Urban and Peri-Urban Agricultural production in Beijing Municipality and its impact on Water quality

RMO-Beijing project is funded by the International Cooperation Programme of the Dutch Agricultural Research Foundation (DLO)

Urban and Peri-Urban Agricultural production in Beijing Municipality and its impact on Water quality

C.A. van Diepen (Alterra)
M.S. van Wijk (LEI)
Prof. Xu Cheng (CAU)
Dr. R. Roetter (Alterra)
Dr. A. W. Jongbloed (ID)
Dr. Yanxia Hu (BAAS)
Dr. Changhe Lu (IGSNRR)
Prof. H. van Keulen (PRI)
J. Wolf (editor, Alterra)

Alterra-rapport 757

Alterra, Green World Research, Wageningen, 2003

ABSTRACT

C.A. van Diepen (Alterra), M.S. van Wijk (LEI), Prof. Xu Cheng (CAU), Dr. R. Roetter (Alterra), Dr. A. W. Jongbloed (ID), Dr. Yanxia Hu (BAAS), Dr. Changhe Lu (IGSNRR), Prof. H. van Keulen (PRI) & J. Wolf (editor, Alterra), 2003. *Urban and Peri-Urban Agricultural production in Beijing Municipality and its impact on Water quality*. Wageningen, Alterra, Green World Research. Alterra-rapport 757. 62 pp.; 2 figs.; 28 tables; 23 refs.

For Beijing Municipality the quantity of available water resources and the quality of the available water have become matters of concern. This is caused by the rapid urbanization and the strong intensification of the agricultural sector. In this literature review for Beijing Municipality the following main topics are covered: (1) water use and water resources; (2) major trends in the agricultural production systems with respect to land use, input use, production and economic role; (3) impacts of agricultural and other activities on water quality. This review indicates the major trends and the districts with most severe environmental problems.

Keywords: agriculture, Beijing, land use, nutrients, pollution, water consumption , water quality, water resources, , urbanization

ISSN 1566-7197

This report can be ordered by paying € 18,- into bank account number 36 70 54 612 in the name of Alterra, Wageningen, the Netherlands, with reference to rapport 757. This amount is inclusive of VAT and postage.

Project 11625 [Alterra-rapport 757/IS/07-2003]

Contents

Annexes

Preface

During the 1990s China's urban population has grown by about 10 million per year, to a total which is estimated to be between 400 and 455 million. It has been estimated by some urban planners that by 2015, 40 percent of the population will be living in urban areas, bringing the total to about 670 million. This urbanisation process and rising incomes are important drivers of changes in the agricultural sector, and the impact of this on the environment. For example, people living in urban areas, eat on average twice as many eggs and 50% more meat than people in rural areas. The associated increase in animal production is becoming a major cause of environmental pollution.

For the Beijing Municipality the quantity of available water resources and the quality of the available water have already become matters of major concern. Rapid urbanization and the strong intensification of the agricultural sector have led to serious water scarcity and, at many places, to poor quality of the water resources. Finding sustainable solutions requires, among others, integrated planning, which takes into account the multiple objectives of future land use and the resource constraints.

To tackle this complex task, the research programme *International Cooperation* (DLO-IC) of Wageningen University and Research Centre, The Netherlands, has approved and funded this project with the intention to stimulate interdisciplinary research on Naturall Resource Management by fostering collaboration among several research institutes (with complementary expertise) of the Wageningen University and Research Centre (Wageningen UR) and with strong research consortia in China. The project consortium is composed of the research institutes BAAS, CAU and IGSNRR in Beijing, China. and Alterra, ID, LEI and PRI of Wageningen UR. The project *Resource Management Options in the Greater Beijing Area* (RMO-Beijing) perfectly fits into one of the 5 themes of DLO-IC programme: Sustainable agriculture in peri-urban areas.

Beijing Municipality provides a superb peri-urban case with its agriculture-environment interactions and its problems typical for agricultural areas faced with growing populations, urbanization and expanding economies. The RMO-Beijing project, initiated in March 2002 and launched in September 2002 with a joint planning meeting of project partners, has three major objectives :

1. to increase awareness among policy makers and other stakeholders in peri-urban Beijing and provide sound information about the impact of different agricultural production systems on environmental quality, especially water quality;
2. to define and analyze (ex-ante) alternative, sustainable land use options for solving resource-use problems in a regional context;
3 to discuss the results with stakeholders as a step in the formulation of resource management policy and implementation options.

The current report provides a comprehensive review of literature and data on the following topics: (1) water use and water resources; (2) major trends in the agricultural production systems with respect to land use, input use, production and economic role; (3) impacts of agricultural and other activities on water quality. This review also allows identification of main knowledge gaps and areas within Beijing Municipality affected by the highest pollution from agriculture.

As a next step within the RMO-Beijing project, issues such as intensification of the agricultural production and its impact on water quality and the competitive demands for the limited water resources will be analyzed in detail in a case study at county level (Shunyi) within Beijing Municipality.

We are very grateful to the various local governmental officials, farmers and other resource managers from Beijing Municipality for their support and permission /approval for conducting the research and for the exchange of information. We also thank our colleagues within the RMO-Beijing research consortium and from collaborative research groups for their contributions to this report. These research teams and the team members are listed in Annex B. The DLO-IC programme is acknowledged for its financial support.

May 2003,

The Authors

Summary

For the Beijing Municipality the quantity of available water resources and the quality of the available water have become matters of concern. This is caused by the rapid urbanization and the strong intensification of the agricultural sector. The aim of the RMO-Beijing project is to raise awareness about the impact of different agricultural production systems on environmental quality, and in particular water quality, in Beijing Municipality and to define sustainable solutions for such problems. This will be achieved in next phases of the project by quantifying the impacts of current and possibly future agricultural activities on the degree of pollution and environmental quality, with special attention for the most intensive forms of agriculture such as vegetable production and livestock raising.

The conditions in which the agricultural sector is operating in urban and peri-urban zones is quite specific, however, only few studies give attention to the peri-urban agricultural sector of Beijing. Hence, this literature review is compiled with focus on both the general structure of the agricultural sector of Beijing and the impacts of urbanization and agriculture on the water resources and quality. This review for Beijing Municipality covers the following main topