considered.

Table 85   Dependent variables of logistic regression models for the analysis of nitrogen balance type membership

dependent variable encoding: 1	n	dependent variable encoding: 0	n
nitrogen balance type 3	103	nitrogen balance type 1 & 2	219
nitrogen balance type 3	103	nitrogen balance type 2	141
nitrogen balance type 2	141	nitrogen balance type 1	78
nitrogen balance type 1	78	nitrogen balance type 2 & 3	244

Further, the farmland per farming work force is included in order to indicate the level of labour input. A minority of farm households rent-in additional land, this situation is included as a dichotomous variable. The farmers have estimated the long term wheat yield at their plots and this estimate is used as variable to evaluate the plot quality. *Income type 1* as a dichotomous variable indicates whether farming is the only income source or whether the farm household have off-farm income sources. Instead of the value of the total farm household two dichotomous covariates are included. This are whether the farm household belongs to the one third of farm households that has an income of less than 4 950 ¥ (*low household income*) or to the one third of farm households that has an income of more than 11 050 ¥ (*high household income*). The relative household income and the income share from farming are pre-selected. In terms of cultivation, the following covariates are pre-selected: usage of manure, average nitrogen price of all crops, and the *sold-harvest ratio* of wheat that indicates the relationship between wheat selling and own consumption. The cropping pattern is included as dichotomous covariate whether or not the farm household cultivates the pure wheat and maize cropping pattern. The location is indicated by the average wheat yield and nitrogen input all farm crops inside the village are included as covariates.

Table 86 shows the models about nitrogen balance indicated by group membership to *nitrogen balance type 1*, *nitrogen balance type 2*, and *nitrogen balance type 3*. Finally, nearly all pre-selected covariates are included in at least one model, but with different levels of significance. The -2 Log likelihood ratio tests as well as the pseudo r^2 of Cox & Snell as well as Nagelkerke show a sufficient model fit for all models.

The location indicating covariates and the covariates nitrogen price as well as manure use show at all models a high significant influence. High village average nitrogen input, low village average wheat yield, a low nitrogen price, and usage of manure increases the probability of nitrogen overuse. This is indicated by a higher odds ratio of group membership in the group of farm households belonging to *nitrogen balance type 3*. There is no clear effect of income structure and income level.

Table 86 **Analysis of the probability of nitrogen balance type 3, of high nitrogen balance, and of nitrogen balance type 1 membership by using logistic regression models**

dependent variable encoding: 1		N type 3	N type 3	N type 2	N type 1
dependent variable encoding: 0		N type 1&2	N type 2	N types 1	N types 2&3
-2 Log likelihood [$-2LL_0$, $-2LL_M$]		442, 325***	335, 297***	303, 256***	442, 286***
Cox & Snell r^2, Nagelkerke r^2		0.300, 0.400	0.155, 0.207	0.193, 0.258	0.373, 0.497
		ß	ß	ß	ß
family size [pers.]	V_{001}	0.359**	0.438***		
family work force [LU]	V_{005}	-0.451**	-0.531**		
highest family education [1-4]	V_{004}				-0.371*
farmland [ha]	V_{014}			1.342**	-1.653***
relative farmland [%]	V_{016}	0.011**			
rent-in farmland [1,0]	V_{020}	-0.887*			
low household income [1,0]	V_{029}				-0.545*
relative household income [%]	V_{032}	-0.006**			
full-farming income [1,0]	V_{038}	-0.527*			
manure usage [1,0]	V_{042}	0.787***	0.528***	0.756*	-1.083***
nitrogen price all farm crops [¥ kg^{-1}]	V_{048}	-0.380***	-0.307***	-0.152***	0.224***
wheat sold-harvest ratio [%]	V_{079}				0.009**
long term wheat yield [t ha^{-1}]	V_{021}		-0.204*		
village average wheat yield [t ha^{-1}]	V_{076}	-0.286***		-0.198***	0.295***
village average wheat nitrogen input [kg ha^{-1}]	V_{067}	0.006***	0.005***	0.005***	-0.006***
average individual probability of group membership		32.7%	43.9%	62.7%	24.2%
share of considered farm households		32.0%	42.2%	64.4%	24.2%

Note   * significant at p<0.10; ** significant at p<0.05; *** significant at p<0.01

The presented coefficients enable to calculate the individual probability of group membership for each farm household. The average individual probability of group membership is quite close to the share of farm households actually belonging to that nitrogen balance type. These results are the basis of the simulations of chapter 8.2.

7.2.3   Cluster Analysis of Nitrogen Balance Types

The previous comparisons of the nitrogen balance types indicate that several variables are excluded which are expected to show a clear influence. These variables might show an opposing effect inside a nitrogen balance type. For this reasons, a cluster analysis is conducted in order to identify homogenous groups inside both nitrogen balance type. For classification the software programme SPSS is used. The k-Means Cluster Analysis is selected, because this procedure attempts to identify relatively homogeneous groups of cases based on selected characteristics and uses an algorithm, which can handle large numbers of cases. The distances are computed

using simple Euclidean distance. On the other hand, the number of clusters must be specified a priori and it only can handle variables at the interval or ratio level. However, these characteristics fit the demand of this research topic.

Farm household structure and wheat cultivation describing variables are considered as clustering variables (Annex Table 33). This are family farmland, income structure, application of manure, and share of wheat own consumption. The amount of five cluster are specified a priori in order to get on the one hand cluster of a sufficient size and on the other hand to identify and exclude obvious outliers. The farm households belonging to *nitrogen balance type 1* are grouped into three cluster of a sufficient size: *cluster 1-A*, *cluster 1-B*, and *cluster 1-C*. Three farm households are grouped into the remaining cluster. Table 87 presents the farm household characteristics and table 88 shows cultivation characteristics. In terms of cultivation characteristics especially in fertilizer costs, nitrogen input level, nitrogen price, yield, and gross margin there are no huge differences between the three clusters.

Only *cluster 1-C* is characterised by usage of manure. The clusters differ in farm household structure. The largest group *cluster 1-B* (n=38) show figures in family size, farmland and income are quite similar to the average values considering all farm households, but farm household of this cluster have a high income share from a local off-farm job. The few farm households belonging to *cluster 1-A* (n=12) have much farmland in absolute and relative figures, mainly due to an above average family size.

Table 87   Farm characteristics of nitrogen clusters of nitrogen balance type 1

	nitrogen cluster 1-A (n=12)	nitrogen cluster 1-B (n=38)	nitrogen cluster 1-C (n=24)	N type 1 farms (n=77)	wheat farms (n=322)
family size [pers.]	5.2	4.3[b]	3.9[b]	4.3[a]	4.4
farming work force ratio [%]	57	76	94	78	80
farmland [ha]	0.62	0.50	0.39	0.49[a]	0.53
relative farmland [%]	129	102	75	99[a]	100
household income [1 000 ¥]	20.5	10.7	3.8	11.0	10.4
relative household income [%]	218	100	37	107	100
farming income share [%]	33[b]	45	82	55[a]	38
long term wheat yield [t ha^{-1}]	5.71[b]	5.59	5.28[b]	5.57	5.34
share: income type 1	0	4 (11%)	20 (83%)	31%	36%
share: income type 2	4 (33%)	28 (74%)	3 (13%)	48%	37%
share: income type 3	8 (67%)	6 (16%)	1 (4%)	21%	26%
share: pure wheat-maize pattern	2 (17%)	10 (26%)	7 (29%)	27%	19%
share: rent-in farmland	3 (25%)	4 (11%)	1 (4%)	12%	10%

Note: two clusters (three farm households with much farmland und high income) are excluded
          [a] no significant difference in mean to N type 3 farms
          [b] no significant difference in mean to the key nitrogen cluster 1-B

The high income share from off-farm activities, mainly migration of at least one family member, results in a household income twice the overall average. Only 57 per cent of the family labour force is working on farm, while the overall average is 80 per cent. These farm households do not apply manure and sell two thirds of the harvested

wheat, while the average figure is one third. *Cluster 1-C* (n=24) shows nearly completely opposed characteristics. Farm households have less farmland in absolute and relative figures and nearly no additional income from off-farm activities. For this reason, their average income is less than half of the overall average and only 37 per cent of the village average. These farm households apply less nitrogen and have the lowest fertilizer costs, but reach an above average wheat yield and gross margin. In spite of manure application, these farm households reaches acceptable nitrogen use efficiency indicated, on average 47 kg of wheat per kg of nitrogen. Share of farm households cultivating exclusively wheat and maize as well as cultivating cotton are similar to the overall share, each (Table 88).

Table 88   Cultivation characteristics of the nitrogen cluster of nitrogen balance type 1

	nitrogen cluster 1-A (n=12)	nitrogen cluster 1-B (n=38)	nitrogen cluster 1-C (n=24)	N type 1 farms (n=77)	wheat farms (n=322)
fertilizer costs all farm crops [¥ ha^{-1}]	1 040[b]	970	890[b]	975	1 340
nitrogen input all farm crops[kg ha^{-1}]	145[b]	155	140[b]	150	255
nitrogen balance all farm crops [kg ha^{-1}]	-15[b]	-10	-20[b]	-15	115
wheat nitrogen input [kg ha^{-1}]	180[b]	185	165[b]	175	360
wheat relative nitrogen input [%]	49[b]	56	53[b]	55	100
wheat nitrogen price [¥ kg^{-1}]	7.68[b]	7.42	7.11[b]	7.34	5.77
share: manure usage [1,0]	0	2 (5%)	6 (25%)	11%	25%
share: no wheat selling [1,0]	1 (8%)	9 (24%)	6 (25%)	22%	31%
wheat sold-harvest ratio [%]	67	41	44[b]	46	39
wheat production per person [kg]	825[b]	605	525[b]	630[a]	595
wheat yield [t ha^{-1}]	6.66[b]	6.79	6.29[b]	6.73	5.73
wheat relative yield [%]	112[b]	114	108[b]	113	100
wheat calc. gross margin [¥ ha^{-1}]	6 060[b]	6 050	5 720[b]	6 080	4 000
wheat yield nitrogen ratio [kg kg^{-1}]	49[b]	43	47[b]	45	22
maize nitrogen input [kg kg^{-1}]	145[b]	165	165[b]	165	215
maize calc. gross margin [¥ kg^{-1}]	5 320[b]	4 770	5 740[b]	5 360	4 660
maize yield nitrogen ratio [kg kg^{-1}]	44[b]	55	56[b]	54	38
cotton cultivation [%]	9 (75%)	13 (34%)	12 (50%)	47%	53%
cotton nitrogen input [kg kg^{-1}]	95[b]	125	60	100	175
cotton calc. gross margin [¥ kg^{-1}]	8 930[b]	11 180	10 670[b]	10 620	9 000
cotton yield nitrogen ratio [kg kg^{-1}]	30[b]	37	43[b]	37	25

Note: two clusters (consisting on 1 and 2 farm households) are excluded
[a] no significant difference in mean to N type 3 farms
[b] no significant difference in mean to the key nitrogen cluster 1-B

In the next step farm households of *nitrogen balance type 3* are clustered. One cluster consisting on four farm households is excluded and the remaining four cluster are of sufficient size: *cluster 3-A*, *cluster 3-B*, *cluster 3-C*, and *cluster 3-D*. Table 89

resent the farm household characteristics and table 90 show cultivation characteristics. Beside high nitrogen input, lower yield, lower gross margin, and lower nitrogen use efficiency, these farm household differ from that of *nitrogen balance type 1* by the lower nitrogen price.

The by far largest cluster of *nitrogen balance type 3* is *cluster 3-C* (n=47) and it shows similar characteristics than the *cluster 1-C*. These are small family size, less farmland and quite low household income. There is a low income share from off-farm activities especially from local off-farm jobs, but this is more than that of *cluster 1-C*. The long term wheat yield show similar figures than *cluster 1-C*, but farm households belonging to *cluster 3-C* show a low actual wheat yield and high nitrogen input resulting in a low gross margin of wheat, maize, and cotton.

Cluster 3-A (n=19) is characterised by low farmland as well, but due to off-farm activities farm households belonging to this cluster gain an average income. Similar to *cluster 3-C* the low *sold-harvest ratio* indicates high own consumption of wheat. Farm households of *cluster 3-B* (n=17) are characterised by nearly twice the average farmland. The household income share from off-farm activities is quite low, but the household income reaches nearly the overall average. Due to high fertilizer costs and low yield, these farm households reach a lower gross margin in wheat, maize, and cotton. In spite of above average farmland and a sufficient wheat production per family member person the *sold-harvest ratio* is lower than it would be expected (Table 89).

Table 89   Farm characteristics of nitrogen cluster of nitrogen balance type 3

	nitrogen cluster 3-A (n=19)	nitrogen cluster 3-B (n=17)	nitrogen cluster 3-C (n=47)	nitrogen cluster 3-D (n=15)	N type 3 farms (n=102)	wheat farms (n=322)
family size [pers.]	4.7	4.9	3.8	5.1	4.4[a]	4.4
farming work force ratio [%]	73	86[b]	90	73	83	80
farmland family ratio [ha pers.$^{-1}$]	0.09	0.18	0.11	0.14	0.12[a]	0.13
farmland [ha]	0.44[b]	0.83	0.42	0.68	0.54[a]	0.53
relative farmland [%]	81[b]	148	83	127	101[a]	100
household income [1 000 ¥]	11.5	8.2	3.6	14.2	8.5	10.4
relative household income [%]	107	87	36	163	87	100
farming income share [%]	35	71[b]	72	37	58[a]	57
long term wheat yield [t ha^{-1}]	5.18[b]	4.92[b]	5.27	4.82[b]	5.15	5.34
share: income type 1	2 (11%)	8 (47%)	30 (64%)	0	31%	36%
share: income type 2	7 (37%)	4 (24%)	15 (32%)	8 (47%)	48%	37%
share: income type 3	10 (53%)	5 (29%)	2 (4%)	7 (47%)	21%	26%
share: pure wheat-maize pattern	2 (11%)	2 (17%)	12 (26%)	0	27%	19%
share: rent-in farmland	0	3 (18%)	1 (2%)	2 (13%)	7%	10%

Note: one cluster (4 farm households with much farmland und high income) are excluded
         [a] no significant difference in mean to N type 1 farms
         [b] no significant difference in mean to the key nitrogen cluster 3-C

Cluster 3-D (n=15) is characterised by above average farmland as well, but due to off-farm activities farm households belonging to this cluster have an above average household income as well. Due to the highest nitrogen input and lowest wheat yield these farm households reach only an average gross margin in wheat of 1 490 ¥ per ha. Similar to the other cluster of *nitrogen balance type 3* the sold-harvest ratio is lower than expected. The average farmland is similar to that of *cluster 1-A*, but half of the farm households do not sell wheat and therefore their *sold-harvest ratio* is half of that of *cluster 1-A*.

The logistic regression models as well as the cluster analyses indicate the farm households belonging to *nitrogen balance type 1* or *nitrogen balance type 3* differ mainly by the price of applied nitrogen. Further, application of manure and a high share of wheat own consumption lead to a higher probability of nitrogen overuse. Available farmland, income from off-farm activities and the level of income show no clear effect. Hence, there are more than one common characteristic of farm households with nitrogen overuse.

The largest group of *nitrogen balance type 3 (cluster 3-C)* is actually characterised by less farmland, low income share from off-farm activities and resulting low income. These farm households have only 85 per cent of the village average wheat yield and in cotton the lowest gross margin. This lead to the assumption that these farm households try to increase their yields and income by increasing fertilizer application, but the applied amount of nitrogen seems to be already beyond the economic as well as agronomical optimum. However, *cluster 1-C* of *nitrogen balance type 1* show similar characteristics as *cluster 3-C* in terms of land, income structure, manure application, but it differs in nitrogen price and share of wheat own consumption. Farm households of *cluster 1-C* show the lowest nitrogen input, but still above average yield.

Considering the long term wheat yield at all plots both cluster show similar figures, the plot quality for cultivation seems to be equal. *Cluster 3-A* is similar to *cluster 3-C*, but these farm households have a higher income share from off-farm activities. There are differences in location between both clusters. *Cluster 3-C* are mainly located in township #2, #3, and #4, while *cluster 1-C* mainly in township #1, but in township #6 and #7 both clusters are located. Considering the results from logistic regression, location characteristics play a major role as well. Location is indicated as the mean of a certain characteristic, hence it includes quantifiable and not quantifiable factors. Since only 20 villages have been surveyed, this low number of elements does not allow a clear analysis of location related influencing factors.

Cluster 1-C indicates that the farm household characteristics of *cluster 3-C* can enable an adequate nitrogen usage, which results in an equalised nitrogen balance and sufficient gross margins. Hence, there is the potential of these farm households to reduce nitrogen overuse without reduction in income. Average farmland, high off-farm income combined with proper nitrogen input and high yields are the characteristics of *cluster 1-A* and *cluster 1-B* of *nitrogen balance type 1*. By contrast, cluster 3-B and cluster 3-D show the highest farmland, but the low long term wheat yield indicates a tendency of lower plot quality for cultivation. These farm households differ mainly in

terms of higher own consumption and cheaper nitrogen from farm households belonging to the corresponding clusters of *nitrogen balance type 1* (Table 90).

Table 90   Cultivation characteristics of nitrogen cluster of nitrogen balance type 3

	nitrogen cluster 3-A (n=19)	nitrogen cluster 3-B (n=17)	nitrogen cluster 3-C (n=47)	nitrogen cluster 3-D (n=15)	N type 3 farms (n=102)	wheat farms (n=322)
fertilizer costs all farm crops [¥ ha^{-1}]	1 560[b]	1 570[b]	1 660	1 820[b]	1 660	1 340
nitrogen input all farm crops [kg ha^{-1}]	370[b]	350[b]	360	345[b]	365	255
nitrogen balance all farm crops [kg ha^{-1}]	230[b]	225[b]	235	225[b]	235	115
wheat nitrogen input [kg ha^{-1}]	555[b]	495[b]	520	590[b]	545	360
wheat relative nitrogen input [%]	141[b]	133[b]	140	152[b]	143	100
wheat nitrogen price [¥ kg^{-1}]	4.08	4.41[b]	4.75	5.42	4.61	5.77
share: manure usage [1,0]	8 (42%)	6 (35%)	18 (38%)	3 (20%)	38%	25%
share: no wheat selling [1,0]	10 (53%)	4 (24%)	17 (36%)	7 (47%)	37%	31%
wheat sold-harvest ratio [%]	27[b]	46	30	34[b]	34	39
wheat production per person [kg]	535[b]	795	445	525[b]	545[a]	595
wheat yield [t ha^{-1}]	5.33[b]	4.93[b]	4.85	4.67[b]	4.98	5.73
wheat relative yield [%]	98	90[b]	85	92[b]	90	100
wheat calculated gross margin [¥ ha^{-1}]	3 160	2 610[b]	2 090	1 490[b]	2 360	4 000
wheat yield nitrogen ratio [kg kg^{-1}]	10[b]	10[b]	10	9[b]	10	22
maize nitrogen input [kg kg^{-1}]	235[b]	255[b]	270	215[b]	255	215
maize calculated gross margin [¥ kg^{-1}]	4 990	4 060[b]	3 940	3 940[b]	4 210	4 660
maize yield nitrogen ratio [kg kg^{-1}]	27[b]	26[b]	25	26[b]	25	38
cotton cultivation	11 (58%)	10 (59%)	20 (43%)	10 (67%)	52%	53%
cotton nitrogen input [kg kg^{-1}]	245[b]	320	205	140[b]	225	175
cotton calculated gross margin [¥ kg^{-1}]	10 470	6 670[b]	6 390	8 710	7 850	9 000
cotton yield nitrogen ratio [kg kg^{-1}]	13[b]	9	15	43	18	25

Note: two clusters (consisting on 1 and 2 farm households) are excluded
[a] no significant difference in mean to N type 1 farms
[b] no significant difference in mean to the key nitrogen cluster 3-C

The nitrogen price shows a clear influence, hence the application or not application of a certain fertilizer type might be an obvious indicator. Unfortunately, there is no difference between the nitrogen balance types in share of farm households applying expensive nitrogen fertilizer which are characterised by a nitrogen price of more than 10 ¥ per kg of nitrogen (Annex Table 34). All compound fertilizer are regarded as expensive nitrogen fertilizer.

7.3   Identification of Nitrogen Overusing Farm Households

As described in the previous chapter, the nitrogen types and its sub-cluster show differences and common characteristics in terms of farm household characteristics as well as cultivation characteristics. For example, one major variable is the nitrogen price, which is calculated from the nitrogen input and the fertilizer costs. Hence, a detailed investigation of the farm households is required to calculate this variable. For this reason, a quick evaluation of farm households in term of nitrogen use is not possible. In another way, the characteristic low nitrogen price does not enable a quick and easy identification of nitrogen overusing farm households.

Why should it be possible to identify easily nitrogen overusing farm households? The overall research topic is the reduction of nitrogen overuse. The identification of nitrogen overusing farm households is an essential step for instruments to reduce nitrogen overuse, as it is discussed in chapter 8.3. For this purpose, easy observable characteristics are required, which allows a classification or to predict the nitrogen balance type of a farm households. What are easy observable characteristics? However, a village leader should be able to characterize a farm household according to these characteristics. Further, dichotomous or binary variables are handier than a discrete variable, because presence or absence of a criterion is usually easier to estimate than a discrete answer. Table 91 presents the seven selected dichotomous variables and the proportion of variable output, which is one.

Table 91   Differences between nitrogen use types indicated by the share of farm households characterised by the presence of pre-selected dichotomous criteria

		nitrogen balance type 1 78 (24%)	nitrogen balance type 2 141 (44%)	nitrogen balance type 3 103 (32%)	all farms 286
labour type 4 on farm [1,0]	V_{010}	38 (49%)	53 (38%)	42 (41%)	133 (41%)
labour type 5 on farm [1,0]	V_{012}	20 (26%)	46 (33%)	25 (24%)	91 (28%)
pure wheat-maize cropping pattern [1,0]	V_{041}	21 (27%)	23 (16%)	16 (16%)	60 (19%)
high relative farmland [1,0]	V_{017}	32 (41%)	70 (50%)	50 (50%)	153 (48%)
high relative household income [1,0]	V_{033}	36 (46%)	60 (43%)	33 (32%)	129 (40%)
full-farming income [1,0]	V_{038}	39 (50%)	78 (55%)	56 (54%)	173 (54%)
high relative wheat yield [1,0]	V_{070}	52 (67%)	64 (45%)	35 (34%)	151 (47%)

Note   [a] chi-square: proportion does not differ significantly (p = 0.1) from overall proportion

It is expected that a village leader usually know, whether or not a farm household does have at least one family member who is working temporary or permanently off-farm. In addition, whether or not the farm households cultivates the pure wheat and maize cropping pattern. The farmland and income related characteristics do not require precise data. These variables consider whether a farm household is above or below the local average. This information can be provided by local statistics, but the

estimates of the village leader usually fulfil the information demand. Further, farming as the major income source of the farm household is considered (Annex Table 35).

In the next step, these characteristics are used for the identification of homogenous groups. In maximum, seven dichotomous variables would allow 128 homogenous farm types, but there are only six farm types, which consist on more than 10 farm households. The largest farm type (*farm type A*) consist on 24 farm households or seven per cent of all farm households and is characterised by no off-farm income, below local average income, above local average farmland, and below local average yield. *Farm type B* and *farm type C* differs only in farmland and wheat yield (Table 92).

Table 92   Definition of farm types and share of farm households belonging to the most common farm types

farm type	A	B	C	D	E
farm households	24 (7%)	21 (7%)	18 (6%)	15 (5%)	12 (4%)
labour type 4 on farm [1,0]	0	0	0	0	0
labour type 5 on farm [1,0]	0	0	0	1	0
pure wheat-maize cropping pattern [1,0]	0	0	0	0	1
high relative farmland [1,0]	1	0	0	1	0
high relative household income [1,0]	0	0	0	1	0
major income farming [1,0]	1	1	1	0	1
high relative wheat yield [1,0]	0	0	1	0	1

Table 93 presents the major farm types of farm households belonging to nitrogen balance type 3. The *farm types A* and *farm type B* are the largest farm types, but there are farm types, which are characterised by off-farm income as well. However, this result indicates a weak tendency that farm households without off-farm income have a higher probability of nitrogen overuse and a high level of nitrogen surplus.

Table 93   Most common farm types of farm households belonging to nitrogen balance type 3

farm type	A	B	G	H	D	I
farm households	11 (11%)	9 (9%)	5 (5%)	5 (5%)	4 (4%)	4 (4%)
labour type 4 on farm [1,0]	0	0	0	1	0	0
labour type 5 on farm [1,0]	0	0	0	0	1	1
pure wheat-maize cropping pattern [1,0]	0	0	1	0	0	0
high relative farmland [1,0]	1	0	0	0	1	0
high relative household income [1,0]	0	0	0	0	1	0
major income farming [1,0]	1	1	1	0	0	0
high relative wheat yield [1,0]	0	0	0	0	0	0

The largest farm type of nitrogen balance type 1 are *farm type C* and *farm type E*, hence farm types, which are characterised by no off-farm income, but high yields (Annex Table 36). Nitrogen balance type 2 is in-between (Annex Table 37). The largest farm types are *farm type A* and *farm type B*, but directly followed by *farm type C* and

farm type E and two farm types with off-farm income and high yield. Summarised, relative wheat yield is the key difference between farm households with nitrogen overuse and adequate nitrogen use. However, this result is not a surprise. A quick identification of farm households with nitrogen surplus based on easy observable characteristics is not possible.

8   Simulation of Scenarios of Nitrogen Surplus Reduction

This chapter discusses instruments of nitrogen input reduction and its impact on nitrogen balance and net income from farming. In the first step, the overall potential of nitrogen surplus reduction and net income from farming improvement is estimated. In the next step, the simulation scenarios estimate the impact of nitrogen input reduction instruments on nitrogen balance and net income from farming.

8.1   Estimation of the Potential of Nitrogen Surplus Reduction and Net Income from Farming Improvement

Several authors such as Zℋℰℕ et al. (2005) discuss that the actual nitrogen application rates are beyond the recommended dosages and result in high levels of nitrogen surplus. This situation arise the question of the potential nitrogen reduction and its impacts on the production and net income, if all farm households would follow the recommendations and harvest the expected yield. First, an approach, which consist of an estimated production function based on the concept of Kℛᴀʏʟ (1993) estimates the potential of nitrogen reduction and impact on production, net income, and nitrogen balance in wheat. Second, the nitrogen input recommendations of Zℋℰℕ et al. (2005) are used to estimate the reduction of nitrogen overuse and the impacts on production, net income, and nitrogen balance in wheat, maize, and cotton.

Beside the potential of nitrogen overuse reduction, the potential income improvement of farm households is under focus of this research approach. As described in chapter 6.1.2 (page 68) already, off-farm activities and the cultivation of cash crops are the major income sources to achieve an above average income. The family structure such as education level plays a role on the probability of off-farm activities (chapter 6.1, page 65). It might be possible to simulate education programmes and its impact on the share of farm households with off-farm activities and finally its impact on income of rural household, but due to the focus on cultivation of the survey, the results would be neither representative nor replicable. The survey did not investigate reasons for a certain cropping pattern. Hence, why do some farmhouse households cultivate the pure wheat and maize cropping pattern, while the majority cultivates a cash crop such as cotton or peanuts cannot be answered. For this reason, it is not possible to estimate the income effect of increased share of farm households cultivating cash crops, but it is possible to estimate the income effect of an improved cultivation system due to a modified nitrogen input.

The production function estimation bases on the concept of Kℛᴀʏʟ (1993) and the nitrogen input recommendations of Zℋℰℕ et al. (2005) as described in chapter 6.3.4 (page 84). This enables to calculate the corresponding gross margin, nitrogen balance and nitrogen efficiency. These data can be used as a reference system to evaluate the survey results and estimate the potential of nitrogen input reduction and its effects on the nitrogen balance and the income level.

Zℋℰℕ et al. (2005) recommended an application rate of 220 kg of nitrogen, but it would be too ambitious that all farm household follow exactly this recommendation.

For this reason, the first scenario takes a range from minus 50 to plus 50 per cent of the recommended application rate into account, hence from 110 to 330 kg of nitrogen.[22] However, a second scenario assumes that all farm households follow the recommended nitrogen application rate of 220 kg of nitrogen. The production function based on the concept of KRAYL (1993) is used to calculate the corresponding wheat yield, gross margin, nitrogen balance and nitrogen use efficiency. The calculations base on the assumptions presented in Table 94.

Table 94   Average nitrogen price, crop price and other variable costs excluding fertilizer costs of wheat, maize, and cotton

	wheat	maize	cotton
average nitrogen price [¥ kg^{-1}]	5.77	4.61	8.41
average crop price [¥ t^{-1}]	1 420	1 100	4 430
average other variable costs (excluding fertilizer costs) [¥ ha^{-1}]	2 250	1 450	2 360

The concept of KRAYL (1993) is limited to the nitrogen input at maximum yield. For this reason a stable maximum yield of 5.40 tons per ha is assumed at nitrogen input levels between 272 kg and 330 kg of nitrogen per ha. Table 95 presents the means of the calculated wheat yield, gross margin, nitrogen balance, and nitrogen use efficiency (yield nitrogen input ratio) for the described nitrogen input range. For comparison, the average survey data including the median (q-50) and the upper (q-25) and lower quartile (q-75) are presented.

Table 95   Average yield, gross margin, nitrogen balance, and nitrogen use efficiency in wheat cultivation considering the production function based on the concept of Krayl as well as the survey results

	estimates of the Krayl based production function	survey results
	mean [-50%; +50%]	mean [q-25; q-50; q-75]
nitrogen input [kg ha^{-1}]	220 [110; 330]	360 [230; 340; 440]
wheat yield [t ha^{-1}]	5.30 [4.38; 5.40]	5.30 [4.69; 5.63; 6.43]
gross margin [¥ ha^{-1}]	4 007 [3 330; 3 514]	4 010 [2 280; 3 830; 5 440]
nitrogen balance [kg ha^{-1}]	71 [-11; 178]	200 [70; 175; 300]
nitrogen use efficiency [kg kg^{-1}]	24 [40; 16]	22 [11; 17; 25]

The overall nitrogen input, wheat production, net income from farming and nitrogen surplus are discussed instead of the indicator per ha (Table 96). In this way, the overall effect can be used for discussion. In the first step, the overall nitrogen input, yield, gross margin and nitrogen balance of all surveyed 322 wheat farmers is compared with the first scenario of the described range of recommended nitrogen input. The overall nitrogen input is reduced by 37 per cent compared to the survey results, due to the reduced average nitrogen input. As a result of the reduced nitrogen input, the nitrogen surplus show a reduction by nearly two thirds. This reduction from

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[22] An equal distribution on the total wheat cultivation area of 122.7 ha is assumed, hence on the same share of cultivation area are e.g. 130 kg or 300 kg of nitrogen applied per ha

23.6 to 9.3 tons of nitrogen underlines the problem of wasted nitrogen and its potential of nitrogen reduction instruments. The net income and the wheat production show marginal lower results in case of the nitrogen input recommendation. Hence, the first scenario would fulfil the overall hypothesis of nitrogen overuse reduction without reduction in food production and income.

Table 96   Differences in overall nitrogen input, wheat production, net income, and overall nitrogen balance in wheat cultivation between the survey results and the estimates based on the recommended range of nitrogen input

	overall nitrogen input	wheat production	net income	overall nitrogen balance
survey results of all 322 wheat farms	42.7 t	680 t	495 500 ¥	23.6 t
recommended range of nitrogen input 110 - 330 kg ha^{-1}	27.0 t	630 t	464 800 ¥	9.3 t
change compared to surveyed farms	-37%	-7%	-6%	-61%

In case of the second scenario, the total nitrogen input, wheat production, net income and nitrogen balance is calculated for the case that all farm households or the whole wheat cultivation area of 122.7 ha would follow the recommendation ZHEN et al. (2005). The results of the second scenario are quite similar to that of the first scenario. In addition, the nitrogen recommendations of ZHEN et al. (2005) for maize and cotton are considered to estimate the corresponding figures for these crops and estimate an aggregated impact (Table 97).

Table 97   Differences in overall nitrogen input, crop production, net income, and overall nitrogen balance of in wheat, maize, and cotton cultivation between the survey results and the estimates based on the recommended nitrogen input

	overall nitrogen input	crop production	net income	overall nitrogen balance
initial values of all 322 wheat farms (122.7 ha)	42.7 t	680 t	495 500 ¥	23.6 t
scenario recommendations (220 kg N, 5.4 t)	27.0 t	650 t	491 900 ¥	8.7 t
change compared to surveyed farms	-37%	-4%	-1%	-63%
initial values of all 274 maize farms (68.1 ha)	14.6 t	430 t	320 500 ¥	4.5 t
scenario recommendations (180 kg N, 6.0 t)	12.3 t	410 t	294 300 ¥	2.0 t
change compared to surveyed farms	-16%	-5%	-8%	-55%
initial values of all 183 cotton farms (45.3 ha)	7.8 t	120 t	391 800 ¥	2.3 t
scenario recommendations (200 kg, 3.0 t)	9.1 t	135 t	419 000 ¥	2.5 t
change compared to surveyed farms	16%	13%	7%	11%
overall initial wheat, maize, cotton	65.1 t	n/a	1 207 800 ¥	33.1 t
scenario recommendations	48.4 t	n/a	1 205 200 ¥	13.2 t
change compared to surveyed farms	-26%	n/a	0%	-60%

As described, the surveyed nitrogen application rates in cotton and yield levels are lower than that of the recommendations, therefore following the recommendations would results in higher net income and higher nitrogen surplus. The aggregated figures indicates no changes in total net income, but a reduction of nitrogen input by 26 per cent and a 60 per cent reduction in nitrogen surplus.

These approaches show an impressive effect on nitrogen surplus reduction, but it arise the question of applicability. First, is it possible to involve all farm households? Second, is it possible to convince farm households to follow the recommendations, which are in the most cases much lower than the present application rates? Third, why should be farm households contributed to modify their cultivation system, which already apply nitrogen at adequate level?

Figure 17 shows overall nitrogen surplus in wheat and wheat cultivation area in relation to nitrogen application rate in wheat, divided into 10 groups. Farm households applying more than 400 kg of nitrogen per ha in wheat cultivate on 27 per cent of the total wheat cultivation area, but originate 59 per cent of the total nitrogen surplus in wheat. Further, those farm households which apply more than 600 kg of nitrogen, cultivate on 9 per cent of the area, but cause 30 per cent of the nitrogen balance. The aggregated data for all crops shows similar results, farm households applying more than 300 kg of nitrogen per ha cultivate on 26 per cent of the total farmland, but originate 56 per cent of the total nitrogen surplus (Annex Figure 9).
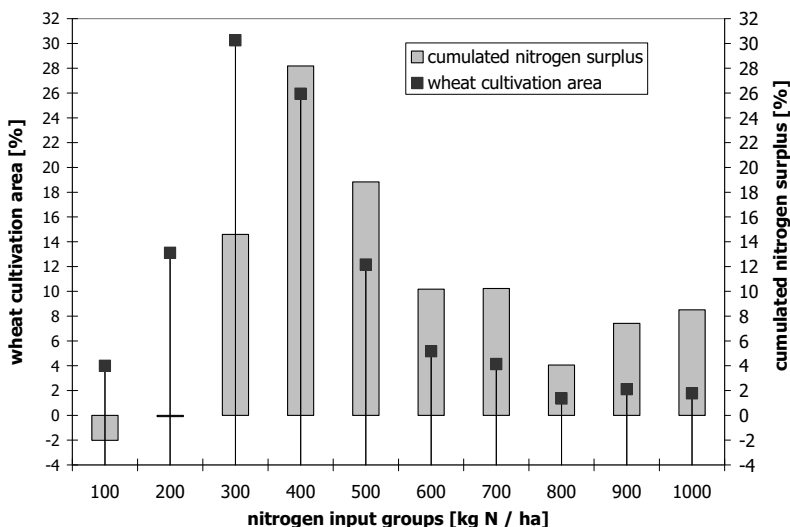
Figure 17   Overall nitrogen surplus in wheat and wheat cultivation area in relation to the nitrogen input

Farm households considered as *nitrogen balance type 3* apply nitrogen far beyond the crop demand and even beyond the economic optimum. Those farm households counted as *nitrogen balance type 2* still apply more nitrogen than required, but in

terms of nitrogen overuse, their overuse is less huge than that of *nitrogen balance type 3* farm households. However, it might be too ambitious to convert heavy nitrogen overusing farm household to adequate nitrogen using farm households which consider the precisely the nitrogen application recommendations. Therefore, the effect of converting half of *nitrogen balance type 3* farm households into *nitrogen balance type 2* farm households is estimated. In total six quadratic production functions are estimated to analyse the relationship between nitrogen input and yield in cultivation, one per nitrogen balance type and per crop, each. The estimated production functions are presented in the annex (Annex Figure 10, Annex Figure 11, Annex Figure 12). Each production function considers only nitrogen input and yield data from its corresponding farm households. The quartiles of the nitrogen input for example in wheat of *nitrogen balance type 3* farm households show an interval from 392 to 631 kg of nitrogen, which stands for the nitrogen input range of half of the farm households counted as *nitrogen balance type 3* (Table 98).

Table 98   **Estimated quadratic production function for wheat, maize, and cotton at the corresponding range of nitrogen input of the considered nitrogen balance type**

	farms [no.]	quadratic production function	range of nitrogen input [kg N ha^{-1}]	r²
wheat: N bal. type 3	103	$y = 0.0180 * N - 1.22 \ 10^{-5} * N^2 - 0.69$	392-631	0.32
wheat: N bal. type 2	141	$y = 0.0067 * N - 1.96 \ 10^{-6} * N^2 + 3.72$	268-374	0.15
maize: N bal. type 3	83	$y = 0.0090 * N - 4.25 \ 10^{-6} * N^2 + 3.88$	157-345	0.27
maize: N bal. type 2	124	$y = 0.0063 * N - 3.39 \ 10^{-6} * N^2 + 5.07$	128-255	0.07
cotton: N bal. type 3	54	$y = 0.0047 * N - 2.89 \ 10^{-6} * N^2 + 1.77$	103-323	0.20
cotton: N bal. type 2	82	$y = 0.0016 * N - 1.83 \ 10^{-6} * N^2 + 2.56$	68-245	0.02

Table 99 presents the effects for wheat of this modification of 52 farm households, which stands for half of the 103 farm households belonging to *nitrogen balance type 3*. These farm households are responsible for 25 per cent of the nitrogen consumption in wheat and one third of the nitrogen surplus in wheat, while their wheat production share is 16 per cent. The modification reduces the overall nitrogen surplus in wheat by 18.2 per cent, while the total wheat production even increases by 1.7 per cent.

Table 99   **Estimated impacts of a modification of 52 farm households (20.7 ha) from nitrogen balance type 3 to nitrogen balance type 2 in wheat**

	nitrogen input	wheat production	net income	nitrogen surplus
all wheat farms (survey results)	42.7 t	680 t	495 500 ¥	23.6 t
52 farms of N bal. type 3 (simulated data)	10.6 t	106 t	43 130 ¥	7.6 t
share on all wheat farms	25%	16%	9%	32%
52 farm of N bal. type 2 (simulated data)	6.6 t	117 t	68 530 ¥	3.3 t
modification (total value)	-3.9 t	11 t	25 400 ¥	-4.3 t
modification (per cent of all farms)	-9%	2%	5%	-18%

The number of modified farm households in maize cultivation amounts to 42 farm households, while in cotton it is 27 farm households. In maize, the impact of this simulated modification is marginally lower than in wheat, the reduction of nitrogen surplus amounts to 14 per cent (Table 100).

Table 100   Estimated impacts of a modification of 42 farm households (9.5 ha) from nitrogen balance type 3 to nitrogen balance type 2 in maize

	nitrogen input	maize production	net income	nitrogen surplus
all maize farms (survey)	14.57 t	430 t	320 000 ¥	4.53 t
42 farms of N bal. type 3 (simulated data)	2.39 t	56 t	36 380 ¥	1.09 t
share on all maize farms	16%	13%	11%	24%
42 farms of N bal. type 2 (simulated data)	1.82 t	58 t	42 100 ¥	0.45 t
modification (total value)	-0.57 t	2 t	5 720 ¥	-0.64 t
modification (per cent of all farms)	-4%	1%	2%	-14%

The nitrogen surplus reduction in cotton is similar to that in wheat. At all farm crops, the net income show marginal increase.

Table 101   Estimated impacts of a modification of 27 farm households (6.7 ha) from nitrogen balance type 3 to nitrogen balance type 2 in cotton

	nitrogen input	cotton production	net income	nitrogen surplus
all cotton farms (survey)	7.79 t	120 t	392 000 ¥	2.29 t
27 farms of N bal. type 3 (simulated data)	1.43 t	17 t	49 400 ¥	0.66 t
share on all cotton farms	18%	14%	13%	29%
27 farms of N bal. type 2 (simulated data)	1.05 t	19 t	57 400 ¥	0.23 t
modification (total value)	-0.38 t	1 t	8 000 ¥	-0.43 t
modification (per cent of all farms)	-5%	1%	2%	-19%

The overall reduced nitrogen input amounts to 4.85 tons or a reduction by 8 per cent, while the net income increases by 39 120 ¥ or 3 per cent. A modification of half of the farm households belonging to *nitrogen balance type 3* into *nitrogen balance type 2* would reduce the nitrogen surplus by 5.37 tons per ha or 18 per cent.

8.2   Instrument Identification and Simulated Scenarios

8.2.1   Identification of Instruments for a Nitrogen Surplus Reduction

The analyses of nitrogen input (chapter 6.2.1) and of nitrogen balance type (chapter 7.2.2) indicate several influencing factors. Most of these factors are unsuitable for modification, such as long term wheat yield or size of family farmland. The factor nitrogen price plays a major role at the nitrogen input models (Table 45, page 72) as well as at the nitrogen balance type models (Table 86, page 111). The nitrogen price is the ratio between the fertilizer costs and the nitrogen input and it shows a broad variation between the surveyed farm households (chapter 5.4). A modification of the nitrogen price seems to be a suitable instrument to reduce nitrogen surplus. Therefore, a modified nitrogen price is simulated and its impact on the nitrogen balance and the net income of farm households is estimated. The analysis of yield (chapter 6.3.5) does not provide corresponding factors as applicable instruments to increase yield in order to improve the nitrogen balance.

The nitrogen balance type simulation scenario estimates the probability modification of *nitrogen balance type 3* and *nitrogen balance type 2*. This simulation scenario estimates the shares of farm households, which theoretically convert form *nitrogen balance type 3* to *nitrogen balance type 2* as well as the share of initial *nitrogen balance type 2* farm households converting to *nitrogen balance type 1*. The differences in nitrogen balance and gross margin between the nitrogen balance types and the amount of theoretically shifting farm households are considered to estimate the impact of this instrument on the nitrogen balance and on net income from farming. The estimation of the farming net income bases on the average gross margin and the cultivation area of the considered crops.

The multiple regression model of gross margin (Table 59, page 90) considers all farm households and indicates a negative impact of the nitrogen price on the gross margin, while the average gross margins of the considered nitrogen balance types promise an opposing effect. Therefore, this multiple regression model is included in order to present an impact on the net income at the bottom line, instead of an overestimated positive impact on the net income. The impact on the net income is estimated from a combination of both model approaches.

A percental increase of the nitrogen price by 10 per cent is simulated. In addition, target scenarios are simulated in order to estimate the requirements for a noticeable nitrogen surplus reduction such as a reduction by 50 per cent. The applicability of all applied instruments and other potential instruments to reduce nitrogen surplus will be discussed in chapter 8.3.

8.2.2   Simulated Impact of Nitrogen Price Scenarios on Gross Margin

The calculated gross margin can be described as a multiple linear regression model of the variables yield, nitrogen input and nitrogen price. A constant crop price is taken into account due to the high share of own consumption. The estimated coefficients of the regression models are taken from table 59 (page 90) and the

equations are presented in the annex (Annex Equation 1, Annex Equation 2, Annex Equation 3). The multiple linear regression models are used to simulate the individual gross margin for each farmer. The average simulated gross margin differs slightly from the average surveyed gross margin. The net income is calculated by the simulated individual gross margin and the individual cultivation area of all surveyed farm households (Table 102).

Table 102   Simulation of nitrogen price modification and its impact on gross margin and net income of wheat, maize, and cotton

nitrogen price increase	initial	+10%
simulated wheat gross margin [¥ ha^{-1}]	4 006	3 887
simulated wheat net income[1] [¥]	470 138	455 887
wheat net income modification [%]		-3.0
simulated maize gross margin [¥ ha^{-1}]	4 717	4 641
simulated maize net income[1] [¥]	316 745	311 479
maize net income modification [%]		-1.7
simulated cotton gross margin [¥ ha^{-1}]	9 132	9 046
simulated cotton net income[1] [¥]	388 179	384 205
cotton net income modification [%]		-1.0
net income of wheat, maize, and cotton [¥]	1 175 062	1 151 572
net income modification [¥]		-23 490
net income modification [%]		-2.0

Note   [1] the simulated net income is the simulated individual gross margin multiplied by the individual cultivation area and does not consider own consumption

As described already in chapter 6.4.2, the nitrogen price shows a weak negative impact on the calculated gross margin. Therefore, the simulated nitrogen price scenarios indicate only relatively low reductions in income. A simulated nitrogen price increase by 10 per cent would result in a reduction by 3.0 per cent of net income in wheat, while in maize and cotton the net income would decrease by 1.7 per cent and 1.0 per cent. The modification of the overall net income of wheat, maize and cotton show a reduction by 2.0 per cent.[23]

8.2.3   Simulated Scenario Considering the Nitrogen Balance Types

The estimation of the impact of a percental increased nitrogen price on the nitrogen balance bases on a modification of the probability of group membership on a considered nitrogen balance type. A logistic regression analysis model estimates in chapter 7.2.2 the odds ratio of the nitrogen balance type's group membership. The logit probability of each farm household can be calculated into an individual probability. Equation 16 shows the logistic regression model (Table 86, page 111), which estimates the logit probability of *nitrogen balance type 3*.

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[23]   The impact on peanuts and other crops is not considered due to insufficient data basis

$$\ln\left(\frac{p(y=1)}{p(y=0)}\right) = 0.359V_{001} - 0.451V_{005} + 0.011V_{016} - 0.887V_{020} - 0.006V_{032}$$

$$(\text{cont.}) \ -0.527V_{038} + 0.787V_{042} - 0.380V_{048} - 0.286V_{076} + 0.006V_{067}$$

y = nitrogen balance type 3 group membership
V_{001} = covariate family size [pers.]
V_{005} = covariate family work force [LU]
V_{016} = covariate relative farmland [%]
V_{020} = covariate rent-in farmland [1,0]
V_{032} = covariate relative income [%]
V_{038} = covariate main income farming [1,0]
V_{042} = covariate manure usage [1,0]
V_{048} = covariate nitrogen price all farm crops [¥ kg^{-1}]
V_{076} = covariate village average wheat yield [t ha^{-1}]
V_{067} = covariate village average nitrogen input all farm crops [kg ha^{-1}]

Equation 16   Logit of probability of nitrogen balance type 3 membership

The aggregation of *nitrogen balance type 2* and *nitrogen balance type 1* are considered as reference option (dependent variable encoding: 0). The initial share of farm households of *nitrogen balance type 3* is 103 farm households or 32.0 per cent of all classified farm households (Table 103).

Table 103   Dependent variables of logistic regression models for the analysis of nitrogen balance type membership

dependent variable encoding: 1	n	dependent variable encoding: 0	n
nitrogen balance type 3	103	nitrogen balance type 1 & 2	219
nitrogen balance type 2	141	nitrogen balance type 1	78

Equation 17 shows the logistic regression model (Table 86, page 111), which estimates the logit probability of *nitrogen balance type 2*. By contrast to the previous model, this model excludes *nitrogen balance type 3* and considers *nitrogen balance type 1* as reference option (dependent variable encoding: 0). The share of *nitrogen balance type 2* farm households is 141 farm households or 64.4 per cent of the aggregation of *nitrogen balance type 2* and *nitrogen balance type 3* (Table 103).

$$\ln\left(\frac{p(y=1)}{p(y=0)}\right) = 1.342V_{014} + 0.756V_{042} - 0.152V_{048} - 0.198V_{076} + 0.905V_{067}$$

y = nitrogen balance type 2 group membership
V_{014} = covariate farmland [ha]
V_{042} = covariate manure usage [1,0]
V_{048} = covariate nitrogen price all farm crops [¥ kg^{-1}]
V_{076} = covariate village average wheat yield [t ha^{-1}]
V_{067} = covariate village average nitrogen input all farm crops [kg ha^{-1}]

Equation 17   Logit of probability of nitrogen balance type 2 membership

A modification of one covariate, in this case nitrogen price will result in a changed individual probability of each farm household. This average probability of all farm households can be regarded as share of farm households belonging to this nitrogen balance type. The difference between the initial probability the modified probability is

considered as the share of farm households, which convert theoretically from this nitrogen balance type to another nitrogen balance type. The impact assessment on net income and nitrogen surplus base on such a theoretical shift of farm households from *nitrogen balance type 3* to *nitrogen balance type 2* as well as from *nitrogen balance type 2* to *nitrogen balance type 1.* This are the differences in gross margin and nitrogen surplus between the nitrogen balance types into account (Table 104).

Table 104   Difference in average nitrogen surplus and gross margin between the considered nitrogen balance types

	all farm crops	wheat	maize	cotton
N type 3 gross margin [¥ ha^{-1}]	4 280	2 360	4 210	7 850
N type 2 gross margin [¥ ha^{-1}]	5 510	4 060	4 590	9 040
difference gross margin [¥ ha^{-1}]	1 230	1 700	380	1 190
N type 3 nitrogen balance [kg ha^{-1}]	235	402	123	110
N type 2 nitrogen balance [kg ha^{-1}]	95	172	65	47
difference nitrogen surplus [kg ha^{-1}]	-140	-230	-58	-63
N type 2 gross margin [¥ ha^{-1}]	5 510	4 060	4 590	9 040
N type 1 gross margin [¥ ha^{-1}]	6 520	6 080	5 360	10 620
difference gross margin [¥ ha^{-1}]	1 010	2 020	770	1 580
N type 2 nitrogen balance [kg ha^{-1}]	95	172	65	47
N type 1 nitrogen balance [kg ha^{-1}]	-15	-14	3	-40
difference nitrogen surplus [kg ha^{-1}]	-110	-186	-62	-87

Table 105 presents the modified probability of *nitrogen balance 3* and of *nitrogen balance 2* as a result of the use of the nitrogen price modification instruments. In case of the instrument "10 per cent increase of the nitrogen price" the average *nitrogen balance type 3* probability share of all farm households decreases from 32.7 to 29.4 per cent. Hence, the share of *nitrogen balance type 3* is reduced by 3.3 percentage points, while the share of *nitrogen balance type 2* farm households is increased by that share. Further, the average probability of *nitrogen type 2* group membership of the considered farm households (*nitrogen type 1* and *nitrogen type 2*) decreases from 62.7 to 60.8 per cent.

Table 105   Estimated impact of nitrogen price modification scenarios on nitrogen balance of all farm crops

nitrogen price increase	initial	+10%
probability of nitrogen balance type 3	32.7%	29.4%
overall nitrogen surplus [kg]		-1 231 (-3.7%)
probability of nitrogen balance type 2	62.7%	60.8%
overall nitrogen surplus [kg]		-379 (-1.1%)
total overall nitrogen surplus [kg]	32 997	-1 610 (-4.9%)

The estimated overall nitrogen surplus of all surveyed farm households amounts to 33 tons of nitrogen, which is on average 115 kg of nitrogen per ha. The described instrument reduces the overall nitrogen surplus by 1.231 kg in case of the *nitrogen*

balance type 3 model and by 379 kg at the *nitrogen balance type 2* model. In total, the simulated nitrogen surplus reduction amounts to 1.6 tons of nitrogen or 4.9 per cent. This result clearly indicates that the main reduction of nitrogen surplus, 76 per cent of the overall nitrogen surplus reduction, originates mainly from a reduction of the relative small share (one third of all farm households) of farm households of *nitrogen balance type 3*. The estimated impact on net income considers the results of this nitrogen balance type models as well as the gross margin model of chapter 8.2.2 (Table 102, page 128). The combined impact of both approaches indicates only a marginal decrease in net income on all farm crops.[24] The instrument "10 per cent increase of the nitrogen price" results in a net income reduction on all farm crops of 0.6 per cent. In details, the nitrogen balance type models simulate a net income increase by 0.9 per cent, while the multiple regression model simulates a net income from farming reduction by 1.6 per cent. These results indicate that a modified nitrogen price does not have a huge impact on the gross margin, even if only one model type is considered (Table 106).

Table 106   Estimated impact of nitrogen price modification scenarios on net income of all farm crops

nitrogen price increase	initial	+10%
probability of nitrogen balance type 3	32.7%	29.4%
net income [¥]		10 815 (0.7%)
probability of nitrogen balance type 2	62.7%	60.8%
net income [¥]		3 484 (0.2%)
net income (GM regression model) [¥]		-23 491 (-1.6%)
total net income [¥]	1 487 000	-9 192 (-0.6%)

In the next step, the impact of these instruments on the wheat, maize, and cotton cultivation is estimated. In case of wheat, the results are quite close to that of for all farm crops. The "10 per cent nitrogen price increase" instrument results in a nitrogen surplus reduction by 5.1 per cent and the impact on net income from farming is a reduction by 0.7 per cent (Table 107).

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[24]   The multiple regression model estimates the impact on the cumulated net income for wheat, maize and cotton. The nitrogen balance type models consider the net income for all farm crops, hence, including peanuts.

Table 107   Estimated impact of nitrogen price modification scenarios on nitrogen surplus and on net income in wheat

nitrogen price increase	initial	+10%
overall nitrogen surplus (N type 3 model) [kg]		-912 (-3.9%)
overall nitrogen surplus (N type 2 model) [kg]		-286 (-1.2%)
total overall nitrogen surplus [kg]	23 566	-1 198 (-5.1%)
net income (N type 3 model) [¥]		6 738 (1.4%)
net income (N type 3 model) [¥]		3 104 (0.6%)
net income (GM regression model) [¥]		-14 251 (-2.9%)
net income (combined model) [¥]	495 500	-4 408 (-0.9%)

The simulated nitrogen price scenario shows a marginal higher impact on net income from farming and a marginal lower overall surplus in maize than in wheat. An increased nitrogen price of 10 per cent results in a reduced nitrogen surplus in maize of 4.1 per cent and a reduction of the net income from farming by 1.2 per cent (Table 108).

Table 108   Estimated impact of nitrogen price modification scenarios on nitrogen surplus and on net income in maize

nitrogen price increase	initial	+10%
overall nitrogen surplus (N type 3 model) [kg]		-127 (-2.8%)
overall nitrogen surplus (N type 2 model) [kg]		-57 (-1.3%)
total overall nitrogen surplus [kg]	4 516	-184 (-4.1%)
net income (N type 3 model) [¥]		833 (0.3%)
net income (N type 3 model) [¥]		709 (0.2%)
net income (GM regression model) [¥]		-5 266 (-1.7%)
net income (combined model) [¥]	319 100	-3 723 (-1.2%)

The simulation scenario shows in cotton the highest impact on reduced nitrogen surplus and the lowest impact on net income. The "10 per cent nitrogen price increase instrument" reduces the nitrogen surplus by 6.6 per cent, while the net income from farming in cotton shows a marginal impact of only 0.4 per cent reduction (Table 109).

Table 109   Estimated impact of nitrogen price modification scenarios on nitrogen surplus and on net income in cotton

nitrogen price increase	initial	+10%
overall nitrogen surplus (N type 3 model) [kg]		-86 (-4.3%)
overall nitrogen surplus (N type 2 model) [kg]		-48 (-2.4%)
total overall nitrogen surplus [kg]	2 028	-134 (-6.6%)
net income (N type 3 model) [¥]		1 629 (0.4%)
net income (N type 3 model) [¥]		868 (0.2%)
net income (GM regression model) [¥]		-3 974 (-1.1%)
net income (combined model) [¥]	366 300	-1.478 (-0.4%)

The target scenario simulations estimate the required nitrogen price modification for a noticeable nitrogen surplus reduction. The nitrogen price must increase by 159 per cent in order to achieve a nitrogen surplus reduction by 50 per cent for all farm crops. This simulation provides for this case a net income from farming reduction of 15 per cent, which combines the net income increase by 10 per cent of the nitrogen type model and the 25 per cent reduction of the multiple linear retrogression model (Table 110).

Table 110   Simulated nitrogen price in order to enable a nitrogen surplus reduction by 50 per cent

	all farm crops	wheat	maize	cotton
nitrogen price increase	+159%	+147%	+204%	+90%
net income modification (N type models)	9.9%	20.6%	6.6%	5.1%
net income (multi. linear reg. models)	-25.2%	-42.3%	-33.6%	-9.7%
total net income modification	-15.3%	-21.8%	-27.0%	-4.6%

The major nitrogen consumer and origin of nitrogen surplus is wheat, but a nitrogen surplus reduction in cotton requires less than doubling of the initial nitrogen price. There is only a weak impact on the net income from farming in cotton.

8.3   Discussion of the Simulated Scenarios

The analysis of influencing factors towards nitrogen input and towards nitrogen balance provides only the variable nitrogen price as an applicable instrument to simulate scenarios on the reduction of nitrogen input and finally nitrogen surplus. Other factors such as education, additional income from off-farm activities, or other farm household related characteristics do not show a sufficient clear and unique impact on nitrogen input. Beside the factor nitrogen input, a modification of the nitrogen balance can be achieved by the factor yield, which indicates the nitrogen uptake. Temporary off-farm activities increase the probability of an above average yield, but a modification of off-farm activities of farm households as an instrument to increase yield might be too ambitious. This analysis provides no applicable instruments to increase crop yield. Summarized, the key variable on the nitrogen balance is nitrogen price, which stands for the ratio between fertilizer costs and nitrogen input. For this reasons, the variable nitrogen price is taken as the only instrument to simulate scenarios on reduction of nitrogen surplus.

The simulation scenarios base on a hypothetical simulated shift of a certain share of farm households from one to another cultivation system. In this case, about one third of farm household belongs to *nitrogen balance type 3* and a conversion of a part of them into farm households of *nitrogen balance type 2*. In addition, a theoretically shift of initially *nitrogen balance type 2* farm households into *nitrogen balance type 1* farm households is simulated.

A nitrogen price increase by 10 per cent results in a nitrogen surplus reduction by 4.9 per cent. A nitrogen surplus reduction by 50 per cent would require a nitrogen price increase by more than 150 per cent. Table 111 presents the simulated impact on nitrogen balance and agricultural income for Germany of ZEDDIES et. al (1997), MOELLER et al. (2003), and SCHAEFER (2006) in comparison to the results for the NCP.

Table 111   Simulated impact on nitrogen surplus and agricultural income for Germany in comparison to the results for the NCP

author, model	scenario location	nitrogen price increase	nitrogen surplus	agricultural income
own calculations	NCP	100%	-36.8%	-8.5%
MOELLER et al. (2003), RAUMIS	Germany	100%	-20.8%	-2.0%
ZEDDIES et al. (1997), LP	Germany	100%	-29.4%	-3.2%
own calculations	NCP	150%	-47.3%	-14.3%
SCHAEFER (2006), EFEM/DNDC	Germany	150%	-39.6%	n/a
own calculations	NCP	200%	-54.7%	-20.7%
ZEDDIES et. al (1997), LP	Germany	200%	-44.0%	-5.3%
own calculations	NCP	300%	-64.0%	-34.7%
ZEDDIES et. al (1997), LP	Germany	300%	-51.0%	-6.3%

MOELLER et al. (2003) uses the Regional Agricultural and Environmental Information System (RAUMIS) and simulates the impact of a 100 per cent on mineral fertilizer. This nitrogen tax reduces the average German nitrogen balance from 77 kg nitrogen per ha

of agricultural area to 61 kg or by 20.8 per cent. The impact on the agricultural income shows a reduction by 2 per cent. Zeddies et. al (1997) analyses a hypothetical nitrogen increase by 100 per cent, 200 per cent, and 300 per cent. These estimations base on a production function analysis and linear programming models. In case of a 100 per cent nitrogen price increase this approach provides a stronger impact (nitrogen surplus reduction by 29.4 per cent and agricultural income reduction by 3.2 per cent) than that of the model of Moeller et al. (2003). The impact assessment of Schaefer (2006) bases on the Economic Farm Emission Model (EFEM) and the Denitrification Decomposition model (DNDC) and indicates that a nitrogen price increase by 150 per cent in Germany reduces the nitrogen surplus by 39.6 per cent. This model does not provide an impact assessment on the agricultural income. In comparison to the simulation results for Germany the simulation for the NCP provides a higher reduction in nitrogen surplus and a much stronger impact on the agricultural income. The overall hypothesis of this research project considers a nitrogen surplus reduction without reduction on the net income of farm households. The simulation for the NCP identifies a weak impact of moderate nitrogen price modifications on the gross margin, but sufficient nitrogen surplus reduction. Summarised, the simulation results indicate that the initial demand of nitrogen surplus reduction without losses in net income can be regarded as fulfilled, but there are limitations. Huge nitrogen surplus reductions such as minus 50 per cent require high nitrogen price increase by 159 per cent and lead to a net income reduction by 15 per cent.

As described in chapter 8.1, the instrument independent estimation of the potential of nitrogen reduction show relative high reduction potential, even if only one third of farm households (*nitrogen balance type 3*) are considered. The simulation of the instrument "10 per cent increase of nitrogen price" shows that the lion's share of the nitrogen surplus reduction originates from that one third of farm households. Hence, a target group specific instrument promises a high nitrogen surplus reduction potential.

The nitrogen price clearly distinguishes farm households who consider the crop demand and farm households who indicate a heavy surplus at the nitrogen balance. This situation might lead to the presumption that increasing nitrogen price reduces the nitrogen surplus as done by the simulated scenarios. As mentioned already, the nitrogen price is a result of the composition of the applied fertilizer, which differs in price and nitrogen content. Therefore, several instruments can obtain a modification of the nitrogen price. Firstly, the price of the fertilizer (at constant nitrogen content) can be increased by taxation (chapter 9.2.1). Secondly, a modified composition of the applied fertilizer can lead to a higher nitrogen price by the reduction of the share of cheap nitrogen fertilizer and a shift to compound fertilizer, which have a higher fertilizer price to nitrogen content. The selection of fertilizer and the application rate of each fertilizer can be regarded as an agricultural technology or an improvement of the present technology (chapter 9.2.2).

9 Discussion and Outlook

9.1 Reasons for Nitrogen Overuse in the North China Plain

First, the overall problem of unsustainable nitrogen use is not the amount of applied nitrogen. The problem is the amount of nitrogen that is not taken up by the plant, which is the result of an imbalanced ratio between nitrogen demand and nitrogen supply. The core problem is nitrogen surplus of the nitrogen balance and its impact on the environment as well as the income of farm households.

This leads automatically to the question, what are the major reasons for the inefficient nitrogen use in China. Answering this question requires a broad interdisciplinary analysis and it cannot be reduced to the cultivation system. The analysis of reasons and solutions of nitrogen overuse should not be limited to failures in the cultivation system. The discussion of nitrogen overuse and its ecological and economic impacts should be done in the interdisciplinary context. For this reason, this discussion includes the farm household structure and the income generation, beside the cultivation system.

As described, farming in the North China Plain (NCP) is characterised by nitrogen overuse. ZHEN et al. (2005) pointed out that the annual fertilizer rates in the wheat and maize cultivation system were much higher than the rates recommended by the local extension service. On the other hand, there might be a lack of transfer of these recommendations in nitrogen application rates to the farm households. Further, JU et al. (2006) stated that fertilizer inputs within each cropping system were very variable among individual fields, reflecting the lack of formal fertilizer recommendations system and weakness of the local extension service. There is a poor development of rational fertilizer recommendations, which leads to the result that farm households usually apply large amount of nitrogen fertilizer (JU, X., C.L. KOU et al. 2006). This situation arises several open questions for further research about the knowledge transfer from the agricultural extension service to the farm household as decision unit.

The overall question is, why do farm households of *nitrogen balance type 3* exist at all. These farm households show a huge nitrogen overuse resulting in heavy nitrogen surplus, but their expenditure for fertilizer is not compensated by high levels of gross margin. The gross margins of these farm households are even lower than that of the majority of farm households. Their nitrogen application is beyond the ecological as well as economical optimum. Why do one third of the survey farm households show these characteristics: low income from farming, but high levels of nitrogen input and heavy nitrogen surplus at the nitrogen balance?

Similar to the results of JU et al. (2006) this survey found no significant correlations between yield and nitrogen application. For that reason, the concept of KRAYL (1993) is considered to estimate an applicable production function. This concept base on a location independent production function, which is converted into a location specific production function by the consideration of a location specific optimum nitrogen input and the corresponding yield. The recommendations of ZHEN et al. (2005) are considered for the NCP. The following optimum analysis of nitrogen input indicates that the present economic optimum of nitrogen input is higher than the

recommendations of e.g. ZHEN et al. (2005) for the NCP. However, this might be not the explanation for the low share of farm households, who follow the recommendations as reported by ZHEN et al. (2005). This result leads to the statement that the present nitrogen price is too low in order to support the nitrogen recommendation.

A discussion whether or not the Chinese farmers realise the environmental impact of nitrogen overuse might be to too ambitious. At the present situation, it would be not realistic to expect from a farm household in the North China Plain to consider ecological criteria at their determination of the level of nitrogen input. There is no doubt that farmers focus on their present income. This arise the first question whether or not farmers have noticed the environmental degradation including its impact on farming in terms of soil quality and availability of unpolluted water. Furthermore, do they have realised the possible impact on their future income from farming. JU et al. (2006) pointed out that lack of adapted production techniques fitting the small-scale conditions and the lack of proper knowledge is the main reason leading many farmers to unconsidered over-fertilisation of crops.

In terms of cultivation knowledge, this thesis cannot provide sufficient answers to the following questions. Do the farmers know the crop demand in nitrogen? What is their key source of information about farming and what is the standard of knowledge of farmers in the NCP about fertilizer application. Is it possible, that this standard of knowledge promotes that high application rates of fertilizer is the key to high yields? As mentioned already, there are recommendations on nitrogen application rates e.g. ZHEN et al. (2005), but at the same time JU et al. (2006) explained the high application rates by the lack of a formal fertilizer recommendation system and the weakness of the local extension service. This situation arise several questions on the impact potential of recommendations. How many farmers actually know the recommended nitrogen dosage for their cultivated crops and how many farmers are able to implement these recommendations? Furthermore, do they consider the staff of the agricultural extension service as a competent source of information? This question leads over to the next question. What is the standard of knowledge of the staff of the agricultural extension service? Further, how strong are their abilities and their motivation to transfer their knowledge to farmers? From the regional point of view, the question arises about the local consistency of the agricultural extension services. How strong is the location related impact indicated by the quality of the local agricultural service on the transfer of nitrogen input recommendations?

As mentioned already, the NCP is characterised by the wheat and maize cultivation system. Further, over-fertilisation is common in the NCP (JU, X., C.L. KOU et al. 2006). This lead to the question, whether the traditional wheat and maize cultivation system itself is the main reason for overuse of nitrogen and high levels of nitrogen surplus. The survey has shown that there is a broad variation in nitrogen application and resulting nitrogen balance of farm households, which practice this traditional cultivation system. Indeed, there are nitrogen overusing farm households, but there is a noticeable share of farm households, which are characterised by an equalised nitrogen balance and above average gross margins. However, a wrong application of nitrogen at this traditional cultivation system and not the cultivation system itself seems to be

responsible for the described high levels of nitrogen surplus. The survey results provides a broad variation between the surveyed farm households in terms of kind of cultivated crops or *cropping pattern* and amount of applied nitrogen at each crop. However, the double cropping system of winter wheat and summer maize including fertilizer application by hand and furrow irrigation can be regarded as the pure traditional farming system. Today, the majority of farm households cultivate in addition cash crops such as cotton. For this reason, the cultivation of wheat, maize and a cash crop at the mentioned fertilizer application and irrigation methods can be considered as present farming system.

In the introduction chapter, the impact of the components income generation and farm household structure on the cultivation system are discussed. As described, off-farm activities as income source plays a major role in rural China and the structure as well as the income level of off-farm income sources show a broad variation. This situation might lead to the expectation of a strong relationship between the structure of income generation and the cultivation system, but similar to the results of CHEN et al. (2006) the analysis of the results of this survey does not provide such a relationship as result. There is no clear and unique impact on the cultivation system, but there are the following tendencies. The farm households of the major cluster inside the *nitrogen balance type 3* are characterised by less farmland and low household income. Further, farm households who belongs to the one third of farm households that has less than 4 950 ¥ farm households income (*low household income*) do have the same share of high fertilizer costs than the overall share. Hence, the assumption farm households that poor farm households apply less fertilizer must be rejected. There is even the weak tendency that a considerable share of these farm households applies even more than the average nitrogen input, which is already beyond the crop demand. In another way, the probability of low income farm households to apply nitrogen farm beyond the agronomic and economic optimum is higher than that of high income farm households. Furthermore, farm household who cultivate wheat for exclusively own consumption apply nitrogen at higher application rates than farm households who sell wheat. Without doubt, farm households of *nitrogen balance type 3* spend a high share of their cash income for fertilizer. For this reason, a reduction of the fertilizer input towards a more efficient use of the crop demand would improve the net cash household income of these households.

Summarised, an adequate use of nitrogen enables an ecological sustainable and economically successful cultivation of the present farming system. This thesis cannot provide an explicit and comprehensive answer on the question, what are the core reasons for wrong use of present traditional system that leads to the described surplus at the nitrogen balance. The broad variation in nitrogen efficiency leads to the assumption that nitrogen overuse is not caused by the lack of adequate selection of cultivated crops and fertilisation technique, but there seems to be a lack of successful knowledge transfer to all farm households. Further research on the field of knowledge transfer system is required to get an answer on the question above.

9.2   Instruments to Reduce Nitrogen Overuse

The goal of the implementation of an instrument is to obtain a pre-defined target. In this case, it is the reduction of nitrogen surplus at the considered nitrogen balance. JU et al. (2004) cited FREDERIKSEN (1997) and lists four main ways to address the problem of nitrogen pollution.

- Command-and-control policy by compulsory rules and controlling nitrogen application rates on an area basis and residual inorganic nitrogen in soil.

- Economic instruments such as taxes on nitrogen fertilizer or subsidies to farmer for environmentally-sound farming practices, or indirect effects through prices of agricultural produce.

- Public information and education methods, such as training courses for farmers, support for advisory services.

- Scientific research and technological development, such as improved agricultural production techniques, which help to realise reasonable nitrogen fertilizer inputs by increasing the recovery rate by crops and reducing nitrogen fertilizer losses.

JU et al. (2004) describes that command-and-control instruments are more applicable for smaller restricted areas and not applicable in an areas such as the North China Plain. Further, upper limits as implemented in developed countries (e.g. Germany) are not directly transferable to the Chinese situation (JU, X., X. LIU et al. 2004). As indicated from the economic optimum analysis, a noticeable share of farm households applies nitrogen beyond the economic optimum. In another way, these farm households do not consider economic criteria or do not know how to consider economic criteria. This situation leads to the question, whether an economic based instrument is a suitable instrument to fit the problem of nitrogen overuse. Fertilisation recommendations can hardly become normal techniques in the fragmented Chinese farming system, because as JU et al. (2004) explained "Chinese farmers operate in small-scale enterprises and the level of specialisation is low". In addition, JU et al. (2004) stated that the main reasons leading farmers to unconsidered over-fertilisation are a lack of proper knowledge and a lack of adapted production techniques fitting the small-scale conditions in intensive crop production, which efficiently decrease environmental pollution. However, economic instruments, improved education, and new technologies are discussed as possible instruments to reduce the nitrogen surplus in China.

9.2.1   Taxation of Nitrogen

Taxation on production factors is an instrument to control the application of these production factors. The taxation on nitrogen is a widely discussed instrument to reduce the nitrogen application rates, e.g. HUANG and URI (1992), HELMING and BROUWER (1997) or ZEDDIES et al. (1997). The general aim of a nitrogen tax is the internalisation of social costs in order to shift the farm level economic optimum to the social economic optimum. In another way, the farm household is economically

forced to consider the social costs, which are originated from the application of nitrogen. The implementation of a nitrogen tax in the North China Plain arise the following questions.

As stated already, farm households in the NCP seems not consider their farm level economic optimum as criteria in their determination of the applied nitrogen. This leads to the question, how will farm households react on an economic instrument such as nitrogen tax, if these farm households do not consider economic criteria at their nitrogen application practices. For that reason, it might be challenged that they really reduce their nitrogen application rates in case of a fertilizer tax.

The theoretical model provides as result that increased nitrogen price would not lead to huge income reductions, but what will be the reaction of farm households to such an instrument in reality. For consideration, agricultural taxes have been abolished in China in 2004 in order to increase the incomes of rural households. The implementation of a tax on agricultural production factors might lead in China to institutional and practical constrains, but a discussion of this topic requires a deep social and institutional analysis, which this research work cannot provide. In addition, taxation on nitrogen fertilizer is an unspecific instrument. It affects all farm households who use nitrogen fertilizer. Hence, it includes those farm households who apply nitrogen at an adequate level as well.

Furthermore, the nitrogen price itself seems to be not the core problem, it is an indicator for a high probability of nitrogen overuse. A low nitrogen price indicates results from the composition of the applied fertilizer, which differs in the price of the pure nitrogen. In that case, there is the application of a high share of "cheap" nitrogen fertilizer. The fertilizer urea and ammonium carbonate are the key source of nitrogen and show a low price of the pure nitrogen. For this reason, a selected tax on these fertilizers might be an instrument to promote a shift to compound fertilizer. As mentioned already, a pure price increase might not lead to the goal of nitrogen surplus reduction. Summarized, the theoretical model based evaluation of the economic instrument "nitrogen price modification" might lead to a reduction of nitrogen surplus without huge net income reduction, but its practical implementation as a fertilizer tat to the farming system of the North China Plain might be connected with several obstacles. A modification of the nitrogen price show promising impact on the reduction of the nitrogen surplus, but the instrument should be not a fertilizer tax. A nitrogen price modification can be better achieved by modifications of the cultivation system modification. This cultivation system modification requires a sustainable implementation of agricultural technology.

9.2.2   Implementation of Agricultural Technology

The development of new agricultural technologies is widely discussed as a solution to increases yield and to reduce the input of production factors. Usually, a new cultivation technology can be a new cultivation technique (e.g. new irrigation technique), a new planting method (e.g. time of sowing), a new position of the cultivated crops in time or in place (e.g. rotation or intercropping), or new corps or cultivars. However, there is no clear border between a new technology and an

improvement of the initial cultivation system, but there is no doubt about the aim, which is a higher output or a reduced input of production factors. In case of nitrogen, this would be a higher nitrogen uptake or a reduced nitrogen input in order to increase the nitrogen use efficiency. The implementation of a new cultivation is connected with benefits, but a modification of the present cultivation system is not without related costs.

The estimated benefits of such a new technology must be compared to the cost of its implementation. Beyond doubt, the evaluation of such a new nitrogen related cultivation technology must include its impact on labour demand and income from farming as well as the availability of natural resources. Further, the applied new technology must fit the core problem, in this case the nitrogen surplus and its environmental and economic damage.

The implementation of a new technology come a long with the following problems, the transfer to the farm households and the utilisation by the farm households. Firstly, the transfer of a new technology to the farm households arise the following questions. Which technology transfer channels are available? How many farm households do these technology transfer channels can reach? How many farm households are willing to adapt the new technology? The partially wrong use (use of nitrogen far beyond the crop demand) of the traditional system indicates a partially failure of the present knowledge transfer system. Secondly, the adoption of a new technology by the farm households is not a process free of failures. As described, heavy nitrogen surplus is among other reasons the result of a wrong use of a cultivation system. Therefore, the probability of a wrong implementation and the potential damage or impact of the wrong application of the new technology on the environment and the farm income must be estimated.

The traditional cultivation system enables a sufficient gross margin without heavy nitrogen surplus, but the wrong use of this cultivation system results in the described nitrogen surplus. This situation leads to the question, whether the implementation of new cultivation system is really a better solution than instruments, which promotes a correct use of the traditional cultivation system. The costs and the benefits of such instruments, which focus on a correct use of the cultivation system, have to be compared with the costs and benefits of new technologies in order to enable an overall evaluation of the new technologies. Furthermore, only a minority of farm households follow the present recommended of nitrogen application rates. This arise the question, how successful a new agricultural technology can be implemented.

The analysis of the cultivation system indicates that a low nitrogen price is an indicator for the overuse of nitrogen input, which results in a nitrogen surplus at the nitrogen balance. As described already, the nitrogen price depends on the selection and the composition of the used fertilizer. In case of a low nitrogen price this selection and composition can be regarded as a "wrong" technology. A selection and composition of fertilizer which leads to a adequate nitrogen input can be regarded as an improvement of the present technology or a even the implementation of a new technology. However, such an improvement might lead as a by-product to an increased nitrogen price. Hence, the discussion about instruments to increase the

nitrogen price in order to reduce the nitrogen overuse may not be limited to pure economic instruments.

There is no doubt that a technology or an improvement of technology is useless without a working system of technology transfer. In another way, a sustainable cultivation system requires a sustainable knowledge transfer.

9.2.3   Education and Agricultural Skills of Farmers

The implementation of the instruments, which are discussed in the previous chapters, includes the farmer as decision unit. The technology-based instruments imply the adoption and correct usage by the farmers. For this reason, a discussion about the knowledge transfer, the implementation of fertilizer recommendations, and new agricultural technologies requires answers on the following questions. How many farmers are able to implement successfully the recommendations on fertilizer application rates? Do farmers can measure the pre-defined amount of nitrogen? Do they have the skills to apply uniformly this pre-defined amount of nitrogen to the field? Basic education and agricultural skills are the basis of an improvement of the present agricultural system.

Basic education and agricultural skills are required to understand and to consider agronomic as well as economic criteria. How many farmers know the approximate nitrogen input to get maximum yield? However, at the present conditions it might be very ambitious, if the following problem would be included into the discussion. The problem, whether farmers consider the maximum yield instead of the economic maximum at the determination of their fertilizer application rates requires a high level of education and agricultural skills.

Beyond doubt, the impact of an education programme goes far beyond the improvement of the present cultivation system in terms of nitrogen application. Improvements of the overall education level are an essential part of the rural development. The benefits and costs of such a instrument overlaps the target reduction of the nitrogen surplus by far. Improvements in the education level of the rural population are the basis of all improvements in the field of rural development.

The farm households in the North China Plain can be regarded as relatively unique in terms of resource allocation, but there is a broad variation in cultivation success. There are differences in location specific soil and climate conditions, but since the farm households are the major decision unit this broad variation in cultivation success might be the result of differences in individual agricultural skills. This presumption leads to the assumption that programmes to improve the agricultural skills of farm households are a promising instrument towards the reduction of inefficient nitrogen use. A further discussion about such instruments requires a detailed analysis about the present agricultural skills of farmers as well as the present knowledge transfer system. Summarised, improvements in education and agricultural skills are the basis instrument as well as are the basis for all advanced instruments.

9.3   Conclusions and Outlook

The farm survey clearly indicates that farming in the North China Plain is not homogenous. On the one hand, the analysis of the farm households at the selected survey sites shows that a high share of farm households seems not consider the crop demand as criteria at the application of fertilizer. On the other hand, farming in the North China Plain is not characterised by a general failure of the agricultural production system. There is a broad variation in efficiency. There are farm households, who cultivate successfully wheat and maize without a heavy surplus at the nitrogen balance. This thesis cannot provide a clear explanation for this situation and a clear identification of farm households who are characterised by overuse of nitrogen. This situation leads to the recommendation that target group specific instruments should be preferred instead of the unspecific instruments, but this kind of instrument requires an identification of the target group. Since the estimation of the nitrogen balance requires a detailed analysis of the cultivation system, a direct identification of such a target group is not possible. For this reason, instead of the estimated nitrogen balance easy observable criteria should be identified, which indicates a high probability that a considered farm household belongs to the target group. This approach of an easy identification of nitrogen overusing farm households failed at this research work, as described in chapter 7.3. The pre-selected variables do not provide farm household characteristics, which stands for a high probability of heavy nitrogen overuse. However, there is a tendency that especially farm households without off-farm income sources tend to apply nitrogen beyond the economic and agronomic optimum. This result might indicate that there actually is no easy observable pattern of nitrogen overusing farm households, or that the available survey data and the pre-selected variables failed to identify this group or groups of farm household. This approach as well as the cluster analysis conducted in chapter 7.2.3 indicates that there are parallel opposing effects or explanations. As described, small scale farm households without off-farm income show a high probability of high nitrogen input, but nitrogen overuse is found at high income farm households as well and there are small scale farm households without additional income from off-farm activities, which show an equalised nitrogen balance and above average gross margin. Hence, there is no unique explanation for the nitrogen application behaviour from the income structure point of view.

The simulation of a modified nitrogen price indicates that a moderate nitrogen price increase leads a sufficient nitrogen surplus reduction without huge income reduction. However, a fertilizer tax might be the major instrument to increase nitrogen price, but in this case, this instrument might not be a solution to reduce nitrogen surplus. Those farm households, who are the main origin of nitrogen surplus do not consider economic criteria at the determination of their nitrogen application level. These farm households show a gross margins, which are below average. An economic instrument such as a tax might not encourage these farmers to reduce their nitrogen application rates.

The nitrogen price represents the composition of the applied fertilizers and is a conspicuous indicator for the degree of nitrogen overuse. The composition of the used

fertilizer stands for the cultivation system of the farm households. A lack of knowledge or wrong information about the crop demand might be responsible for such a cultivation system, which is characterised by low nitrogen efficiencies and low gross margins. An improvement of such a cultivation system requires an improvement of the agricultural knowledge.

Lack of knowledge is often a major obstacle for the adequate usage of a technology, but the topic knowledge system in the agricultural production is an own research topic and would exceed the scope of this research work. Doubtless, education and agricultural skills are the basis for a sustainable agricultural production system as well as a forward-looking rural development. The agricultural skill of farmer can be improved by training course concepts such as the farmer field schools, which are described by several authors such as QUIZON et al. (2001) or TRIPP et al. (2005).

As mentioned already, often the lack of a highly resource efficient technology is presented as reason and as solution for the problem of nitrogen overuse. New agricultural technologies actually are able to lead to an advanced improvement in efficiency, but for a successful implementation, a working knowledge transfer system is preconditioned. The correct application present cultivation system must be considered as precondition for the implementation of new technologies, otherwise a wrong application of a new technology might lead to implementation costs without benefits or even to a misuse and decreased resource efficiency. A sustainable agricultural production system includes a sustainable implementation of the applied technologies.

Income generation for rural households is the core target for the development of rural China. The income gab increases not only between rural and urban China. Today, about two thirds of farm households have additional off-farm income sources and income from off-farm activities exceeds the income from farming. This leads to question how the income of rural households can be increased and how poverty alleviation can be obtained. Improvement of off-farm income opportunities might be an answer, but the dependency of rural households from farming should not be underestimated. Even those farm households with a successful family business still cultivate crops on their allocated farmland. In rural China, this farmland is regarded as old-age insurance. As described in chapter 2 already, off-farm activities usually enables higher incomes than income from farming. Without doubt, on the one hand local off-farm jobs are considered as a solution to increase the average income of rural households.

On the other hand, the broad variation in gross margin indicates that there is a high potential to increase income from farming by supporting those farm households with low gross margins. For that reason, the reduction of insufficient farming practices is expected to have both, a noticeable impact on improving of rural households and to reduce environmental pollution from nitrogen overuse. Summarized, the improvement of the present farming system towards a more sustainable cultivation system requires a sustainable implementation of its correct use and it can achieve both, the economic as well as the ecologic goals.

10 Summary/Zusammenfassung

Summary

Today, China had solved its long-standing problem of inadequate grain production, but there are two new targets for rural China. Firstly, one goal is rural development towards an improved income generation of rural households in order to slow down the increasing income disparity in China, especially between rural and urban residents. Secondly, decades of inefficient utilisation of resources and high consumption of materials led to overexploitation of water and land resources. Over-fertilisation and low nitrogen use efficiency are representative for the production system in the North China Plain, which is characterised by small-scale farm households who traditionally cultivate winter wheat and summer maize.

This thesis is embedded in the Sino-German Research Training Group "Modeling Material Flows and Production Systems for Sustainable Resource Use in Intensified Crop Production in the North China Plain", a cooperation of the University of Hohenheim in Stuttgart and the Chinese Agricultural University in Beijing. The overall hypothesis of this project is that substantial changes in farming systems and management practices can reduce environmental pollution and at the same time stabilise or increase income of farmers. As a subproject, this thesis focuses on the identification and evaluation of applicable instruments for this goal. The final target of this thesis is the simulation of scenarios in order to estimate the impact of identified instruments on the nitrogen balance as well as on the net income of farm households.

The literature review indicates that nitrogen application in the cultivation of wheat and maize in the North China Plain shows a broad variation. A considerable high share of farm households applies nitrogen input levels far beyond the crop demand. This situation raises the question, what do over-fertilising farm households have in common or in another way, which factors lead to nitrogen overuse. This question is the basis of the discussion on applicable instruments to reduce the described nitrogen overuse and finally the intended simulation approach.

The analysis of impact factors on the nitrogen application level requires a broad analysis of the cultivation system, the farm household characteristics, and the income sources of the farm households. The descriptive results of the farm survey on 340 farm households in the North China Plain conducted in 2005 are presented in chapter 5. The farming system at the survey sites is characterised by farm households, who cultivate the wheat and maize rotation system. In most cases, it is extended by cash crops such as cotton or peanuts. The farm size is on average 0.5 ha of allocated farmland per farm household. About two thirds of the farm households have some kind of additional off-farm income source, which usually exceeds the income share from farming. Farm households without off-farm income sources generate only half of the average farm household income. The average farm household income reaches 10 150 ¥ (1 015 €) per year, but there is a broad variation within the survey sites as well as between the surveyed townships. As mentioned already, over-fertilisation is prevalent for farming in the North China Plain. On average 360 kg of nitrogen per ha are applied in wheat and 220 kg in maize, while CHEN (2003) recommends 180 kg per ha for wheat and maize.

Further, fertilizer costs are the major share of variable costs at all cultivated crops. The major nitrogen fertilizers are urea and ammonium carbonate. Nearly 80 per cent of the applied nitrogen originates from these fertilizers. Manure is only applied in wheat and it plays only a minor role as nitrogen source. About one third of the farm households cultivates wheat exclusively for own consumption and these farm households apply more nitrogen in wheat cultivation than the remaining farm households. The average yield of 5.7 t per ha in wheat and of 6.4 tons in maize enables gross margins of about 4 000 ¥ (400 €) per ha, while in cotton and cultivation of peanuts the average gross margin is twice this amount.

In chapter 6 the efficiency of the agricultural system is analysed. This analysis includes an impact analysis on nitrogen input and yield as well as an economic and ecologic optimum analysis of the nitrogen input. Nitrogen application rates show a broad variation at all cultivated crops. The impact analysis on nitrogen input does not show any clear and unique influence from the income structure of the farm household. Hence, additional cash income and less available family work force for farm work have no impact on the nitrogen application level. The analysis of the fertilizer costs instead of the amount of applied nitrogen confirms this statement. The nitrogen input analysis provides the nitrogen price as major impact factor. Higher nitrogen input levels are connected with lower nitrogen prices. Differences in nitrogen price result from the composition of the applied fertilizer, which differs in the ratio between fertilizer price and nitrogen content. The yield of wheat and maize indicates a high variation within the survey sites, but especially between the surveyed townships. A multifactorial regression analysis identified the location as the only significant influencing factor on yield. From the agronomic point of view, nitrogen is a major yield factor, but the survey data do not indicate a clear impact of nitrogen input on yield. The estimated relationship between nitrogen input and wheat yield provides a constant-shaped yield function. This result allows the assumption that due to the long term high nitrogen inputs the crop demand for nitrogen is fulfilled in the short term and additional nitrogen input is without impact on the yield. The quadratic regression models of nitrogen input and yield in wheat and maize fail to provide applicable economic optima of nitrogen input. For this reason, the concept of KRAYL (1993) is considered to estimate an applicable production function for wheat and maize. This concept is based on a location independent production function, which can be transferred into a location specific production function by the consideration of a location specific optimum nitrogen input and the corresponding yield. In this case the recommendations of ZHEN et al. (2005) are considered, which recommend for wheat a nitrogen input of 220 kg per ha in order to harvest 5.3 t per ha. The economic optimum nitrogen input levels are higher than the nitrogen recommendations of ZHEN et al. (2005), but still lower than the average nitrogen application rates. Hence, the present nitrogen price does not support the implementation of the recommended nitrogen application rates. The estimation of the economic optimum nitrogen input considers a production function based on the concept of KRAYL (1993) which is enlarged by factor and product prices. These are the crop prices and the costs of the other variable inputs, which are the variable costs excluding fertilizer costs. In this way, the gross margin can be described as a function of nitrogen input including the uniform factor crop price and the constant

"other fertilizer costs". The calculated maximum gross margin in wheat of 4 057 ¥ per ha is achieved at a nitrogen input of 272 kg per ha. This level of nitrogen input is lower than the present average nitrogen input, but higher than the recommendations presented by ZHEN et al. (2005). Similar to the gross margin, the nitrogen balance is described as a function of nitrogen input, which considers the nitrogen input from fertilizer and straw left on the field from the previous cultivation as nitrogen inflow and the nitrogen content of the harvested crops as nitrogen outflow. Natural inflows and outflows are not taken into account. A nitrogen input of 205 kg per ha would result in the maximum accepted nitrogen surplus of 50 kg per ha and a gross margin of 3 365 ¥ per ha.

Chapter 7 focuses on the estimation of the nitrogen balance and the analysis of relevant impact factors. The estimated nitrogen balances show at all crops, but especially in wheat cultivation a high level of nitrogen surplus, which is on average 200 kg of nitrogen per ha. The corresponding figures for maize, peanuts, and cotton are less than 100 kg of nitrogen per ha. Similar to nitrogen input, the nitrogen balance is indicated by a broad variation. This variation allows a classification of farm households into three nitrogen balance types: "equalized nitrogen balance", "slight nitrogen surplus", and "heavy nitrogen surplus". The farming system of "heavy nitrogen surplus" farm households can be characterized by low yields, high nitrogen input, and low calculated gross margin. These farm households have a share of 32 per cent of all farm households and cultivate about one third of the wheat of all surveyed farms, but their cumulated nitrogen input amounts to 50 per cent. Furthermore, this group of farm households accounts for 67 per cent of the cumulated nitrogen surplus. This situation leads to the question, which factors lead to that kind of nitrogen overuse. A binary logistic regression model is used to analyse the impact of pre-selected factors on the probability of a group membership interval, in this case to the "equalized nitrogen balance" as well as the "heavy nitrogen surplus" group. The covariates "family size", "education", "farmland", and "off-farm activities" do not show any significant influence. Similar to the nitrogen input analysis, a low nitrogen price and the application of manure increases the probability of a farm households of membership of the "heavy nitrogen surplus" group. Also, a low village average wheat yield and a high village average nitrogen input in wheat increases the probability. In order to identify parallel impacts of farm household characteristics on the nitrogen balance the group of farm households of "heavy nitrogen surplus" and "equalized nitrogen balance" are clustered. The farm households of the major cluster of the "heavy nitrogen surplus" group are characterized by less farmland and low farm households income without off-farm activities. Farm households of these characteristics are found at a minor cluster of the "equalized nitrogen balance" group, as well. A low income does not automatically lead to nitrogen application rates beyond the crop demand. Indeed, the combination of low income and high nitrogen input shows a higher probability than the combination of high income and high nitrogen input. Without doubt, the assumption that a lower income leads to a lower nitrogen input must be rejected. The nitrogen price might be a clear indicator for classification of farm households, but this criterion requires the analysis of the cultivation system of the considered farm household. For this reason, easy observable dichotomous variables are pre-selected and analysed whether a

certain pattern can be used as criterion for identification as a part of a target group specific instrument. This approach does not provide applicable results.

Chapter 8 deals with the simulation of scenarios of the nitrogen surplus reduction and the estimated impact on the net income of farm households. In the first step, the instrument independent potential nitrogen surplus reduction is estimated. The cumulated nitrogen surplus of wheat cultivation of all surveyed farm households can be reduced by more than 60 per cent, if all farm household would follow the nitrogen input recommendations and harvest the target yield of ZHEN et al. (2005). This scenario shows no changes in net income. However, the approach that all farmers would modify their present nitrogen application level to the recommended application rates might be too ambitious. Hence, it might be more realistic to consider a theoretical shift of half of the farm households belonging to the "heavy nitrogen surplus" group to the "slight nitrogen surplus" group. The nitrogen surplus reduction in wheat would be 18 per cent. The affected group of farm households represents 17 per cent of the wheat cultivation area, but accounts initially for 32 per cent of the total nitrogen surplus in wheat. This hypothetical shift considers the modification of the share of farm households belonging to a certain nitrogen balance type. The average nitrogen surplus and gross margin in combination with the share of farm households of nitrogen balance type is taken to estimate the overall nitrogen surplus and net income from farming of the considered nitrogen balance type. A change in the share of farm households modifies the overall nitrogen surplus and net income from farming of each nitrogen balance type and these modified values are considered as the impact of the evaluated instrument, which originate that change of share. The individual gross margin multiplied by the individual cultivation area of all farm households is summed up and it is considered as net income from farming. In the following step, the impact of an instrument on the nitrogen balance and the net income is simulated. The variable nitrogen price shows a highly significant influence towards the classification of nitrogen balance type. For this reason, a modification of the nitrogen price is selected as considered instrument. A higher nitrogen price reduces the probability of "heavy nitrogen surplus" and this difference in probability can be regarded as the share of farm households, which convert form "heavy nitrogen surplus" to "slight nitrogen surplus". In addition, a theoretical shift of "slight nitrogen surplus" farm households into "equalised nitrogen balance" farm households is considered. As instruments, a percental increase of the nitrogen price by 10 per cent is simulated. An increased nitrogen price by 10 per cent results in a reduction of the total nitrogen surplus of 4.9 per cent. The estimation of the impact on the net income from farming considers the described theoretical shift of farm households to another nitrogen balance type and a multiple regression model of the gross margin. The latter model considers all farm households and indicates a negative impact of the nitrogen price on the gross margin. A combination of both models results in a marginal reduction of net income from farming by 0.6 per cent, in case of a 10 per cent nitrogen price increase. In addition, a target simulation focuses on a more noticeable nitrogen surplus reduction. The average nitrogen price increase by 159 per cent to obtain a nitrogen surplus reduction of 50 per cent, but the net income from farming shows a reduction by 15.3 per cent. Summarized, the considered instrument "nitrogen price modification" fulfils the

demand partly. It allows a nitrogen surplus reduction without a strong impact on the net income, but there are two major disadvantages. Firstly, huge nitrogen price modifications are required to gain a noticeable impact on nitrogen surplus reduction. Secondly, a nitrogen price modification affects all farmers, but there is a broad variation of the nitrogen balance and a high share of farm households actually has an equalized nitrogen balance.

The discussion about the reasons for nitrogen overuse in the wheat and maize farming system in the North China Plain leads to the following results. This thesis cannot provide a comprehensive answer on the question, what the core reasons for the described surplus at the nitrogen balance are. The described high variation in nitrogen input and the reported low rate of farm households, which follow the recommended nitrogen application rates, leads to the assumption that an insufficient knowledge transfer system is the key reason for the inadequate use of the traditional cultivation system in terms of fertilizer application in the North China Plain. Lack of knowledge might be an explanation that low income farm households without off-farm activities do not have less fertilizer costs, but even have a higher probability to apply above average nitrogen rates than farm households, which have additional income from off-farm activities. The discussion about applicable instruments focuses on nitrogen tax, implementation of new agricultural technologies, and improvements in education and agricultural skills. The modification of the nitrogen price by a nitrogen tax is considered as an economically applicable instrument, but there are the described disadvantages. Furthermore, an economic instrument might not be suitable, if a noticeable share of the target group seems not to consider their farm level economic optimum as criterion in their determination of the applied nitrogen. In addition, a low nitrogen price is a suitable indicator for nitrogen overuse, but not its explanation. The nitrogen price represents the composition of the used fertilizer. An unfavourable composition can be regarded as an insufficient use of the cultivation system, which results in the described nitrogen overuse. Hence, an improvement in application of the cultivation technology might be more successful than an economic instrument. The discussion about new technologies focuses on their implementation. Only a minority of farm households follows the presently recommended nitrogen application rates and at a noticeable share of farm households the traditional cultivation system is not free of cultivation mistakes, especially in terms of nitrogen application. This raises the question, how successful a new agricultural technology can be implemented. The correct application present of the cultivation system and a proper working knowledge transfer system are the preconditions for the implementation of new technologies. For this reason, improvement in education and agricultural skills are the base instruments as well as the basis for all advanced instruments, because a sustainable cultivation system requires a sustainable implementation of its correct use.

Zusammenfassung

Die chinesische Landwirtschaft hat es geschafft, die Getreideversorgung für ihre Bevölkerung sicherzustellen. Chinas großes Problem der unzureichenden Getreideproduktion konnte gelöst werden. Jedoch entstanden zwei neue Aufgaben für das ländliche China. Zum einen muss das ländliche Einkommen gesteigert werden, um die stetig wachsende Einkommensdisparität zwischen der Land- und der Stadtbevölkerung zu verringern. Zum anderen hat die ineffiziente Ressourcennutzung in der Landwirtschaft der letzten Jahrzehnte zu einer Übernutzung der Rohstoffe Wasser und Boden geführt. Daher kann die gegenwärtige landwirtschaftliche Produktion nicht als nachhaltig bezeichnet werden. Überdüngung und eine geringe Stickstoffeffizienz sind charakteristisch für die landwirtschaftliche Produktion in der Nordchinesischen Tiefebene, die durch kleinflächige Familienbetriebe und den traditionellen Anbau von Winterweizen und Sommermais geprägt ist.

Diese Arbeit ist Teil des Deutsch-Chinesischen Graduiertenkollegs "Modellierung von Stoffflüssen und Produktionssystemen für eine nachhaltige Ressourcennutzung in intensiven Acker- und Gemüsebausystemen der Nordchinesischen Tiefebene". Forschungsaufgabe dieses Gemeinschaftsprojekts der Universität Hohenheim in Stuttgart und der China Agricultural University in Peking ist die Hypothese, dass eine Modifizierung des gegenwärtigen Anbausystems hinsichtlich einer ökologisch nachhaltigeren Produktion ohne Einkommensminderung möglich ist. Diese Arbeit hat die Zielsetzung, entsprechende Instrumente zu identifizieren und zu bewerten. Daher besteht die zentrale Aufgabe dieser Arbeit in der Simulation der herausgearbeiteten Instrumente, um ihre Auswirkungen auf die Stickstoffbilanz sowie auf das Einkommen der landwirtschaftlichen Haushalte abzuschätzen.

Die im Rahmen des Forschungsprojektes durchgeführte Literaturrecherche hat gezeigt, dass der Stickstoffeinsatz in der Nordchinesischen Tiefebene durch eine breite Streuung gekennzeichnet ist und dass größtenteils die ausgebrachte Stickstoffmenge den Stickstoffbedarf bei weitem übersteigt. Diese Situation wirft die Frage nach Gemeinsamkeiten von Überdüngung gekennzeichneter landwirtschaftlicher Haushalte auf. Welche Faktoren führen zu einem überhöhten Stickstoffeinsatz? Diese Fragestellung ist die Grundlage zur Diskussion möglicher Instrumente zur Reduzierung des überhöhten Stickstoffeinsatzes.

Die Analyse der Einflussfaktoren auf den Stickstoffeinsatz erfordert eine ausgiebige Untersuchung des Anbausystems sowie der Struktur der landwirtschaftlichen Haushalte mit besonderem Augenmerk auf die Einkommensquellen der landwirtschaftlichen Familien. Die Ergebnisse der im Jahr 2005 durchgeführten Befragung von 340 landwirtschaftlichen Betrieben in der Nordchinesischen Tiefebene werden in Kapitel 5 präsentiert. Die landwirtschaftlichen Betriebe an den Befragungsstandorten bauen Weizen und Mais im Rotationsverfahren an. Häufig jedoch wird dieses Anbausystem durch den Anbau von Wirtschaftskulturen wie Baumwolle oder Erdnüssen erweitert. Die durchschnittliche Betriebsgröße liegt bei 0.5 ha Ackerland. Zwei Drittel der landwirtschaftlichen Haushalte erwirtschaften zusätzliches Einkommen aus Tätigkeiten außerhalb des eigenen landwirtschaftlichen Betriebes. Dieses zusätzliche Einkommen

übersteigt meist den Anteil des landwirtschaftlichen Einkommens am Gesamtein-kommen. Familien ohne zusätzliches nicht-landwirtschaftliches Einkommen steht im Durchschnitt nur die Hälfte des Durchschnittseinkommens landwirtschaftlicher Haus-halte zur Verfügung. Das durchschnitte Jahreseinkommen der befragten Haushalte beträgt 10 150 ¥ (1 015 €). Jedoch zeigt sich eine breite Streuung innerhalb der Befragungsstandorte, und der untersuchten Gemeinden. Wie bereits beschrieben, ist die Stickstoffüberdünung weitverbreitet in der Nordchinesischen Tiefebene. Im Durch-schnitt werden im Weizenanbau 360 kg und im Maisanbau 220 kg Stickstoff pro ha gedüngt, während CHEN (2003) Düngeempfehlungen für den Anbau von Weizen und Mais von 180 kg pro ha präsentiert. Düngemittel haben in allen analysierten Kulturen den höchsten Anteil an den jeweiligen variablen Kosten. Die wichtigsten Dünger in diesem Anbausystem sind Harnstoff und Ammoniumcarbonat. Diese tragen mit fast 80 Prozent den Hauptanteil am ausgebrachten Stickstoff. Stallmist wird nur im Weizen-anbau eingesetzt und spielt als Stickstoffquelle nur eine untergeordnete Rolle. Ein Drittel der landwirtschaftlichen Haushalte baut Weizen nur für den Eigenbedarf an, jedoch düngen diese Haushalte mehr Stickstoff als jene Haushalte mit Weizenverkauf. Der durchschnittliche Weizenertrag von 5,7 t pro ha und 6,4 t beim Mais führen zu einem durchschnittlichen Deckungsbeitrag von 4 000 ¥ (400 €), während beim Anbau von Baumwolle und Erdnüssen der doppelte durchschnittliche Deckungsbeitrag erzielt wird.

Im Kapitel 6 wird eine Effizienzanalyse des landwirtschaftlichen Systems durch-geführt. Diese beinhaltet eine Analyse der Einflussfaktoren auf den Stickstoffeinsatz und den Ertrag, wie auch eine Schätzung des ökonomischen wie ökologischen Stick-stoffeinsatzoptimums. Die einzelnen Stickstoffdüngungen im Weizen- und Maisanbau zeigen eine breite Streuung, allerdings kann kein Zusammenhang zwischen der Einkommensstruktur der landwirtschaftlichen Betriebe und dem Düngemitteleinsatz aufgezeigt werden. Zusätzliches Einkommen und eine verminderte Verfügbarkeit von Familienarbeitskräften durch Tätigkeiten außerhalb der eigenen Landwirtschaft zeigen keinen Einfluss weder auf den Stickstoffeinsatz noch auf die Ausgaben für Düngemittel. In den durchgeführten Analysen zeigt sich der Faktor Stickstoffpreis als relativ starker Einflussfaktor. Ein geringer Stickstoffpreis ist mit einem hohen Gesamtstickstoffeinsatz verbunden. Die Unterschiede beim Stickstoffpreis hängen von der Zusammensetzung der eingesetzten Dünger und deren Verhältnis von Düngemittelpreis zu Stickstoffinhalt ab. Ebenfalls zeigt der Weizen und Maisertrag eine breite Streuung. Eine multi-faktorielle Regressionsanalyse zeigt den Standort als Haupteinflussfaktor. Aus agronomischer Sicht ist der Stickstoff ein wichtiger Einflussfaktor auf den Ertrag. Es lässt sich aber bei den erhobenen Daten kein eindeutiger Zusammenhang feststellen. Der Einfluss des Faktors Stickstoff auf den Ertrag gleicht besonders im Weizen einer Konstante. Dieses Ergebnis führt zu der Vermutung, dass durch langjährige hohe Düngegaben der Pflanzenbedarf bereits gedeckt ist und daher gegenwärtige Stickstoffgaben keinen kurzfristigen Einfluss auf den Ertrag haben. Die quadratischen Regressionsmodelle zeigen keinen signifikanten Einfluss der Variable Stickstoffeinsatz auf den Ertrag und ermöglichen daher auch keine Berechnung des ökonomischen Optimums des Stickstoffeinsatzes. Aus diesem Grund wird auf das Konzept von KRAYL (1993) bei der Schätzung einer Produktionsfunktion für Weizen und Mais

zurückgegriffen. Dieses Konzept basiert auf einer standortunabhängigen Produktionsfunktion, die durch die Berücksichtigung von einem lokalspezifischen Stickstoffoptimum und dem entsprechenden Ertrag in eine lokalspezifische Produktionsfunktion umgewandelt werden kann. Hier werden die Empfehlungen von ZHEN et al. (2005) berücksichtigt, welche für den Weizenanbau eine Stickstoffdüngung von 220 kg pro ha empfehlen, um einen Ertrag von 5,3 t pro ha zu erzielen. Das berechnete ökonomische Optimum beim Stickstoffeinsatz ist jedoch höher als die Stickstoffempfehlungen von ZHEN et al. (2005), aber geringer als die durchschnittlichen Stickstoffapplikationen der befragten landwirtschaftlichen Haushalte. Dies lässt den Rückschluss zu, dass der gegenwärtige Stickstoffpreis keine Unterstützung für die Düngeempfehlungen darstellt. Für eine Schätzung des ökonomischen Stickstoffeinsatzoptimums wird eine auf dem Konzept von KRAYL (1993) basierende Produktionsfunktion um die Faktor- und Produktpreise erweitert. Im Detail sind dies die Produktpreise der einzelnen Kulturen und die aufsummierten verbleibenden variablen Kosten ohne die Aufwendungen für Düngemittel. Zwischen dem Stickstoffeinsatz und dem Stickstoffpreis wurde ein Zusammenhang festgestellt, der als Potenzfunktion beschrieben werden kann. Der Stickstoffpreis steht für die Zusammensetzung der eingesetzten Stickstoffdünger. Daher kann der Deckungsbeitrag als Funktion vom Stickstoffeinsatz mit dem einheitlichen Faktor Produktpreis und der Konstanten "verbleibende variable Kosten" beschrieben werden. Der maximale berechnete Deckungsbeitrag im Weizenanbau von 4 057 ¥ wird bei einem Stickstoffeinsatz von 272 kg pro ha erreicht. Dieser Stickstoffeinsatz ist geringer als der erhobene durchschnittliche Stickstoffeinsatz, jedoch höher als die präsentierten Düngeempfehlungen von ZHEN et al. (2005). In Anlehnung an den Deckungsbeitrag wird die Stickstoffbilanz ebenfalls als eine Funktion vom Stickstoffeinsatz dargestellt. Diese berücksichtigt als Stickstoffzufuhr neben den Stickstoffdüngern die auf dem Feld verbliebenen Ernterestе und als Stickstoffausfuhr der Gesamtstickstoffgehalt des Ernteguts. Natürliche Zu- und Abflüsse werden nicht berücksichtigt. Ein Stickstoffzufluss von 205 kg pro ha würde zu dem maximal akzeptierten Stickstoffüberschuss von 50 kg und bei einem Deckungsbeitrag von 3 365 ¥ pro ha führen.

In Kapitel 7 steht die Schätzung der Stickstoffbilanz so wie der Analyse von entsprechenden Einflussfaktoren im Vordergrund. Die Schätzung der Stickstoffbilanzen zeigt bei allen Kulturen hohe Überschüsse an, vor allem jedoch im Weizenanbau. Hier wurde ein durchschnittlicher Überschuss von 200 kg pro ha geschätzt, während dieser beim Anbau von Mais, Erdnüssen und Baumwolle unter 100 kg pro ha liegt. Ebenso wie bei den Stickstoffgaben weisen die Stickstoffbilanzen eine breite Streuung auf. Diese Streuung lässt eine Klassifizierung der landwirtschaftlichen Betriebe in drei Stickstoffbilanztypen zu: "ausgeglichene Stoffbilanz", "leichter Stickstoffüberschuss" und "extremer Stickstoffüberschuss". Das Anbausystem von landwirtschaftlichen Betrieben des Typs "extremer Stickstoffüberschuss" kann wie folgt charakterisiert werden: geringe Erträge, hohe Stickstoffdüngung und geringe Deckungsbeiträge. Zu diesem Typ zählen 32 Prozent der landwirtschaftlichen Betriebe und diese produzieren rund ein Drittel des Weizens, jedoch beträgt ihr Anteil am Stickstoffverbrauch 50 Prozent und am Stickstoffüberschuss sogar 67 Prozent. Die Situation stellt die Frage nach den Faktoren, die zu derartigen hohen Stickstoffgaben führen. Das binäre

logistische Regressionsmodell ist ein geeignetes Instrument, um den Einfluss von im Voraus ausgewählten Faktoren im Bezug auf ihren Einfluss auf die Wahrscheinlichkeit einer Gruppenzugehörigkeit, in diesem Fall "extremer Stickstoffüberschuss" als auch "ausgeglichene Stickstoffbilanz" zu analysieren. Die Faktoren "Familiengröße", "Bildung", "landwirtschaftliche Nutzfläche" sowie "nicht-landwirtschaftliche Tätigkeiten" zeigen keinen Einfluss hinsichtlich der Stickstoffbilanztypen. Wie bei der Stickstoff-einsatzanalyse steigert ein geringer Stickstoffpreis sowie der Einsatz von Stallmist die Wahrscheinlichkeit einer Zugehörigkeit zum Typ "extremer Stickstoffüberschuss". Ebenfalls steigert ein geringer Dorfdurchschnitt des Weizenertrags und ein höherer Dorfdurchschnitt beim Stickstoffeinsatz die Wahrscheinlichkeit der Zugehörigkeit zu dieser Kategorisierung. Zusätzlich wurde eine Clusteranalyse innerhalb der beiden betrachteten Stickstoffbilanztypen durchgeführt, um parallele Einflüsse bzw. Erklärungsansätze von Charakteristika der landwirtschaftlichen Haushalte auf die Stickstoffbilanz der betrachteten Kategorien zu identifizieren. Die landwirtschaftlichen Haushalte des größten Clusters des Stickstoffbilanztyps "extremer Stickstoff-überschuss" sind durch ihre geringe Anbaufläche und ihr geringes Einkommen aufgrund fehlender nicht-landwirtschaftlicher Tätigkeiten gekennzeichnet. Haushalte dieser Art finden sich ebenfalls in einem untergeordneten Cluster des Stickstoffbilanztyps "ausgeglichene Stoffbilanz". Ein geringes Einkommen ist also nicht automatisch mit einer Düngung jenseits des Pflanzenbedarfs verbunden. Allerdings zeigt sich, dass die Kombination geringes Einkommen mit hohen Stickstoffdüngungen eine höher Wahrscheinlichkeit aufweist als die Kombination höheres Einkommen mit hoher Stickstoffdüngung. Zweifelsohne muss die Hypothese abgelegt werden, dass geringer Einkommen zu einem geringen Stickstoffeinsatz führt. Der Stickstoffpreis scheint zwar ein sicherer Indikator für die Kategorisierung von landwirtschaftlichen Haushalten hinsichtlich der Stickstoffbilanz zu sein, jedoch erfordert dies eine Analyse des Anbausystems des jeweiligen landwirtschaftlichen Haushalts. Daher wurde leicht beobachtbare dichotome Variablen ausgesucht, damit entsprechende Muster als Kriterium zur Identifizierung und Nutzung von Zielgruppen gerichteter Instrumente verwendet werden können. Jedoch konnte dieser Ansatz keine anwendbaren Ergebnisse präsentieren.

Kapitel 8 beschäftigt sich mit der Simulation von Szenarien zur Reduzierung des Stickstoffbilanzüberschusses und der Abschätzung des Einflusses auf die Einkommen von landwirtschaftlichen Haushalten. Im ersten Schritt wird das Reduktionspotential des Stickstoffüberschusses ohne Berücksichtigung eines entsprechenden Instruments geschätzt. Der kumulierte Stickstoffüberschuss aller berücksichtigen landwirtschaft-lichen Haushalte kann um 60 Prozent reduziert werden, sofern alle landwirtschaftliche Betriebe der auf ZHEN et al. (2005) basierenden auf Stickstoffdüngeempfehlung folgen und die dazugehörigen Ernteerwartungen erfüllen. Dieses Szenario zeigt keine Veränderungen bei den Einkommen. Jedoch ist dieser Ansatz, dass tatsächlich alle landwirtschaftlichen Betriebe ihre gegenwärtigen Stickstoffdüngungen hinsichtlich der Düngeempfehlungen anpassen, sehr ambitiös. Ein mehr an die Umsetzbarkeit angepasster Ansatz wäre eine theoretische Umwandlung der Hälfte der landwirtschaft-lichen Betriebe des Stickstoffbilanztyps "extremer Stickstoffüberschuss" zur Kategorie "leichter Stickstoffüberschuss". In diesem Fall würde der kumulierte Stickstoffüber-

schuss um 18 Prozent reduziert werden. Diese Gruppe der theoretisch umgewandelten landwirtschaftlichen Betriebe hat einen Anteil von 17 Prozent an der Weizenanbaufläche und ist für 32 Prozent des kumulierten Stickstoffüberschusses verantwortlich. Diese theoretische Umwandlung betrachtet die Änderung der Anteilgröße der einzelnen Stickstoffbilanztypen. Der durchschnittliche Stickstoffbilanzüberschuss und Deckungsbeitrag in Verbindung mit der jeweiligen Anteilgröße dient als Grundlage zur Schätzung des jeweils kumulierten Stickstoffbilanzüberschusses und des Deckungsbeitrages jedes Stickstoffbilanztyps. Eine Veränderung der Anteilgröße führt zu einer Veränderung des kumulierten Stickstoffbilanzüberschusses und Deckungsbeitrags, die dann zur Bemessung des Wirkungsgrads des analysierten Instruments, dass diese Veränderung erzeugt hat, angesehen wird. Eine Veränderung des kumulierten Deckungsbeitrags wird einem veränderten landwirtschaftlichen Einkommen gleichgesetzt. Im nun folgenden Schritt wird der Einfluss von ausgewählten Instrumenten auf die Stickstoffbilanz wie auch das Haushaltseinkommen simuliert. Die Variable Stickstoffpreis zeigt einen hoch signifikanten Einfluss auf die Zuordnung hinsichtlich des Stickstoffbilanztyps. Aus diesem Grund kann eine Veränderung des Stickstoffpreises als geeignetes Instrument angesehen werden. Eine Steigerung des Stickstoffpreises reduziert die Wahrscheinlichkeit des Typs "extremer Stickstoffüberschuss" und die Differenz zwischen der Ursprungswahrscheinlichkeit und der dann simulierten Wahrscheinlichkeit kann als Anteil der landwirtschaftlichen Betriebe angesehen werden, die von der theoretischen Umwandlung vom Typ "extremer Stickstoffüberschuss" zum Typ "leichter Stickstoffüberschuss" betroffen sind. Zusätzlich wird eine theoretische Umwandlung vom Typ "leichter Stickstoffüberschuss" zum Typ " ausgeglichene Stoffbilanz " berücksichtigt. Eine Erhöhung des Stickstoffpreises um 10 Prozent wird simuliert, im ersten Fall führt dies zu einer simulierten Stickstoffüberschussreduktion von 4,9 Prozent. Die Schätzung des Einflusses auf die Einkommen der landwirtschaftlichen Haushalte basiert auf der beschriebenen theoretischen Umwandlung des Stickstoffbilanztyps sowie eines multiplen Regressionsmodells des Deckungsbeitrages, welches alle landwirtschaftlichen Betriebe berücksichtigt und einen negativen Einfluss des Stickstoffpreises auf den Deckungsbeitrag anzeigt. Eine Kombination beider Modellansätze zeigt bei einer Stickstoffpreissteigerung um 10 Prozent einen nur geringfügigen Einkommensrückgang um 0,6 Prozent auf. Zusätzlich wurde eine Simulation hinsichtlich einer deutlicheren Reduzierung des Stickstoffüberschusses durchgeführt. Dabei ist eine Stickstoffpreissteigerung um 159 Prozent notwendig, um eine simulierte Reduzierung des Stickstoffüberschusses von 50 Prozent zu erreichen. In diesem Fall sinkt das kumulierte landwirtschaftliche Einkommen der landwirtschaftlichen Haushalte um 15.3 Prozent. Zusammengefasst lässt sich sagen, dass das Instrument Stickstoffpreiserhöhung den gestellten Ansprüchen teilweise genügt. Es ermöglicht eine Stickstoffüberschussreduktion ohne gravierende Einkommenseinbußen, aber es ist auch mit folgenden Nachteilen behaftet. Zum einen ist eine extreme Stickstoffpreisänderung notwendig, um eine deutliche Reduzierung des Stickstoffüberschusses zu erzielen. Zum anderen beeinträchtigt eine Stickstoffpreisänderung auch jene landwirtschaftlichen Betriebe, die eine ausgeglichene Stickstoffbilanz aufweisen.

Die Diskussion über die Ursachen der Stickstoffüberdüngung im Anbau von Weizen und Mais in der Nordchinesischen Tiefebene hat zu folgenden Resultaten geführt. Diese Arbeit bietet keine umfassende Erklärung hinsichtlich der Frage nach den Gründen, die zu der beschriebenen Stickstoffüberdüngung geführt hat. Die breite Streuung beim Stickstoffeinsatz verbunden mit der geringen Anzahl an landwirtschaftlichen Haushalten, die die Düngeempfehlungen befolgen, lässt die Vermutung zu, dass der unzureichende Wissenstransfers die Hauptursache für den unsachgemäßen Einsatz des traditionellen Anbausystems im Bezug auf die Düngung in der Nordchinesischen Tiefebene ist. Ein geringerer Wissensstand kann eine Erklärung sein, dass einkommensschwache landwirtschaftliche Haushalte ohne zusätzliche außerlandwirtschaftliche Aktivitäten keine geringeren Düngemittelaufwendungen haben. Vielmehr weisen sie sogar eine höhere Wahrscheinlichkeit auf als landwirtschaftliche Haushalte mit zusätzlichen Einkommensquellen außerhalb der eigenen Landwirtschaft. Die Diskussion über entsprechende Instrumente berücksichtigt eine Stickstoffsteuer, neue Agrartechnologien und Maßnahmen zur Förderung der Bildung und landwirtschaftliche Fertigkeiten. Die Simulation einer Stickstoffsteuer zeigt ein relativ schwaches Potential zur Reduzierung des Stickstoffüberschusses ohne jedoch das Einkommen des landwirtschaftlichen Haushalts zu stark zu beinträchtigen. Trotzdem ist dieses Instrument mit den bereits beschriebenen Nachteilen behaftet. Des Weiteren basiert ein ökonomisches Instrument auf einer betriebswirtschaftlichen Betrachtungsweise. Es scheint aber so, als wenn genau diese bei einem Großteil der landwirtschaftlichen Haushalte eben nicht die Grundlage bei der Bestimmung des Stickstoffeinsatzes ist. Ein geringer Stickstoffpreis ist zwar ein zuverlässiger Indikator für Stickstoffüberdüngung, aber keine Erklärung für diese. Der Stickstoffpreis zeigt die Zusammensetzung der eingesetzten Dünger an. Eine ungünstige Zusammensetzung kann als unsachgemäße Anwendung des Anbausystems angesehen werden, die dann zu den beschriebenen Stickstoffbilanzüberschüssen führt. Daher erscheinen Maßnahmen zur verbesserten Anwendung der Anbaumethoden erfolgversprechender als ökonomische Instrumente. Die Diskussion über neue Technologien setzt ein besonderes Augenmerk auf ihre Implementierung. Nur eine Minderheit der landwirtschaftlichen Betriebe berücksichtigt die Düngeempfehlungen und auch ein beträchtlicher Teil der Betriebe zeichnet sich durch eine unsachgemäße Anwendung des traditionellen Anbausystems aus. Daher stellt sich die Frage, wie erfolgreich neue Technologien eingeführt werden können. Eine korrekte Anwendung des gegenwärtigen Anbausystems und ein funktionierendes System des Wissenstransfers stellen die Voraussetzungen für eine erfolgreiche Einführung von neuen Technologien dar. Daher sind Verbesserungen in der Bildung sowie in den landwirtschaftlichen Fertigkeiten notwendig und sind ebenfalls die Grundlage für weiterführende Instrumente, weil ein nachhaltiges landwirtschaftliches Produktionssystem eine nachhaltige Implementierung seiner korrekten Anwendung erfordert.

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Annex

Annex Table 1   Rural population in the provinces of the North China Plain in 2003

	total population [mio pers.]	rural population [mio pers.]	total rural labour force [mio pers.]	rural labour force in agriculture [mio pers.]	rural labour force in off-farm work [mio pers.]
Hebei	67.3	53.8	27.5	16.6	10.9
Jiangsu	73.8	52.1	26.5	12.3	14.2
Anhui	63.3	51.4	28.6	18.6	10.0
Shandong	90.8	70.4	37.2	22.6	14.5
Henan	96.3	79.4	46.9	33.2	13.7
NCP Provinces[1]	391.3	307.1	166.7	103.4	63.4
China	1 284.5	n.a.	n.a.	324.9	n.a.

Source: (ANHUI PROVINCE STATISTICAL BUREAU 2003), (HENAN PROVINCE STATISTICAL BUREAU 2003), (HEBEI PROVINCE STATISTICAL BUREAU 2003), (JIANGSU PROVINCE STATISTICAL BUREAU 2003), (SHANDONG PROVINCE STATISTICAL BUREAU 2003), (NATIONAL BUREAU OF STATISTICS 2003)

Note: [1] data for Hebei, Jiangsu, Anhui, Shandong and Henan, this includes those parts of these provinces which not belong to the NCP and excludes the municipality of Beijing and Tianjin

Annex Table 2   Education level of rural labour in the provinces of the North China Plain in 2003

	illiterate [%]	primary school, 6 years [%]	middle school, additional 3 years [%]	high school and high education [%]
Hebei	1.9	24.4	58.1	15.5
Jiangsu	6.2	25.5	53.8	14.6
Anhui	11.3	27.1	52.3	9.3
Shandong	5.8	22.8	53.4	18.0
Henan	6.6	21.4	58.5	13.4
NCP Provinces[1]	6.4	24.2	55.5	14.2

Source: (ANHUI PROVINCE STATISTICAL BUREAU 2003), (HENAN PROVINCE STATISTICAL BUREAU 2003), (HEBEI PROVINCE STATISTICAL BUREAU 2003), (JIANGSU PROVINCE STATISTICAL BUREAU 2003), (SHANDONG PROVINCE STATISTICAL BUREAU 2003)

Note: [1] data for Hebei, Jiangsu, Anhui, Shandong and Henan, this includes those parts of these provinces which not belong to the NCP and excludes the municipality of Beijing and Tianjin

Annex Table 3   Share of family work force at a certain education level at the survey sites

county township	Liangshan #1	#2	Huimin #3	#4	Kaifeng #5	#6	Quzhou #7	#8	Yanjin #9	#10	all farms
illiterate [%]	14	16	14	8	15	22	9	12	5	9	12
primary school [%]	36	43	27	24	33	18	27	29	15	14	27
middle school [%]	41	32	49	54	40	48	43	54	61	63	49
high school [%]	8	7	9	13	10	12	20	5	20	13	12

Note: data basis is 1 000 family labourer

Annex Table 4   Family work force working exclusively on farm at the survey sites

county	Liangshan		Huimin		Kaifeng		Quzhou		Yanjin		all
township	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	farms
share of local labour [%]	69	58	61	64	84	88	70	74	69	80	72
work force [LU]	1.8	1.9	1.7	2.0	2.8	2.5	2.3	2.4	2.2	2.6	2.2
age [years]	46	45	45	44	42	43	43	44	40	38	43
primary school[1] [%]	41	55[a]	23[a]	19	27	21	29	35	12	3	26
middle school[1] [%]	50	28	60	65	48	55	34	53	56	79	53
high school[1] [%]	9	7	3	13	18	18	31	9	29	18	16

Note: [1] share of household having with this level as highest family education of family labour working exclusively on farm
[a] additionally in TS #2 10% and in TS #3 13% of the surveyed rural labour are illiterate

Annex Table 5   Family work force with temporary off-farm job and working on own farm only when needed at the survey sites

county	Liangshan		Huimin		Kaifeng		Quzhou		Yanjin		all
township	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	farms
share of local labour [%]	17	24	28	17	3	2	12	11	17	19	15
work force [LU]	1.2	1.3	1.2	1.1			1.4	1.2	1.4	1.2	1.2
age [years]	40	33	32	37			40	25	40	35	35
primary school[1] [%]	31[a]	17	20	13			20	0	8	0	13
middle school[1] [%]	23	72	55	60			50	100	67	58	60
high school[1] [%]	23	11	20	27			30	0	25	37	23

Note: [1] share of household having with this level as highest family education of family labour with temporary off-farm job and working on own farm only when needed
[a] these data are under estimated, in TS 1 23 % are illiterate

Annex Table 6   Family work force working exclusively off-farm at the survey sites

county	Liangshan		Huimin		Kaifeng		Quzhou		Yanjin		all
township	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	farms
share of local labour [%]	14	18	11	19	13	10	18	15	13	1	13
work force [LU]	1.3	1.5	1.1	1.3	1.4	1.5	1.8	1.2	1.6		1.4
age [years]	25	26	22	26	21	22	26	21	22		24
primary school[1] [%]	20	33	13	7	10	0	0	8	0		11
middle school[1] [%]	70	42	50	67	70	50	75	75	63		64
high school[1] [%]	0	17	38	20	10	50	17	17	38		20

Note: [1] share of household having with this level as highest family education of family labour working exclusively off-farm

Annex Table 7 **Share of labour type 3, labour type 4, and labour type 5 at the survey sites**

| county | Liangshan | | Huimin | | Kaifeng | | Quzhou | | Yanjin | | all |
township	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	farms
share labour type 3 [%]	69	58	61	64	84	88	70	74	69	80	72
share labour type 4 [%]	17	24	28	17	3	2	12	11	17	19	15
share labour type 5 [%]	14	18	11	19	13	10	18	15	13	1	13

Annex Table 8 **Land rent-in characteristics at the survey sites**

| county | Liangshan | | Huimin | | Kaifeng | | Quzhou | | Yanjin | | all |
township	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	farms
farm do rent-in [%]	12	0	31	16	9	0	6	3	3	18	10
area rent-in [ha]	0.20		0.12	0.14						0.36	0.23
rent [¥ ha^{-1}]	3 550		2 360	3 150						2 680	3 030

Annex Table 9 **Reasons of farmer not to rent-in land at the survey sites**

| county | Liangshan | | Huimin | | Kaifeng | | Quzhou | | Yanjin | | all |
township	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	farms
no need [%]	24	16	44	25	61	9	37	50	9	12	29
no land available [%]	3	53	38	56	15	88	14	32	62	41	40
not profitable [%]	41	44	0	6	9	0	20	3	0	8	14
lack of labour [%]	50	19	0	9	24	3	26	12	32	15	19

Note: multiple answers are possible

Annex Table 10 **Livestock characteristics of farm households at the survey sites**

| county | Liangshan | | Huimin | | Kaifeng | | Quzhou | | Yanjin | | all |
township	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	farms
farms with livestock [%]	26	34	63	16	9	0	6	3	3	18	40
manure production [t]	1.6	4.1	5.7	6.9	10.1	6.7	3.3	3.1	4.1	5.8	5.5
farms with cattle[1] [%]	9	3	44	34	52	6	9	0	6	9	17
farms with goat[2] [%]	15	22	0	0	6	3	0	9	0	3	6
farms with pig[3] [%]	3	9	9	19	9	12	20	12	35	38	17
farms with poultry [%]	3	0	6	6	0	0	9	6	12	0	4

Note: [1] on average the farm household have 2 cattle
[2] on average the farm household have 3 goat
[3] on average the farm household have 5 pigs

Annex Table 11   Income per capita of rural population in the provinces of the North China Plain

	urban resident	rural resident					
	total net income [¥ pers.$^{-1}$]	total net income [¥ pers.$^{-1}$]	income from agriculture [¥ pers.$^{-1}$]	transfer and property income [¥ pers.$^{-1}$]	total off-farm income [¥ pers.$^{-1}$]	off-farm family business income [¥ pers.$^{-1}$]	off-farm income as employee [¥ pers.$^{-1}$]
Hebei	7 239	2 853	805	136	1 912	840	1 072
Jiangsu	9 263	4 239	958	256	3 025	836	2 189
Anhui	6 778	2 127	782	108	1 237	418	819
Shandong	8 400	3 150	1 146	179	1 825	729	1 096
Henan	6 926	2 236	966	112	1 158	522	636
NCP[1]	7 721	2 921	931	158	1 831	669	1 162
Beijing	13 251	5 398	n.a.	n.a.	n.a.	n.a.	n.a.
China	8 177	2 476	887	149	n.a.	n.a.	n.a.

Source: (ANHUI PROVINCE STATISTICAL BUREAU 2003), (HENAN PROVINCE STATISTICAL BUREAU 2003), (HEBEI PROVINCE STATISTICAL BUREAU 2003), (JIANGSU PROVINCE STATISTICAL BUREAU 2003), (SHANDONG PROVINCE STATISTICAL BUREAU 2003), (NATIONAL BUREAU OF STATISTICS 2003)

Note: [1] data for Hebei, Jiangsu, Anhui, Shandong and Henan, this includes those parts of these provinces which not belong to the NCP and excludes the municipality of Beijing and Tianjin

Annex Table 12   Structure of employment of rural work force in the provinces of the North China Plain in 2003

Province	total work force [mil. pers.]	rural work force in off-farm work [mil. pers.]	employed at township and village enterprises [mil. pers.]	employed at private enterprises [mil. pers.]	self-run business [mil. pers.]
Hebei	27.3	10.9	8.86	1.12	2.11
Jiangsu	26.5	14.2	9.72	2.18	1.92
Anhui	28.4	10.0	5.02	0.36	1.94
Shandong	37.0	14.5	11.71	1.01	1.75
Henan	46.9	13.7	9.39	0.31	1.32
NCP Provinces[1]	166.7	63.4	47.46	4.98	9.04

Source: (NATIONAL BUREAU OF STATISTICS OF CHINA 2003)

Note: [1] data for Hebei, Jiangsu, Anhui, Shandong and Henan, this includes those parts of these provinces which not belong to the NCP and excludes the municipality of Beijing and Tianjin

Annex Table 13   Income characteristics of the major cropping pattern

cropping pattern	farms	farming net cash income [¥ year^{-1}]	share of farms with off-farm income [%]	total income [¥ year^{-1}]
cotton -other	7	5 490	86	12 630
wheat -peanut	14	3 980	36	9 170
wheat -peanut -other	8	8 020	63	16 700
wheat -cotton	12	2 270	42	6 910
wheat -cotton -other	10	2 900	90	8 310
wheat -other	4	4 150	50	10 250
wheat -maize	60	1 750	50	6 390
wheat -maize -other	21	1 650	81	11 360
wheat -maize -peanut	34	6 560	59	12 140
wheat -maize -peanut -cotton	9	11 250	78	17 210
wheat -maize -peanut -other	7	2 550	57	7 090
wheat -maize -peanut -cotton -other	5	6 610	60	12 630
wheat -maize -cotton	92	3 390	68	9 810
wheat -maize -cotton -other	44	3 470	73	12 640
all farms	344	3 650	64	10 150

Note: only cropping pattern with more than one case are listed
^{1} average of those farms actually having any kind of off-farm income

Annex Table 14   Net income of selected crops at the survey sites

	wheat profit [¥ year^{-1}]			maize profit [¥ year^{-1}]				peanut profit [¥ year^{-1}]	cotton profit [¥ year^{-1}]
	cash^{1}	food^{1}	total^{2}	cash^{1}	food^{1}	feedgrain^{1}	total^{2}		
TS #1	580	780	1 110	590	250	220	500		2 410
TS #2	410	890	1 140	710		390	740		1 240
TS #3	630	520	980	1 200		880	1 530		2 950
TS #4	850	540	720	740		1 090	980		2 030
TS #5	960	1 010	1 980	400	290	720	610	4 110	
TS #6	1 350	1 140	2 280	1 320	550	1 070	1 460		800
TS #7	690	630	1 100	1 050	350	1 380	1 290		2 320
TS #8	810	500	670	1 030	220	1 180	1 150		2 400
TS #9	2 000	840	2 390	1 410	340	1 040	1 850		3 270
TS #10	3 060	830	3 830	1 590	110	1 000	1 550	4 490	2 180
all	1 300	740	1 650	1 070	240	950	1 220	4 040	2 220

Note: ^{1} this the average profit of those farmer actually selling, eating, or feeding this crop
^{2} this the average profit of all farm household cultivating this crop

Annex Table 15   Income share structure of off-farm income sources at the survey sites

county	Liangshan		Huimin		Kaifeng		Quzhou		Yanjin		all
township	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	farms
farming income [%]	53	22	42	38	49	60	54	58	46	72	50
total off-farm total share[1] [%]	42	71	38	43	26	33	36	36	41	19	38
total off-farm share[2] [%]	65	84	49	55	54	63	63	59	69	33	60
local off-farm total share[1] [%]	21	36	18	18	1	0	11	20	21	7	15
local off-farm share[2] [%]	55	67	36	37	13	13	49	53	64	21	46
migration total share[1] [%]	12	25	15	14	14	16	22	13	13	7	15
migration share[2] [%]	59	72	61	51	47	73	63	26	54	37	59
family business total share[1] [%]	9	10	5	11	11	17	3	4	7	5	8
family business share[2] [%]	62	41	33	51	51	61	25	24	42	40	45

Note: livestock net income is excluded
[1] average share of this income source including those without this income
[2] average share of only those household actually having this kind of income

Annex Table 16   Other cultivated crops in the provinces of North China Plain in 2003

	soybean [1000 ha]	rapeseed [1000 ha]	potato [1000 ha]	rice [1000 ha]	orchards [1000 ha]	vegetables [1000 ha]
Hebei	380	30	380	80	1 060	1 070
Jiangsu	390	680	130	1 840	180	1 340
Anhui	1 010	1 010	440	1 970	90	650
Shandong	320	20	400	110	750	2 003
Henan	610	380	470	500	350	1 503
NCP Provinces[1]	2 710	2 130	1 820	4 500	2 430	6 602
China	12 500	7 143	n.a.	28 200	9 098	17 353

Source: (National Bureau of Statistics of China 2003), (Anhui Province Statistical Bureau 2003), (Henan Province Statistical Bureau 2003), (Hebei Province Statistical Bureau 2003), (Jiangsu Province Statistical Bureau 2003), (Shandong Province Statistical Bureau 2003)
Note: [1] data for Hebei, Jiangsu, Anhui, Shandong and Henan, this includes those parts of these provinces which not belong to the NCP and excludes the municipality of Beijing and Tianjin

Annex Table 17   Characteristics of main wheat varieties

variety name	cases [amount]	yield [t ha⁻¹]	cases of bought seeds [amount]	sowing rate [kg ha⁻¹]	seed price [¥ kg⁻¹]
no name available	154 (43%)	5.76	110 (71%)	263	2.56
Jining-12 (济宁12)	14 (4 %)	5.18	8 (57%)	195	2.22
Lumai no.1 (鲁麦1号)	24 (7%)	4.80	17 (71%)	195	2.46
Yumai-18 (豫麦18)	60 (17%)	5.40	46 (77%)	195	2.76
Yumai-34 (豫麦34)	56 (16%)	6.46	52 (93%)	218	2.36
all cases	361	5.67	277 (77%)	233	2.52

Annex Table 18   Characteristics of maize varieties

variety name	cases [amount]	yield [t ha^{-1}]	sowing rate [kg ha^{-1}]	seed price [¥ kg^{-1}]
no name available	98 (34%)	6.90	42	8.0
Ludan50 (鲁单50)	9 (3%)	4.41	59	5.6
Nongda108 (农大108)	101 (35%)	6.05	42	7.4
Yuyu 22 (豫玉22)	12 (4%)	5.36	50	8.0
Zhengdan958 (郑单958)	11 (4%)	6.54	40	6.4
all cases	289	6.37	43	7.8

Annex Table 19   Peanut cultivation characteristics at the survey sites

county (township)	Kaifeng (TS #5)	Yanjin (TS #10)	all farms
cultivation area [ha]	0.57	0.62	0.51
buying seeds [%]	23	0	18
seed cost [¥ ha^{-1}]	470	0	280
fertilizer cost [¥ ha^{-1}]	680	910	600
nitrogen input [kg ha^{-1}]	105	190	135
nitrogen price [¥ kg^{-1}]	7.98	4.90	6.35
nitrogen use efficiency [kg kg^{-1}]	34	22	29
irrigation cost [¥ ha^{-1}]	610	520	490
herbicides usage[1] [%]	39	97	58
insecticides usage [%]	71	91	70
insecticide cost [¥ ha^{-1}]	180	160	145
plastic usage [¥ ha^{-1}]	55	0	25
variable cost [¥ ha^{-1}]	2 540	2 050	2 130
yield [t ha^{-1}]	3.21	3.50	3.31
peanut selling farms [%]	100	100	90
sold-harvest ratio [%]	87	85	76
crop price [¥ kg^{-1}]	3.29	3.01	3.08
calculated revenue [¥ ha^{-1}]	9 880	10 770	10 180
calculated gross margin [¥ ha^{-1}]	7 350	8 720	8 050

Note: [1] average herbicide costs are 110 ¥ ha^{-1}

Annex Table 20   Characteristics of peanut cultivation in the provinces of the North China Plain in 2003

province	Hebei	Jiangsu	Anhui	Shandong	Henan
total peanut area [1000 ha]	490	210	270	990	960
yield [t ha^{-1}]	3.06	1.98	1.67	3.45	1.38
seed costs [¥ ha^{-1}]	1 082	983	864	1 124	1 017
fertilizer costs [¥ ha^{-1}]	689	755	384	954	426
manure costs [¥ ha^{-1}]	111	84	123	183	24
costs plastic to cover soil [¥ ha^{-1}]	66	56		200	
pesticide costs [¥ ha^{-1}]	126	186	99	164	165
machinery costs [¥ ha^{-1}]	195	261	180	260	288
irrigation costs [¥ ha^{-1}]	234	140		84	63
total costs [¥ ha^{-1}]	4 875	4 620	3 510	5 790	4 305
revenue [¥ ha^{-1}]	11 205	7 560	5 385	12 120	4 935
net profit [¥ ha^{-1}]	5 670	2 430	1 590	5 265	150

Source: (National Bureau of Statistics of China 2003), (National Development and Reform Commission 2004)

Annex Table 21   Cotton cultivation characteristics at the survey sites

county	Liangshan		Huimin		Kaifeng	Quzhou		all
township	#1	#2	#3	#4	#6	#7	#8	farms
cultivation area [ha]	0.28	0.16	0.27	0.19	0.34	0.22	0.27	0.25
buying seeds [%]	90	91	97	97	93	77	86	93
seed costs [¥ ha^{-1}]	520	550	690	820	550	1 040	780	730
fertilizer costs [¥ ha^{-1}]	800	1 100	1 710	1 600	1 380	900	1 160	1 230
nitrogen input [kg ha^{-1}]	75	155	250	250	130	120	185	180
nitrogen price [¥ kg^{-1}]	11.07	8.37	7.41	6.89	13.69	9.05	7.13	8.41
nitrogen use efficiency [kg kg^{-1}]	41	28	15	17	18	39	20	24
irrigation costs [¥ ha^{-1}]	35	220	110	260	260	280	270	200
herbicides usage[1] [%]	20	9	90	90	7	65	46	53
insecticides usage [%]	40	73	100	100	93	62	75	75
insecticide costs [¥ ha^{-1}]	360	810	1 050	810	820	650	1 150	750
costs of plastic [¥ ha^{-1}]	155	300	115	275	25	170	125	155
variable cost [¥ ha^{-1}]	2 220	3 350	4 260	4 530	3 210	3 660	4 060	3 590
yield [t ha^{-1}]	2.15	2.67	3.20	3.06	1.36	3.35	3.20	2.79
crop price [¥ kg^{-1}]	4.88	4.62	4.84	4.87	4.16	4.23	4.09	4.53
calculated revenue [¥ ha^{-1}]	9 740	12 100	14 400	13 860	6 130	15 230	14 340	12 630
calculated gross margin [¥ ha^{-1}]	7 520	8 750	10 240	9 330	2 920	11 570	10 280	9 050

Note: [1] average herbicide costs are 110 ¥ ha^{-1}

Annex Table 22   Characteristics of cotton cultivation in the provinces of the North China Plain in 2003

province	Hebei	Jiangsu	Anhui	Shandong	Henan
total cotton area [1000 ha]	580	370	390	880	930
yield [t ha^{-1}]	0.95	0.71	0.89	1.04	0.55
seed costs [¥ ha^{-1}]	503	458	407	401	410
fertilizer costs [¥ ha^{-1}]	954	1 260	1 424	1 337	800
manure costs [¥ ha^{-1}]	93	110	285	269	99
costs of plastic to cover soil [¥ ha^{-1}]	308	137	81	306	56
pesticides costs [¥ ha^{-1}]	450	480	570	518	219
machinery costs [¥ ha^{-1}]	371	125	134	263	143
irrigation costs [¥ ha^{-1}]	494	183	147	212	155
total costs [¥ ha^{-1}]	7 455	7 890	8 220	8 505	6 150
revenue [¥ ha^{-1}]	19 605	13 740	15 315	19 635	10 035
net profit [¥ ha^{-1}]	11 280	5 055	6 540	10 020	3 375

Source: (NATIONAL BUREAU OF STATISTICS OF CHINA 2003), (NATIONAL DEVELOPMENT AND REFORM COMMISSION 2004)

Annex Table 23   Pre-selected variables for income structure regression models

code	shortcut	unit	explanation
V$_{001}$	family size	[per.]	number of family members
V$_{005}$	family work force	[LU]	amount of total family labour
V$_{004}$	highest family education	[1-4]	highest education of family members
V$_{003}$	household head age	[a]	age of household head
V$_{041}$	pure wheat-maize pattern	[1,0]	cultivation of only wheat maize
V$_{014}$	farmland	[ha]	farmland of the farm household
V$_{016}$	relative farmland	[%]	farmland per family as percent of village average
V$_{020}$	rent-in additional land	[1,0]	farm household rent-in additional land
V$_{021}$	long term wheat yield	[ha]	estimated long term wheat yield on farm plots
V$_{076}$	village average wheat yield	[t ha^{-1}]	average yield at village level
V$_{015}$	village average farmland	[ha]	village average farmland per farm household
V$_{025}$	village share income type 1	[%]	share of farm households at village level which have only farming net cash income

Annex Table 24   Pre-selected variables for income level regression models

code	shortcut	unit	explanation
V_{001} family size	[per.]	number of family members
V_{005} family work force	[LU]	amount of total family labour
V_{004} highest family education	[1-4]	highest family education of all family labour
V_{003} household head age	[a]	age of household head
V_{010} labour type 4 on farm	[1,0]	labour type 4 (temporary off-farm and temporary on own farm) on farm available
V_{012} labour type 5 on farm	[1,0]	labour type 5 (fulltime off-farm) on farm available
V_{041} pure wheat-maize pattern	[1,0]	cultivation of only wheat maize
V_{014} farmland	[ha]	total farmland per family
V_{016} relative farmland	[%]	farmland per family as percent of village average
V_{021} long term wheat yield	[ha]	estimated long term wheat yield on farm plots
V_{015} village average farmland	[ha]	village average farmland per farm household
V_{031} village average household income	[1 000 ¥]	average household income at village level
V_{076} village average wheat yield	[t ha^{-1}]	average yield at village level

Annex Table 25   Pre-selected variables used in nitrogen input regression models

code	shortcut	unit	explanation
V_{022} household income type 1	[1,0]	only farming net cash income
V_{004} highest family education	[1-4]	highest family education inside farm family
V_{010} labour type 4 on farm	[0,1]	labour type 4 (temporary off-farm and temporary on own farm) on farm available
V_{012} labour type 5 on farm	[0,1]	labour type 5 (fulltime off-farm) on farm available
V_{041} pure wheat and maize cultivation	[1,0]	cultivation of only wheat maize
V_{014} farmland	[ha]	total farmland per family
V_{016} relative farmland	[%]	farmland per family as percent of village average
V_{029} high household income	[1,0]	household income exceeds 11 050 ¥
V_{030} low household income	[1,0]	household income is less than 4 950 ¥
V_{032} relative household income	[%]	household income as percentage of village average household income
V_{038} full-farming income	[1,0]	income share from farming exceeds 50%
V_{042} manure usage	[1,0]	application of manure
V_{021} long term wheat yield	[¥ kg^{-1}]	estimated long term wheat yield on farm plots
nitrogen price	[¥ kg^{-1}]	fertilizer costs to nitrogen input ratio
sold-harvest ratio	[%]	amount sold to total harvest ratio
village average nitrogen input	[kg ha^{-1}]	average nitrogen input at village level
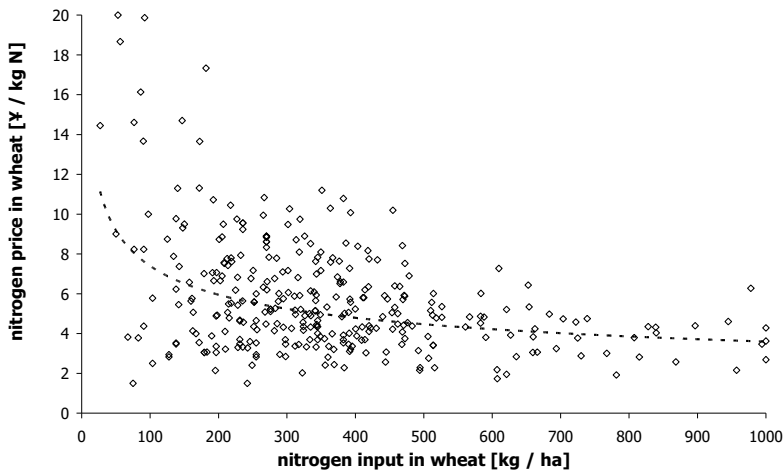
Annex Figure 1   Relationship between average nitrogen price and average nitrogen input in wheat including an estimated power function
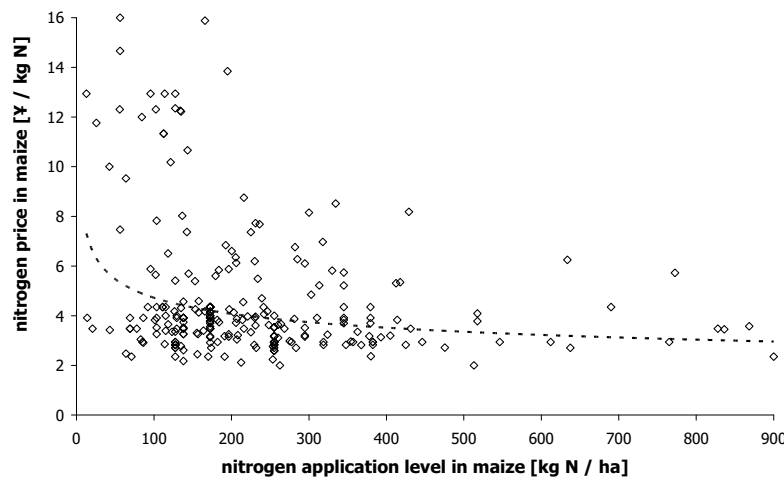
Annex Figure 2   Relationship between average nitrogen price and average nitrogen input in maize including an estimated power function
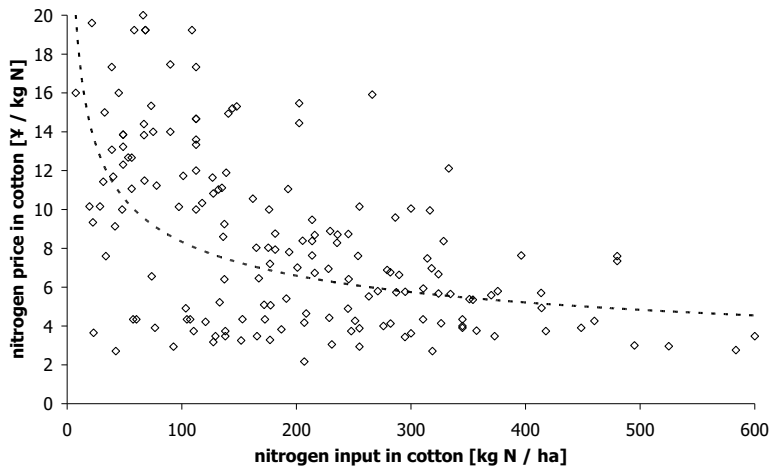
Annex Figure 3   **Relationship between average nitrogen price and average nitrogen input in cotton including an estimated power function**
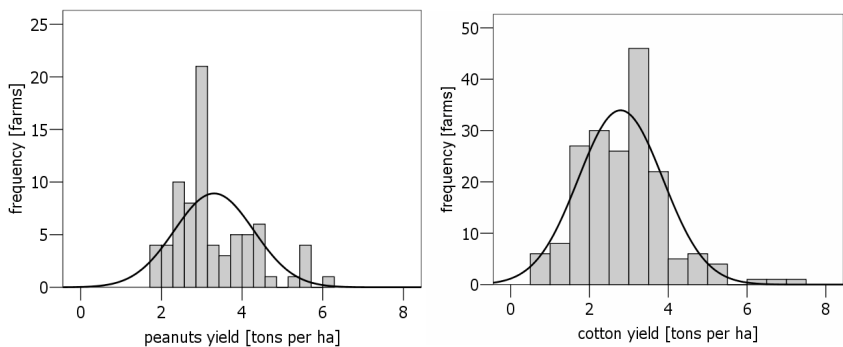
Annex Figure 4   **Histogrammes of yield in peanuts and in cotton**
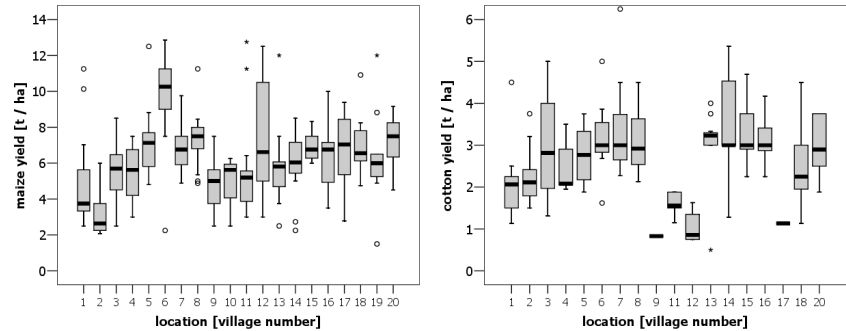
Legend: ° outlier: are cases with values between 1.5 and 3 box lengths from the upper or lower
          edge of the box. The box length is the interquartile range.
        * extreme cases: are cases with values more than 3 box lengths from the upper or lower
          edge of the box. The box length is the interquartile range.
        location: the names and the administrative affiliation of the villages are presented in Table 2

Annex Figure 5   Average maize and cotton yield in 2004 at village level

Annex Table 26   Average maize and cotton yield and distribution of high and low yield between the defined income types

	income type 1	income type 2	income type 3	all
average maize yield [t ha^{-1}]	6.28	6.56	6.32	6.40
share: low maize yield	56%	43%	52%	50%
share: high maize yield	44%	57%	48%	50%
average cotton yield [t ha^{-1}]	2.74	2.92	2.69	2.79
share: low cotton yield	54%	46%	52%	50%
share: high cotton yield	46%	54%	48%	50%
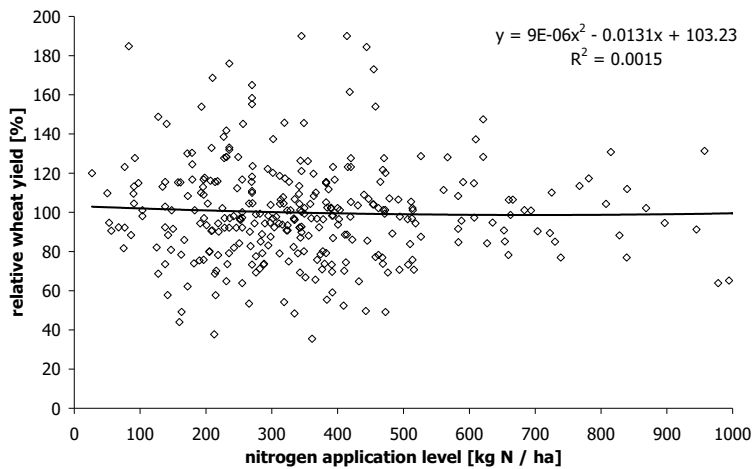
Annex Figure 6   **Relative yield and nitrogen input in wheat including an estimated quadratic function**
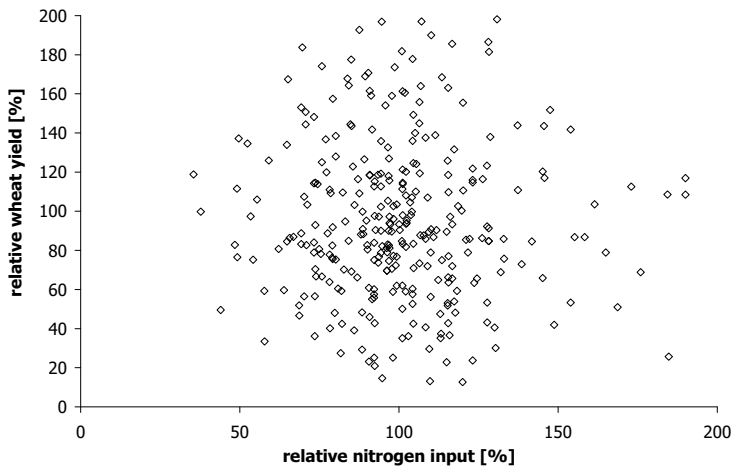
Annex Figure 7   **Relative yield and relative nitrogen input in wheat**

Annex Table 27   Adjusted share of farm households belonging to each relative yield to relative nitrogen input group

	wheat	maize	cotton
high relative yield (>100%), low relative nitrogen input (≤100%)	25.5%	22.3%	26.4%
high relative yield (>100%), high relative nitrogen input (>100%)	22.5%	27.1%	17.4%
low relative yield (≤100%), low relative nitrogen input (≤100%)	28.1%	32.2%	27.1%
low relative yield (≤100%), high relative nitrogen input (>100%)	23.1%	17.5%	27.0%
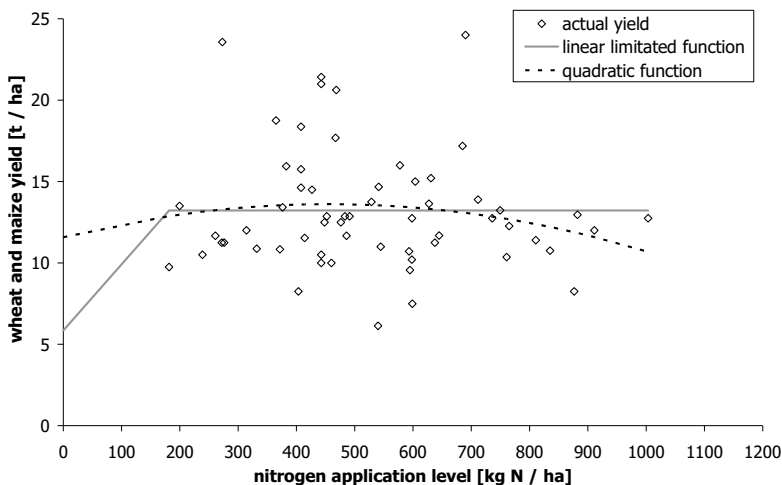
Annex Figure 8   Scatter plot of the relationship between nitrogen input and yield in aggregated wheat and maize cultivation including an estimated linear limited and an quadratic function

Annex Table 28   Quadratic and Liebig yield function of aggregated wheat and maize

	only wheat	only maize	wheat and maize	
	quadratic yield function	quadratic yield function	quadratic yield function	Liebig yield function
model ft [r²]	0.01	0.04	0.03	<0.01
constant [t ha^{-1}]	6.70	4.33	11.58	5.82
nitrogen input [kg ha^{-1}]	0.0016	0.0187	0.0089	0.082
yield at limitation level [kg ha^{-1}]	n/a	n/a	n/a	13.23
nitrogen input at limitation level [kg ha^{-1}]	n/a	n/a	n/a	90
square of nitrogen input	-3.1 10^{-6}	-3.5 10^{-5}	-9.8 10^{-6}	n/a

Annex Table 29   Pre-selected variables used in yield regression models

code	shortcut	unit	explanation
V_{022} household income type 1	[1,0]	only farming net cash income
V_{004} highest family education	[1-4]	highest education of family members
V_{010} labour type 4 on farm	[0,1]	labour type 4 (temporary off-farm and temporary on own farm) on farm available
V_{012} labour type 5 on farm	[0,1]	labour type 5 (fulltime off-farm) on farm available
V_{041} pure wheat and maize cultivation	[1,0]	cultivation of only wheat maize
V_{019} farmland farming work force ratio	[ha LU^{-1}]	farming labour farmland ratio
V_{014} farmland	[ha]	total farmland per family
V_{016} relative farmland	[%]	farmland per family as percent of village average
V_{029} high household income	[1,0]	household income exceeds 11 050 ¥
V_{030} low household income	[1,0]	household income is less than 4 950 ¥
V_{032} relative household income	[%]	household income as percentage of village average household income
V_{042} general manure usage	[1,0]	application of manure
cultivation area	[ha]	cultivation area of the crop

Annex Table 30   Pre-selected variables for the stochastic frontier analysis

code	shortcut	unit	explanation
V_{001} family size	[per.]	number of family members
V_{005} family work force	[LU]	amount of total family labour
V_{004} highest family education	[1-4]	highest family education of all family labour
V_{003} household head age	[a]	age of household head
V_{010} labour type 4 on farm	[1,0]	labour type 4 (temporary off-farm and temporary on own farm) on farm available
V_{012} labour type 5 on farm	[1,0]	labour type 5 (fulltime off-farm) on farm available
V_{041} pure wheat-maize pattern	[1,0]	cultivation of only wheat maize
V_{016} relative farmland	[%]	farmland per family as percent of village average
V_{020} rent-in farmland	[1,0]	farm household rent-in additional land

Annex Table 31   Characteristics of farm below and above average nitrogen use

	all farms with wheat	farms below average nitrogen balance	farms above average nitrogen balance
number of farms	322	161 (50 %)	161 (50 %)
nitrogen surplus at farm level [kg N ha^{-1}]	113	30	196
nitrogen surplus ratio at farm level [%]	85	22	148
wheat: nitrogen surplus [kg N ha^{-1}]	201	62	339
wheat nitrogen surplus ratio [%]	136	39	233
number of farms	272	138 (51 %)	134 (49 %)
maize: nitrogen surplus [kg N ha^{-1}]	68	25	112
maize: nitrogen surplus ratio [%]	51	21	81
number of farms	77	33 (43 %)	44 (57 %)
peanut: nitrogen surplus [kg N ha^{-1}]	73	55	86
peanut: nitrogen surplus ratio [%]	112	72	141
number of farms	172	86 (50 %)	86 (50 %)
cotton: nitrogen surplus [kg N ha^{-1}]	48	4	92
cotton: nitrogen surplus ratio [%]	49	16	82

Annex Table 32   Pre-selected variables used in nitrogen balance type models

code	shortcut	unit	explanation
V_{001} family size	[pers.]	number of family members
V_{005} family work force	[LU]	amount of total family labour
V_{004} highest family education	[1-5]	highest education of family members
V_{010} labour type 4 on farm	[1,0]	labour type 4 (temporary off-farm and temporary on own farm) on farm available
V_{012} labour type 5 on farm	[1,0]	labour type 5 (fulltime off-farm) on farm available
V_{041} pure wheat-maize pattern	[1,0]	cultivation of only wheat maize
V_{019} farmland farming work force ratio	[ha LU^{-1}]	farming labour farmland ratio
V_{014} farmland	[ha]	total farmland per family
V_{016} relative farmland	[%]	farmland per family as percent of village average
V_{020} rent-in farmland	[1,0]	farm household rent-in additional land
V_{029} high household income	[1,0]	household income exceeds 11 050 ¥
V_{030} low household income	[1,0]	household income is less than 4 950 ¥
V_{032} relative household income	[%]	household income as percentage of village average household income
V_{038} full-farming income	[1,0]	income share from farming exceeds 50%
V_{048} nitrogen price all farm crops	[¥ kg^{-1}]	average weighted nitrogen price at all crops cultivated by the farm household
V_{042} manure usage	[1,0]	application of manure
V_{079} wheat sold-harvest ratio	[%]	amount sold to total harvest ratio
V_{021} long term wheat yield	[t ha^{-1}]	estimated long term wheat yield on farm plots
V_{022} income type 1	[1,0]	only farming net cash income
V_{076} village average wheat yield	[t ha^{-1}]	average yield at village level
V_{067} village average nitrogen input	[kg ha^{-1}]	average nitrogen input at village level

Annex Table 33   Pre-selected variables used in nitrogen cluster

code	shortcut	unit	explanation
V_{041} pure wheat-maize pattern	[1,0]	cultivation of only wheat maize
V_{014} farmland	[ha]	total farmland per family
V_{016} relative farmland	[%]	farmland as percent of village average
V_{020} rent-in farmland	[1,0]	farm household rent-in additional land
V_{028} farm household income	[1000¥]	total cash income of farm household
V_{032} relative household income	[%]	household income as percentage of village average household income
V_{040} off-farm income ratio	[%]	off-farm income to household income ratio
V_{069} wheat nitrogen price	[¥ kg^{-1}]	fertilizer costs to nitrogen input ratio
V_{070} wheat manure usage	[1,0]	application of manure
V_{079} wheat sold-harvest ratio	[%]	amount sold to total harvest ratio
V_{021} long term wheat yield	[t kg^{-1}]	estimated long term wheat yield on farm plots
V_{022} income type 1	[1,0]	only farming net cash income
V_{023} income type 3	[1,0]	farming and local off-farm job income
V_{024} income type 2	[1,0]	farming and income from migration

Annex Table 34   Expensive nitrogen fertilizer distribution

group	use of expensive nitrogen[1] at all crops	group	use of expensive nitrogen[1] in wheat
all farm households	210 out of 322 (65%)	all farm households	142 out of 322 (44%)
nitrogen balance type 1	51 out of 78 (65%)	nitrogen balance type 1	32 out of 78 (41%)
cluster 1-A	6 out of 12 (50%)	cluster 1-A	5 out of 12 (42%)
cluster 1-B	26 out of 38 (68%)	cluster 1-B	15 out of 38 (40%)
cluster 1-C	16 out of 24 (67%)	cluster 1-C	10 out of 24 (42%)
nitrogen balance type 3	64 out of 103 (62%)	nitrogen balance type 3	43 out of 103 (42%)
cluster 3-A	10 out of 19 (53%)	cluster 3-A	8 out of 19 (42%)
cluster 3-B	12 out of 17 (71%)	cluster 3-B	7 out of 17 (41%)
cluster 3-C	27 out of 47 (57%)	cluster 3-C	17 out of 47 (36%)
cluster 3-D	11 out of 15 (73%)	cluster 3-D	8 out of 15 (53%)

Note   [1] all fertilizer (usually compound fertilizer) with an nitrogen price of more than 10 ¥ per kg

Annex Table 35   Easy observable characteristics

code	shortcut	unit	explanation
V_{010}	labour type 4 on farm	[1,0]	labour type 4 (temporary off-farm and temporary on own farm) on farm available
V_{012}	labour type 5 on farm	[1,0]	labour type 5 (fulltime off-farm) on farm available
V_{041}	pure wheat-maize cropping pattern	[1,0]	cultivation of only wheat and maize
V_{017}	high relative farmland	[1,0]	relative farmland exceeds 100%
V_{033}	high relative household income	[1,0]	relative households income exceeds 100%
V_{038}	full-farming income	[1,0]	income share from farming exceeds 50%
V_{078}	high relative wheat yield	[1,0]	relative yield exceeds 100%

Annex Table 36   Raster of nitrogen balance type 1

farm types / farm households	C 6 (8%)	L 5 (6%)	E 4 (5%)
labour type 4 on farm [1,0]	0	1	0
labour type 5 on farm [1,0]	0	0	0
pure wheat-maize cropping pattern [1,0]	0	0	1
high relative farmland [1,0]	0	0	0
high relative household income [1,0]	0	1	0
full-farming income [1,0]	1	0	1
high relative wheat yield [1,0]	1	0	1

Annex Table 37   Raster of nitrogen balance type 2

farm types	A	B	C	E	J	K
farm households	11 (8%)	9 (6%)	9 (6%)	6 (4%)	6 (4%)	5 (%)
labour type 4 on farm [1,0]	0	0	0	0	1	0
labour type 5 on farm [1,0]	0	0	0	0	1	1
pure wheat-maize cropping pattern [1,0]	0	0	0	1	0	0
high relative family farmland [1,0]	1	0	0	0	1	0
high relative household income [1,0]	0	0	0	0	1	1
full-farming income [1,0]	1	1	1	1	0	0
high relative wheat yield [1,0]	0	0	1	1	1	1
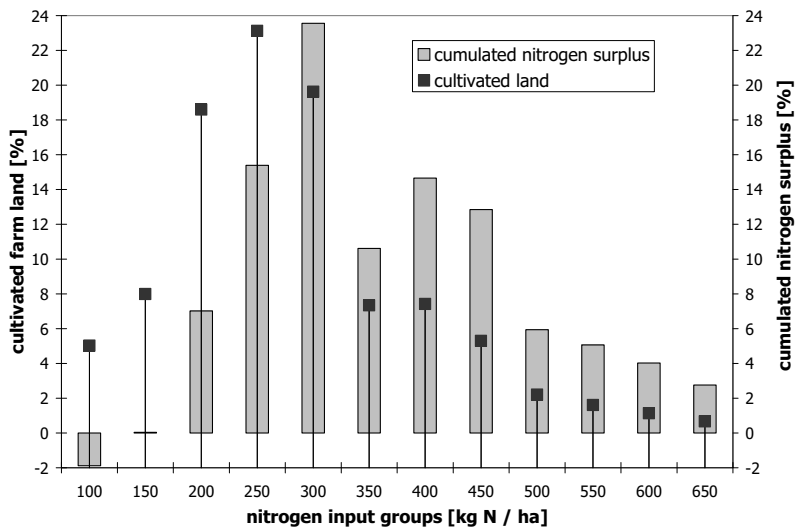
Annex Figure 9   Overall nitrogen surplus of all crops and cultivated farmland in relation to the nitrogen application rate
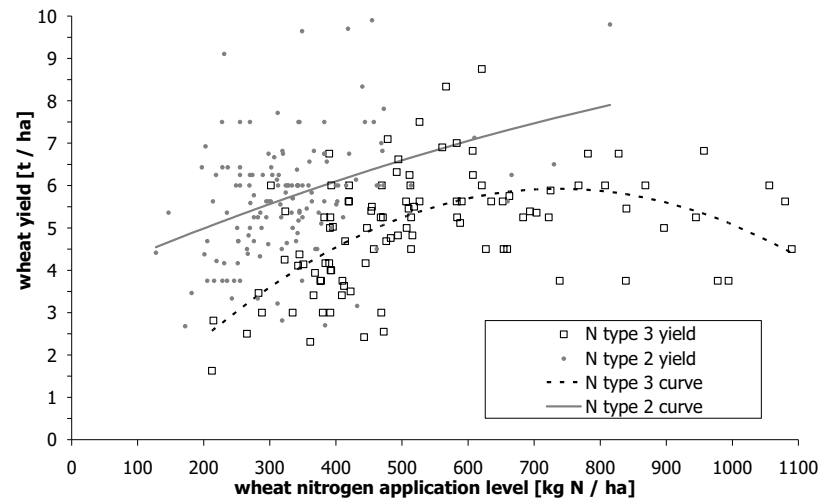
Annex Figure 10   Wheat production function of nitrogen balance type 2 and type 3 farm households
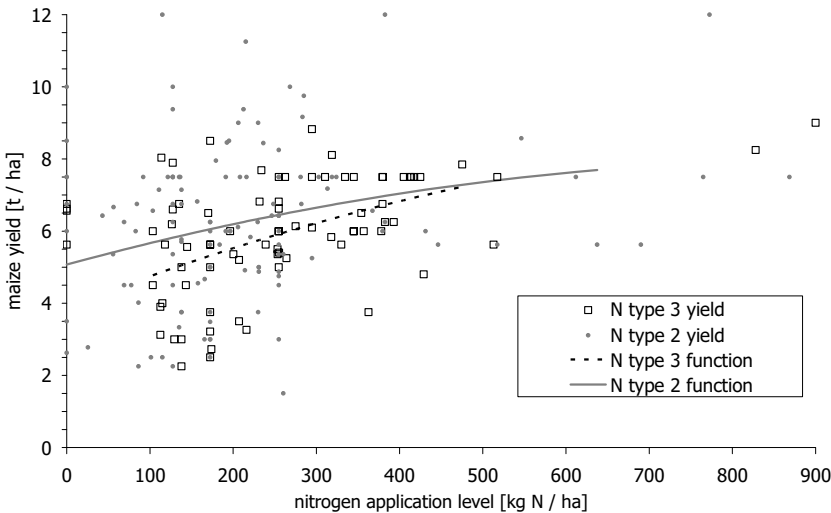
Annex Figure 11   Maize production function nitrogen balance type 2 and type 3 farm households
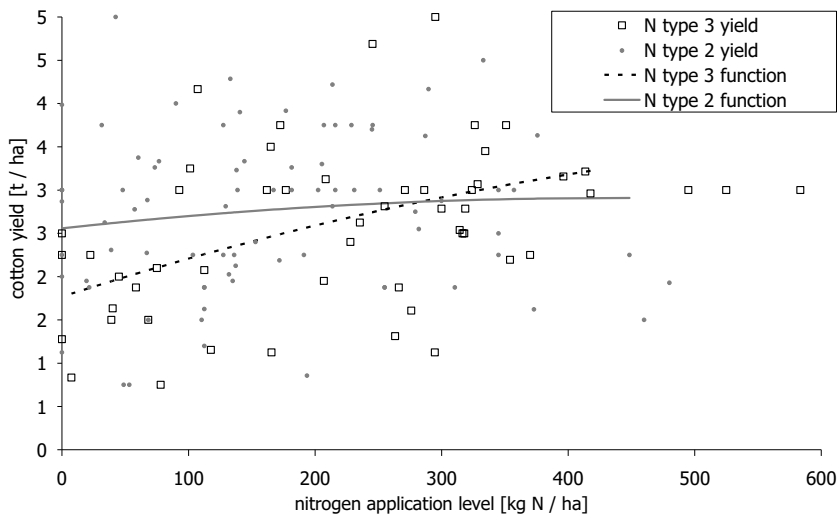
Annex Figure 12   Cotton production function nitrogen balance type 2 and nitrogen balance type 3 farm households
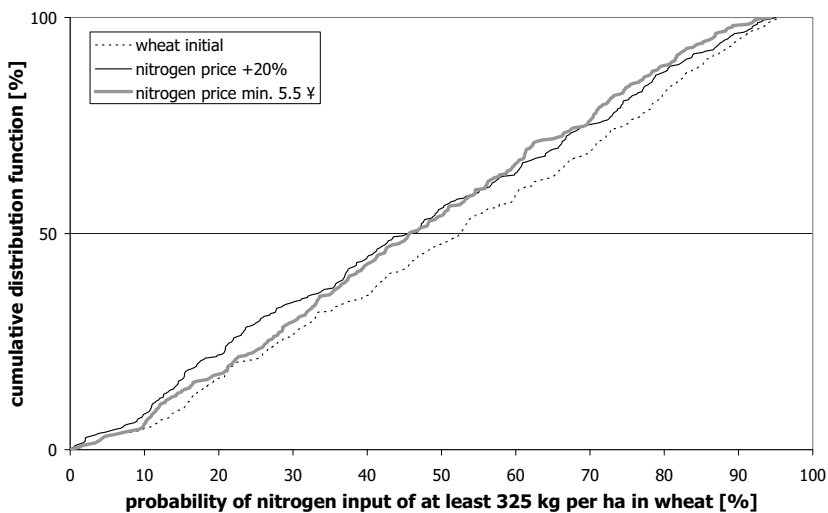
Annex Figure 13   Cumulative distribution function of high nitrogen input in wheat

$$G(Y, N, Q) = 1277Y - 5.306N - 205.9Q - 205$$

G = gross margin [¥ ha^{-1}]
Y = yield [t ha^{-1}]
N = nitrogen input [kg ha^{-1}]
Q = nitrogen price [¥ kg^{-1}]

Annex Equation 1   Multiple linear regression model of gross margin in wheat

$$GM(Y, N, Q) = 1077Y - 4.639N - 174.9P - 395$$

GM = gross margin
Y = yield [t ha^{-1}]
N = nitrogen input [kg ha^{-1}]
Q = nitrogen price [¥ kg^{-1}]

Annex Equation 2   Multiple linear regression model of gross margin in maize

$$GM(Y, N, Q) = 4229Y - 6.626N - 114.3P - 657$$

GM = gross margin
Y = yield [t ha^{-1}]
N = nitrogen input [kg ha^{-1}]
Q = nitrogen price [¥ kg^{-1}]

Annex Equation 3   Multiple linear regression model of gross margin in cotton

Annex Box 1: Survey questionnaire

Name of interviewer: _____

Date of interview: _____   Interview number: _____

1   General *(filled in by interviewer)*

1.1.1   Explain the administrative affiliation

province	1.1.1.1	
county	1.1.1.3	
administrative village	1.1.1.5	

prefecture	1.1.1.2	
township	1.1.1.4	
natural village	1.1.1.6	

1.1.2   Distance from the natural village to the township [km] _____

2   Farm description

2.1   Farm characteristics

2.1.1   Who is managing this farm:

managed by a single farm family	2.1.1.1
managed by a cooperative	2.1.1.2
part of a state company	2.1.1.3
farm family don't cultivate their land, rented land out	2.1.1.4

other: | 2.1.1.5

2.1.2   Name of the family head: _____

2.1.3   What did you mainly produced since 2000 (please tick)

	2000	2001	2002	2003	2004
wheat	2.1.3.1	2.1.3.2	2.1.3.3	2.1.3.4	2.1.3.5
maize	2.1.3.6	2.1.3.7	2.1.3.8	2.1.3.9	2.1.3.10
rice	2.1.3.11	2.1.3.12	2.1.3.13	2.1.3.14	2.1.3.15
soy bean	2.1.3.16	2.1.3.17	2.1.3.18	2.1.3.19	2.1.3.20
cotton	2.1.3.21	2.1.3.22	2.1.3.23	2.1.3.24	2.1.3.25
vegetables	2.1.3.26	2.1.3.27	2.1.3.28	2.1.3.29	2.1.3.30
oil bearing crops	2.1.3.31	2.1.3.32	2.1.3.33	2.1.3.34	2.1.3.35
fruit trees	2.1.3.36	2.1.3.37	2.1.3.38	2.1.3.39	2.1.3.40
livestock	2.1.3.41	2.1.3.42	2.1.3.43	2.1.3.44	2.1.3.45
forage	2.1.3.46	2.1.3.47	2.1.3.48	2.1.3.49	2.1.3.50

2.1.4   How much farm land [mǔ] do you cultivate now: _____

2.2 Farm household

2.2.1 How many members live in this household (for how many people food is needed)_____

2.2.2 How many of these household members earn money (that money is part of the household income)_____

2.2.3 Describe these family members: their relation to household head, their age, their main living place (in the farm house or in another house), their highest level of education, the position inside the village and their occupation (whether they are available for farm work). If having an off-farm job or non-agricultural on-farm job, describe this off-farm job more in detail: kind of job is it, how many months does this job take, where is this job located and what is the income from this job?

relation to household head [code]	sex [code]	living place [code]	age [years]	education [code]	position in village [code]	occupation [code]	detailed discretion of off-farm job or non-agricultural on-farm job			
							kind of job [job-code]	duration in months per year [month]	working place [code]	annual income [¥]
2.2.3.1	2.2.3.2	2.2.3.3	2.2.3.4	2.2.3.5	2.2.3.6	2.2.3.7	2.2.3.8	2.2.3.9	2.2.3.10	2.2.3.11
2.2.3.12	2.2.3.13	2.2.3.14	2.2.3.15	2.2.3.16	2.2.3.17	2.2.3.18	2.2.3.19	2.2.3.20	2.2.3.21	2.2.3.22
2.2.3.23	2.2.3.24	2.2.3.25	2.2.3.26	2.2.3.27	2.2.3.28	2.2.3.29	2.2.3.30	2.2.3.31	2.2.3.32	2.2.3.33
2.2.3.34	2.2.3.35	2.2.3.36	2.2.3.37	2.2.3.38	2.2.3.39	2.2.3.40	2.2.3.41	2.2.3.42	2.2.3.43	2.2.3.44
2.2.3.45	2.2.3.46	2.2.3.47	2.2.3.48	2.2.3.49	2.2.3.50	2.2.3.51	2.2.3.52	2.2.3.53	2.2.3.54	2.2.3.55
2.2.3.56	2.2.3.57	2.2.3.58	2.2.3.59	2.2.3.60	2.2.3.61	2.2.3.62	2.2.3.63	2.2.3.64	2.2.3.65	2.2.3.66
2.2.3.67	2.2.3.68	2.2.3.69	2.2.3.70	2.2.3.71	2.2.3.72	2.2.3.73	2.2.3.74	2.2.3.75	2.2.3.76	2.2.3.77
2.2.3.78	2.2.3.79	2.2.3.80	2.2.3.81	2.2.3.82	2.2.3.83	2.2.3.84	2.2.3.85	2.2.3.86	2.2.3.87	2.2.3.88

household head (1)
spouse (2)
children (3)
other (4)

male (1)
female (2)

illiterate (1)
primary school (2)
middle school (3)
high school (4)
college or above (5)

not working at all (1)
going to school (2)
fulltime on own farm all the time (3)
only when needed on own farm (4)
permanent fulltime off-farm (5)

same prefecture (1)
other prefecture in same province (2)
other province (3)

in farm house (1)
other house (2)

member of the village committee (1)
former member of the village committee (2)

government employee (3)
former government employee (4)

2.3   Land resources and land use rights

2.3.1   Describe the plots in detail which this farm has cultivated or left fallow in 2004: Since when [year] do you cultivate this plot? Has this plot been left fallow in 2004? If yes, for what reason? What kind of land or kind of land use contract do you have?

plot	area [mǔ]	cultivated this plot since [year]	left fallow [code]	crops [code]	kind of land use right [code]	if the plot is rented in, describe it in detail:			own land: length of use [years]	average wheat yield [jin / mǔ]
						kind of rent [code]	annual rental payment [¥ / mǔ]	length of contract [month]		
1	2.3.1.1	2.3.1.2	2.3.1.3	2.3.1.4	2.3.1.5	2.3.1.6	2.3.1.7	2.3.1.8	2.3.1.9	2.3.1.10
2	2.3.1.11	2.3.1.12	2.3.1.13	2.3.1.14	2.3.1.15	2.3.1.16	2.3.1.17	2.3.1.18	2.3.1.19	2.3.1.20
3	2.3.1.21	2.3.1.22	2.3.1.23	2.3.1.24	2.3.1.25	2.3.1.26	2.3.1.27	2.3.1.28	2.3.1.29	2.3.1.30
4	2.3.1.31	2.3.1.32	2.3.1.33	2.3.1.34	2.3.1.35	2.3.1.36	2.3.1.37	2.3.1.38	2.3.1.39	2.3.1.40
5	2.3.1.41	2.3.1.42	2.3.1.43	2.3.1.44	2.3.1.45	2.3.1.46	2.3.1.47	2.3.1.48	2.3.1.49	2.3.1.50
6	2.3.1.51	2.3.1.52	2.3.1.53	2.3.1.54	2.3.1.55	2.3.1.56	2.3.1.57	2.3.1.58	2.3.1.59	2.3.1.60

no (0)   land productivity is exhausted (1)   polluted irrigation water (3)
revenue from agriculture too low (2)   not enough family labor (4)

cash (1)
kind (2)

if payment in kind,
estimate value

own land (1)
rented land (chu zu) from…   other farmers in own village (2)
other farmers in other village (3)
own village collective (4)
other village collective (5)

subleased land (zhuan bao) (6)
swapped land (hu huan) with farmers in same village (7)
swapped land (hu huan) with farmers in other village (8)
assigned land (9)

2.3.2   Have you transferred out land to others in 2004, in case describe the contract in detail.

area [mǔ]	kind of transfer, to whom rented out	start of contract [date]	end of contract [date]	year of first renting [year]	type of rent [code]	rent per year [¥/mǔ]
2.3.2.1	2.3.2.2	2.3.2.3	2.3.2.4	2.3.2.5	2.3.2.6	2.3.2.7
2.3.2.8	2.3.2.9	2.3.2.10	2.3.2.11	2.3.2.12	2.3.2.13	2.3.2.14
2.3.2.15	2.3.2.16	2.3.2.17	2.3.2.18	2.3.2.19	2.3.2.20	2.3.2.21

to farmer in same village (1)   to own collective (3)   subleased land (zhuan bao) (5)
to farmer in other village (2)   to other collective (4)   swapped land (hu huan) (6)
assigned land (7)

no rent at all (0)
in cash (1)
in kind (2), estimate value

if farmer has to pay other
farmer to cultivate the land
write "minus" rent

2.3.3   Which crops have you harvested in 2004? These are winter crops sown in autumn 2003 and summer crops sown in spring 2004. Use the crop code list.

wheat or maize variety or crop [crop-code]	sowing area [mǔ]	seed demand [jin]	seed price [¥ / jin]	seed origin [code]
2.3.3.1	2.3.3.2	2.3.3.3	2.3.3.4	2.3.3.5
2.3.3.6	2.3.3.7	2.3.3.8	2.3.3.9	2.3.3.10
2.3.3.11	2.3.3.12	2.3.3.13	2.3.3.14	2.3.3.15
2.3.3.16	2.3.3.17	2.3.3.18	2.3.3.19	2.3.3.20
2.3.3.21	2.3.3.22	2.3.3.23	2.3.3.24	2.3.3.25
2.3.3.26	2.3.3.27	2.3.3.28	2.3.3.29	2.3.3.30
2.3.3.31	2.3.3.32	2.3.3.33	2.3.3.34	2.3.3.35
2.3.3.36	2.3.3.37	2.3.3.38	2.3.3.39	2.3.3.40
2.3.3.41	2.3.3.42	2.3.3.43	2.3.3.44	2.3.3.45

bought from extension service (1)   collected from own fields (4)
free seeds for testing (2)   exchange with other farmers (5)
bought from private seed dealer (3)

2.3.4   Why did you not rent in land? *(Ask only if no land rented in 2.3.1, multi selection)*

I don't need any more land	2.3.4.1
no land available	2.3.4.2
lack of money	2.3.4.3
agriculture is not profitable enough	2.3.4.4
farmer does not have enough working time	2.3.4.5
no hired labour available	2.3.4.6
I don't have the right to get land through these transfers	2.3.4.7
other:	2.3.4.8

2.3.5   Why you didn't rent out land to others? *(Ask only if no land rented out in 2.3.2, multi)*

I need all the land myself, no other income sources	2.3.5.1
nobody wants to rent my land	2.3.5.2
if I rent out land, this land might be taken away from me in the future	2.3.5.3
I don't have the right to rent out land	2.3.5.4
other:	2.3.5.5

2.3.6   Is there "unused" waste land in your village?   yes/no: | 2.3.6.1

2.3.7   If yes, could you attain the use right to this waste land?   yes/no: | 2.3.7.1

2.3.8   Do you know when the last land reallocation (small reallocation among single households or village wide reallocation, *cunzhuang tiaozheng*) occurred in your village? In case of, did your land have been changed and what were the reasons for that change? When do you expect the next reallocation?

			small	village wide
		no, I don't know	2.3.8.1	2.3.8.2
yes	there was a land reallocation in [year], but my land was not changed:		2.3.8.3	2.3.8.4
	there was a land reallocation in [year] and my land was change	due to a change in the household size (death, birth marriage, family member left village)	2.3.8.5	2.3.8.6
		because a family member reached adulthood	2.3.8.7	2.3.8.8
		due to other reasons:	2.3.8.9	2.3.8.10
next reallocation (0=within the next 5 years, 1=in more than 5 years, 2= don't know, 3= there will be no more reallocations			2.3.8.11	2.3.8.12

2.3.9   Describe how your land has been changed:
         (*Ask only if farmer's land was changed, see 2.3.8, multiple answers are possible*):

	small	village wide
I got no plot in return	2.3.9.1	2.3.9.2
I got plots of poorer quality	2.3.9.3	2.3.9.4
I got land of better quality	2.3.9.5	2.3.9.6
land was taken away from me and… I got land that is more far away from my farm	2.3.9.7	2.3.9.8
I got land that is nearer to my farm	2.3.9.9	2.3.9.10
I got land of smaller size	2.3.9.11	2.3.9.12
I got land of larger size	2.3.9.13	2.3.9.14
I got land of the same size at a different location	2.3.9.15	2.3.9.16
no land was taken away from me, I just got more land in that reallocation	2.3.9.17	2.3.9.18
overall my situation has improved	2.3.9.19	2.3.9.20
overall my situation worsened	2.3.9.21	2.3.9.22
overall my situation is unchanged	2.3.9.23	2.3.9.24

2.3.10   What is your opinion on the land reallocation practices in your village? Should they
         continue or should they stop at the present situation? If you say: yes, reallocations
         should stop, or no, reallocations should continue, than explain your opinion:

I don't know (or farmer has no opinion)	2.3.10.1
yes (multi) it is better when farmers use the same plots for a long time	2.3.10.2
the village leader just uses reallocations for his own benefit	2.3.10.3
the reallocations are unfair, I am usually worse off after the reallocation	2.3.10.4
because: 2.3.10.5	
it gives everyone equal rights and equal chances	2.3.10.6
no (multi) it gives land to those who need it the most and who use the land most productively	2.3.10.7
the reallocations are fair, they helps to reward good farmers and punish others	2.3.10.8
because: 2.3.10.9	

2.3.11   Do you have a written certificate which states your land use rights?

	no	2.3.11.1
yes	issued by village committee	2.3.11.2
	issued by township government	2.3.11.3
	issued by county governments or higher authorities	2.3.11.4
	from others	2.3.11.5
	I don't know	2.3.11.6

2.3.12   Have you been affected by land requisitions recently?

	no	2.3.12.1
yes	how much land has been requisitioned [mǔ]?	2.3.12.2
	what were the reasons? (1=industrial use, 2=residential use, 3=road construction)	2.3.12.3
	did you receive any compensation for the land requisitioned?	2.3.12.4
	what was the compensation that you got? [¥ / mǔ]	2.3.12.5
	did the collective owner of the land also receive a compensation?	2.3.12.6
	what was the compensation that the collective owner got? [¥ / mǔ]	2.3.12.7
	I don't know	2.3.12.8

3   Cultivation techniques

All questions regard to crop season 2003/2004 (winter crops sown in autumn 2003 and harvested in spring 2004, summer crops sown and harvested in 2004)

3.1   Soil preparation and sowing

3.1.1   Describe the ploughing for each crop. Which ploughing method is used and who is ploughing. How many people are working and how long does it take to plough all plots of each crop. In case of hired labour or cooperative, what are the total salary costs for ploughing? Describe the costs for machinery in section 4.2.

crop	method [code]	person [code]	labour [person]	working time [hours]	total salary [¥]
wheat	3.1.1.1	3.1.1.2	3.1.1.3	3.1.1.4	3.1.1.5
maize	3.1.1.6	3.1.1.7	3.1.1.8	3.1.1.9	3.1.1.10
	3.1.1.11	3.1.1.12	3.1.1.13	3.1.1.14	3.1.1.15
	3.1.1.16	3.1.1.17	3.1.1.18	3.1.1.19	3.1.1.20
	by hand (1) *use ox (2)* *use tractor (3)*	*farm family (1)* *hired labour (2)*	*together with other farmers (3)* *collective (4)*		

3.1.2   Describe sowing for each crop. Which sowing method is used and who is sowing. How many people are working and how long does it take to sow all plots of each crop. In case of hired labour or cooperative, what are the total salary costs for sowing? Describe the costs for machinery in section 4.2.

crop	method [code]	person [code]	labour [person]	working time [hours]	total salary [¥]
wheat	3.1.2.1	3.1.2.2	3.1.2.3	3.1.2.4	3.1.2.5
maize	3.1.2.6	3.1.2.7	3.1.2.8	3.1.2.9	3.1.2.10
	3.1.2.11	3.1.2.12	3.1.2.13	3.1.2.14	3.1.2.15
	3.1.2.16	3.1.2.17	3.1.2.18	3.1.2.19	3.1.2.20
	by hand (1) *machine (2)*	*farm family (1)* *hired labour (2)*	*together with other farmers (3)* *collective (4)*		

3.2   Irrigation

3.2.1   Which kind of irrigation system do you use? Describe each irrigation application at each crop: month of irrigation, duration of application in hours per mǔ. If this is not possible estimate the costs direct at 3.2.3.

crop	irrigation system [code]	month of irrigation, duration of application in hours per mǔ							
		1. irrigation: month, hours		2. irrigation: month, hours		3. irrigation: month, hours		4. irrigation: month, hours	
3.2.1.1	3.2.1.2	3.2.1.3	3.2.1.4	3.2.1.5	3.2.1.6	3.2.1.7	3.2.1.8	3.2.1.9	3.2.1.10
3.2.1.11	3.2.1.12	3.2.1.13	3.2.1.14	3.2.1.15	3.2.1.16	3.2.1.17	3.2.1.18	3.2.1.19	3.2.1.20
3.2.1.21	3.2.1.22	3.2.1.23	3.2.1.24	3.2.1.25	3.2.1.26	3.2.1.27	3.2.1.28	3.2.1.29	3.2.1.30
3.2.1.31	3.2.1.32	3.2.1.33	3.2.1.34	3.2.1.35	3.2.1.36	3.2.1.37	3.2.1.38	3.2.1.39	3.2.1.40
3.2.1.41	3.2.1.42	3.2.1.43	3.2.1.44	3.2.1.45	3.2.1.46	3.2.1.47	3.2.1.48	3.2.1.49	3.2.1.50
3.2.1.51	3.2.1.52	3.2.1.53	3.2.1.54	3.2.1.55	3.2.1.56	3.2.1.57	3.2.1.58	3.2.1.59	3.2.1.60

no irrigation (0)   *sprinkler irrigation system (3)*
water hose by hand (1)   *underground pipe system (4)*
furrow system by floating the fields (2)

3.2.2   Estimate the electricity or fuel cost of one hour irrigation. Describe the water pump in the machinery section 4.2

	electricity cost per hour [¥ / hour]	fuel costs per hour [¥ / hour]
water hose (by hand)	3.2.2.1	3.2.2.2
furrow system (floating the fields)	3.2.2.3	3.2.2.4
sprinkler irrigation system	3.2.2.5	3.2.2.6

3.2.3   *(Only ask, if no answer possible in 3.2.1 and 3.2.2)* Which kind of irrigation system do you use? If possible estimate the costs of each application for each crop. If not possible estimate the overall costs per season for each crop.

crop	irrigation system	month of irrigation, costs of application								total
		1. irrigation: month, costs [month] ; [¥]		2. irrigation: month, costs [month] ; [¥]		3. irrigation: month, costs [month] ; [¥]		4. irrigation: month, costs [month] ; [¥]		seasonal costs [¥]
wheat	3.2.3.1	3.2.3.2	3.2.3.3	3.2.3.4	3.2.3.5	3.2.3.6	3.2.3.7	3.2.3.8	3.2.3.9	3.2.3.10
maize	3.2.3.11	3.2.3.12	3.2.3.13	3.2.3.14	3.2.3.15	3.2.3.16	3.2.3.17	3.2.3.18	3.2.3.19	3.2.3.20
3.2.3.21	3.2.3.22	3.2.3.23	3.2.3.24	3.2.3.25	3.2.3.26	3.2.3.27	3.2.3.28	3.2.3.29	3.2.3.30	3.2.3.31
3.2.3.32	3.2.3.33	3.2.3.34	3.2.3.35	3.2.3.36	3.2.3.37	3.2.3.38	3.2.3.39	3.2.3.40	3.2.3.41	3.2.3.42
all crops	3.2.3.43	3.2.3.44	3.2.3.45	3.2.3.46	3.2.3.47	3.2.3.48	3.2.3.49	3.2.3.50	3.2.3.51	3.2.3.52

> no irrigation (0)
> water hose by hand (1)
> furrow system by floating the fields (2)
> sprinkler irrigation system (3)
> underground pipe system (4)

3.2.4   Are there any other costs than those mentioned above connected with irrigation?

_____

3.2.5   Imagine your total expenses for irrigation would increase by a certain amount without a change in the price you get for your products. Please tick at which level you would change your cultivation practice? *(multiple answers in columns)*

price increase of	10 ¥/mǔ	20 ¥/mǔ	30 ¥/mǔ	40 ¥/mǔ	> 50 ¥/mǔ	don't know
cultivate the same crops, but reduce the amount of water used for these crops	3.2.5.1	3.2.5.2	3.2.5.3	3.2.5.4	3.2.5.5	3.2.5.6
start / expand cultivate crops list below:						
cotton	3.2.5.7	3.2.5.8	3.2.5.9	3.2.5.10	3.2.5.11	3.2.5.12
vegetables	3.2.5.13	3.2.5.14	3.2.5.15	3.2.5.16	3.2.5.17	3.2.5.18
others:	3.2.5.19	3.2.5.20	3.2.5.21	3.2.5.22	3.2.5.23	3.2.5.24
leave some land fallow during dry season	3.2.5.25	3.2.5.26	3.2.5.27	3.2.5.28	3.2.5.29	3.2.5.30

3.2.6   Have you noticed any of the following phenomena in your village? If yes, evaluate how severe these phenomena are in your opinion (tick field according to answer).

		not existent don't know	yes, but it's not severe	yes, it's severe	yes, very severe
ask in case of groundwater as main water source	groundwater tube wells had to shut down, because no water could be pumped anymore	3.2.6.1	3.2.6.2	3.2.6.3	3.2.6.4
	the quality of groundwater has become poorer	3.2.6.5	3.2.6.6	3.2.6.7	3.2.6.8
ask in case of surface water as main water source	the availability of surface water has decreased over the last years	3.2.6.9	3.2.6.10	3.2.6.11	3.2.6.12
	the quality of surface water has become poorer	3.2.6.13	3.2.6.14	3.2.6.15	3.2.6.16

3.3 Fertilizer application

3.3.1   Who selects (decides the type and brand of fertilizer) and buys the fertilizer

farmer selects fertilizer and buys the fertilizer	3.3.1.1
cooperative selects fertilizer, but farmer buys the selected fertilizer	3.3.1.2
fertilizer is provided by the cooperative	3.3.1.3

other: 3.3.1.4

3.3.2   Do you apply manure? Please explain your answer.

yes, because livestock and manure is available	3.3.2.1
yes, because, cheaper than fertilizer	3.3.2.2
yes, because, improves the soil quality	3.3.2.3

yes, because: 3.3.2.4

no, because, application is too time consuming	3.3.2.5
no, because, effect on yield takes too long	3.3.2.6
no, because not enough livestock or manure is available	3.3.2.7

no, because: 3.3.2.8

3.3.3   Make for each crop a fertilizing calendar (mineral and organic fertilizer)

Crop	2003				2004										
	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
wheat	3.3.3.1	3.3.3.2	3.3.3.3	3.3.3.4	3.3.3.5	3.3.3.6	3.3.3.7	3.3.3.8	3.3.3.9	3.3.3.10	3.3.3.11	3.3.3.12	3.3.3.13	3.3.3.14
maize	3.3.3.15	3.3.3.16	3.3.3.17	3.3.3.18	3.3.3.19	3.3.3.20	3.3.3.21	3.3.3.22	3.3.3.23	3.3.3.24	3.3.3.25	3.3.3.26	3.3.3.27	3.3.3.28
3.3.3.29	3.3.3.30	3.3.3.31	3.3.3.32	3.3.3.33	3.3.3.34	3.3.3.35	3.3.3.36	3.3.3.37	3.3.3.38	3.3.3.39	3.3.3.40	3.3.3.41	3.3.3.42	3.3.3.43
3.3.3.44	3.3.3.45	3.3.3.46	3.3.3.47	3.3.3.48	3.3.3.49	3.3.3.50	3.3.3.51	3.3.3.52	3.3.3.53	3.3.3.54	3.3.3.55	3.3.3.56	3.3.3.57	3.3.3.58
3.3.3.59	3.3.3.60	3.3.3.61	3.3.3.62	3.3.3.63	3.3.3.64	3.3.3.65	3.3.3.66	3.3.3.67	3.3.3.68	3.3.3.69	3.3.3.70	3.3.3.71	3.3.3.72	3.3.3.73
3.3.3.74	3.3.3.75	3.3.3.76	3.3.3.77	3.3.3.78	3.3.3.79	3.3.3.80	3.3.3.81	3.3.3.82	3.3.3.83	3.3.3.84	3.3.3.85	3.3.3.86	3.3.3.87	3.3.3.88
3.3.3.89	3.3.3.90	3.3.3.91	3.3.3.92	3.3.3.93	3.3.3.94	3.3.3.95	3.3.3.96	3.3.3.97	3.3.3.98	3.3.3.99	3.3.3.100	3.3.3.101	3.3.3.102	3.3.3.103

3.3.4 Describe each application of fertilizer in detail: type of fertilizer (use the fertilizer code list), application method, application amount, nutrient content (written on the fertilizer package) and the price of the fertilizer. Who applied the fertilizer and how long does it take for one person to apply fertilizer at one mǔ. In case of hired labour, what are the salary costs per mǔ for one application? Do you know the place of production (origin) of the used fertilizer? Describe the costs of used machinery for fertilizer application in section 4.2.

F-#	fertilizer [code]	production place [place]	application method [code]	application amount [jin]	nutrient content [N-P-K]			fertilizer price [¥ / jin]	applying person [code]	working time [hour] of one person to apply 1 mǔ	salary costs for application [¥ / mǔ]
	3.3.4.1	3.3.4.2	3.3.4.3	3.3.4.4	3.3.4.5	3.3.4.6	3.3.4.7	3.3.4.8	3.3.4.9	3.3.4.10	3.3.4.11
	3.3.4.12	3.3.4.13	3.3.4.14	3.3.4.15	3.3.4.16	3.3.4.17	3.3.4.18	3.3.4.19	3.3.4.20	3.3.4.21	3.3.4.22
	3.3.4.23	3.3.4.24	3.3.4.25	3.3.4.26	3.3.4.27	3.3.4.28	3.3.4.29	3.3.4.30	3.3.4.31	3.3.4.32	3.3.4.33
	3.3.4.34	3.3.4.35	3.3.4.36	3.3.4.37	3.3.4.38	3.3.4.39	3.3.4.40	3.3.4.41	3.3.4.42	3.3.4.43	3.3.4.44
	3.3.4.45	3.3.4.46	3.3.4.47	3.3.4.48	3.3.4.49	3.3.4.50	3.3.4.51	3.3.4.52	3.3.4.53	3.3.4.54	3.3.4.55
	3.3.4.56	3.3.4.57	3.3.4.58	3.3.4.59	3.3.4.60	3.3.4.61	3.3.4.62	3.3.4.63	3.3.4.64	3.3.4.65	3.3.4.66
	3.3.4.67	3.3.4.68	3.3.4.69	3.3.4.70	3.3.4.71	3.3.4.72	3.3.4.73	3.3.4.74	3.3.4.75	3.3.4.76	3.3.4.77
	3.3.4.78	3.3.4.79	3.3.4.80	3.3.4.81	3.3.4.82	3.3.4.83	3.3.4.84	3.3.4.85	3.3.4.86	3.3.4.87	3.3.4.88
	3.3.4.89	3.3.4.90	3.3.4.91	3.3.4.92	3.3.4.93	3.3.4.94	3.3.4.95	3.3.4.96	3.3.4.97	3.3.4.98	3.3.4.99
	3.3.4.100	3.3.4.101	3.3.4.102	3.3.4.103	3.3.4.10	3.3.4.10	3.3.4.10	3.3.4.107	3.3.4.108	3.3.4.109	3.3.4.110
	3.3.4.111	3.3.4.112	3.3.4.113	3.3.4.114	3.3.4.11	3.3.4.11	3.3.4.11	3.3.4.118	3.3.4.119	3.3.4.120	3.3.4.121
	3.3.4.122	3.3.4.123	3.3.4.124	3.3.4.125	3.3.4.12	3.3.4.12	3.3.4.12	3.3.4.129	3.3.4.130	3.3.4.131	3.3.4.132
	3.3.4.133	3.3.4.134	3.3.4.135	3.3.4.136	3.3.4.13	3.3.4.13	3.3.4.13	3.3.4.140	3.3.4.141	3.3.4.142	3.3.4.143
	3.3.4.144	3.3.4.145	3.3.4.146	3.3.4.147	3.3.4.14	3.3.4.14	3.3.4.15	3.3.4.151	3.3.4.152	3.3.4.153	3.3.4.154

by hand (1)	cover application with soil (3)
put fertilizer into irrigation water (2)	spray liquid fertilizer (4)

farm family member (1)	cooperative (3)
hired labour (2)	together with other farmers (4)

3.4   Weed control

3.4.1   Describe the weeding activities at each crop. Which method is used? How often do you weed the plots of one crop per season? How long does it take for one person to weed one mǔ? Who is weeding? In case of hired labour weed, estimate the total salary costs per season. Describe herbicide application in section 3.5.

	method [code]	[frequency] per season	working time [hour] for one person to weed one mǔ	weeding person [code]	estimate total annual salary for weeding [¥]
wheat	3.4.1.1	3.4.1.2	3.4.1.3	3.4.1.4	3.4.1.5
maize	3.4.1.6	3.4.1.7	3.4.1.8	3.4.1.9	3.4.1.10
3.4.1.11	3.4.1.12	3.4.1.13	3.4.1.14	3.4.1.15	3.4.1.16
3.4.1.17	3.4.1.18	3.4.1.19	3.4.1.20	3.4.1.21	3.4.1.22

| no weeding (0) use hoe (1) pluck by hand (2) | | | farmer (1)   cooperative (3) hired labour (2) | |

3.5   Application of pesticides against pests, disease and weeds

3.5.1   Describe the pesticide application activities for each crop. Who is applying the pesticides? How often are pesticides applied per season? In case of hired labour apply pesticides estimate the total salary per season. Describe the costs for machinery in section 4.2. Estimate the pesticide costs for each crop per season. If possible distinguish between herbicides (against weeds) and insecticides & fungicides (against pests and diseases).

crop	person [code]	[frequency] per season	estimate total salary for one season [¥]	insecticide & fungicide cost [¥ / season]	herbicide cost [¥ / season]
wheat	3.5.1.1	3.5.1.2	3.5.1.3	3.5.1.4	3.5.1.5
maize	3.5.1.6	3.5.1.7	3.5.1.8	3.5.1.9	3.5.1.10
3.5.1.11	3.5.1.12	3.5.1.13	3.5.1.14	3.5.1.15	3.5.1.16
3.5.1.17	3.5.1.18	3.5.1.19	3.5.1.20	3.5.1.21	3.5.1.22
3.5.1.23	3.5.1.24	3.5.1.25	3.5.1.26	3.5.1.27	3.5.1.28
3.5.1.29	3.5.1.30	3.5.1.31	3.5.1.32	3.5.1.33	3.5.1.34

| farm family (1)   cooperative (3) hired labour (2)   together with other farmers (4) | | | |

4   Harvesting and Marketing

4.1.1   Do you have any kind of marketing contracts, in case what are the conditions?

_____

_____

4.1.2   Describe harvesting: which harvesting method is used and how many family members are harvesting. How many hired labour are harvesting and what is the total salary for them? Are there any other harvesting costs, but describe the costs for machinery in section 4.2:

crop [code]	method [code]	number of family members [persons]	number of hired labour [persons]	harvesting duration [hour]	total salary costs for harvesting [¥]	other harvesting cost, please describe it
wheat	4.1.2.1	4.1.2.2	4.1.2.3	4.1.2.4	4.1.2.5	4.1.2.6
maize	4.1.2.7	4.1.2.8	4.1.2.9	4.1.2.10	4.1.2.11	4.1.2.12
4.1.2.13	4.1.2.14	4.1.2.15	4.1.2.16	4.1.2.17	4.1.2.18	4.1.2.19
4.1.2.20	4.1.2.21	4.1.2.22	4.1.2.23	4.1.2.24	4.1.2.25	4.1.2.26
4.1.2.27	4.1.2.28	4.1.2.29	4.1.2.30	4.1.2.31	4.1.2.32	4.1.2.33
4.1.2.34	4.1.2.35	4.1.2.36	4.1.2.37	4.1.2.38	4.1.2.39	4.1.2.40

by hand (1)   by harvesting machine (2)

4.1.3   How much did you harvested in 2004. How much did you stored from last season. If you are selling, which marketing channels do you use, which marketing costs (transport and market fee) are connected with it. If you use different marketing channels, how much did you sell at each marketing channel? Describe the received price of the used marketing channel? What else then selling do you do with the harvest?

crop [code]	total yield this season [jin]	stored from last season [jin]	amount sold [jin]	marketing channel [code]	market fee [¥]	transport costs [¥]	market price common price [¥ / jin]	minimum price [¥ / jin]	maximum price [¥ / jin]	own food [jin]	own forage [jin]	taxes and fees [jin]
wheat	4.1.3.1	4.1.3.2	4.1.3.3	4.1.3.4	4.1.3.5	4.1.3.6	4.1.3.7	4.1.3.8	4.1.3.9	4.1.3.10	4.1.3.11	4.1.3.12
maize	4.1.3.13	4.1.3.14	4.1.3.15	4.1.3.16	4.1.3.17	4.1.3.18	4.1.3.19	4.1.3.20	4.1.3.21	4.1.3.22	4.1.3.23	4.1.3.24
4.1.3.25	4.1.3.26	4.1.3.27	4.1.3.28	4.1.3.29	4.1.3.30	4.1.3.31	4.1.3.32	4.1.3.33	4.1.3.34	4.1.3.35	4.1.3.36	4.1.3.37
4.1.3.38	4.1.3.39	4.1.3.40	4.1.3.41	4.1.3.42	4.1.3.43	4.1.3.44	4.1.3.45	4.1.3.46	4.1.3.47	4.1.3.48	4.1.3.49	4.1.3.50
4.1.3.51	4.1.3.52	4.1.3.53	4.1.3.54	4.1.3.55	4.1.3.56	4.1.3.57	4.1.3.58	4.1.3.59	4.1.3.60	4.1.3.61	4.1.3.62	4.1.3.63
4.1.3.64	4.1.3.65	4.1.3.66	4.1.3.67	4.1.3.68	4.1.3.69	4.1.3.70	4.1.3.71	4.1.3.72	4.1.3.73	4.1.3.74	4.1.3.75	4.1.3.76
4.1.3.77	4.1.3.78	4.1.3.79	4.1.3.80	4.1.3.81	4.1.3.82	4.1.3.83	4.1.3.84	4.1.3.85	4.1.3.86	4.1.3.87	4.1.3.88	4.1.3.89

farmer transports to state company or cooperative (1)   farmer sells at a market by himself (3)   private dealer comes to the farm (5)   transport and sell to livestock farm (7)
state company picks up at the farm (2)   farmer transports to private dealer (4)   consumers comes to the farm (6)   sell to processor (8)

4.1.4   What will happen with the straw (not used parts of the crop):

	removed (use as forage or sold)	burned	left on field
wheat	4.1.4.1	4.1.4.2	4.1.4.3
maize	4.1.4.4	4.1.4.5	4.1.4.6
4.1.4.7	4.1.4.8	4.1.4.9	4.1.4.10
4.1.4.11	4.1.4.12	4.1.4.13	4.1.4.14
4.1.4.15	4.1.4.16	4.1.4.17	4.1.4.18
4.1.4.19	4.1.4.20	4.1.4.21	4.1.4.22

4.1.5   Which important work is done after harvesting? Please describe the crop, the work, the labour demand and the expenses:

crop	kind of work	method [code]	working time of one person for one jin of end product	total costs [¥]
maize	tresh the bulb to get grain	4.1.5.1	4.1.5.2	4.1.5.3
cotton	remove wool from capsule	4.1.5.4	4.1.5.5	4.1.5.6
cotton	remove seed from wool	4.1.5.7	4.1.5.8	4.1.5.9
4.1.5.10	4.1.5.11	4.1.5.12	4.1.5.13	4.1.5.14
4.1.5.15	4.1.5.16	4.1.5.17	4.1.5.18	4.1.5.19
4.1.5.20	4.1.5.21	4.1.5.22	4.1.5.23	4.1.5.24

farmer doesn't do it (1)   farmer does it by using a machine (3)
farmer does it by hand (2)   farmer pays hired labour (4)

4.2   Materials and machinery

4.2.1   Are there other materials needed for cultivation, what is their expenditure per mǔ?

	crops	expenditure [¥ / mǔ]
plastic to cover the soil	4.2.1.1	4.2.1.2
4.2.1.3 others:	4.2.1.4	4.2.1.5
4.2.1.6 others:	4.2.1.7	4.2.1.8

4.2.2   Which machinery is rented in? Estimate the total renting fee per seasons.

machinery	total renting fee per season [¥]
wheat cutter	4.2.2.1
corn thresher	4.2.2.2
plough	4.2.2.3
two wheel tractor	4.2.2.4
three wheel truck	4.2.2.5
four wheel tractor	4.2.2.6
knapsack sprayer	4.2.2.7
sowing machine	4.2.2.8
irrigation pump	4.2.2.9

4.2.3 Which machinery (productive fixed asset) does the farmer own used for farming? If you have more than one of each type, describe each machine separately. What is their purchase price and how much are the maintenance costs including fuel per year? Do you rent the machine to other farmers? If, estimate the income from renting?

machine	purchase year	original price [¥]	financing source	currently expected selling price [¥]	maintenance costs per year [¥]	share of ownership	income from renting to others [¥]
wheat cutter	4.2.3.1	4.2.3.2	4.2.3.3	4.2.3.4	4.2.3.5	4.2.3.6	4.2.3.7
corn thresher	4.2.3.8	4.2.3.9	4.2.3.10	4.2.3.11	4.2.3.12	4.2.3.13	4.2.3.14
plough	4.2.3.15	4.2.3.16	4.2.3.17	4.2.3.18	4.2.3.19	4.2.3.20	4.2.3.21
two wheel tractor	4.2.3.22	4.2.3.23	4.2.3.24	4.2.3.25	4.2.3.26	4.2.3.27	4.2.3.28
three wheel truck	4.2.3.29	4.2.3.30	4.2.3.31	4.2.3.32	4.2.3.33	4.2.3.34	4.2.3.35
four wheel tractor	4.2.3.36	4.2.3.37	4.2.3.38	4.2.3.39	4.2.3.40	4.2.3.41	4.2.3.42
knapsack sprayer	4.2.3.43	4.2.3.44	4.2.3.45	4.2.3.46	4.2.3.47	4.2.3.48	4.2.3.49
sowing machine	4.2.3.50	4.2.3.51	4.2.3.52	4.2.3.53	4.2.3.54	4.2.3.55	4.2.3.56
irrigation pump	4.2.3.57	4.2.3.58	4.2.3.59	4.2.3.60	4.2.3.61	4.2.3.62	4.2.3.63
			own money (1) informal credit (3) *formal credit (2)*			*owned only by farmer himself (1)* *shared with other farmers, indicate share (2)*	*tax (1)* *other describe:*

5 Livestock and fishery

5.1.1 How many animals do you have and their value? Estimate the annual costs of livestock and the returns. How much manure is produced?

animal	amount in beginning of 2004 [number of animals]	estimated value in beginning of 2004 [¥]	expenditure for forage, medicals and others [¥]	total returns in 2004 [¥]	manure [m³]
cattle	5.1.1.1	5.1.1.2	5.1.1.3	5.1.1.4	5.1.1.5
goat, sheep	5.1.1.6	5.1.1.7	5.1.1.8	5.1.1.9	5.1.1.10
mule, horse	5.1.1.11	5.1.1.12	5.1.1.13	5.1.1.14	5.1.1.15
pig	5.1.1.16	5.1.1.17	5.1.1.18	5.1.1.19	5.1.1.20
donkey	5.1.1.21	5.1.1.22	5.1.1.23	5.1.1.24	5.1.1.25
poultry	5.1.1.26	5.1.1.27	5.1.1.28	5.1.1.29	5.1.1.30
rabbit	5.1.1.31	5.1.1.32	5.1.1.33	5.1.1.34	5.1.1.35
fishery	5.1.1.36	5.1.1.37	5.1.1.38	5.1.1.39	5.1.1.40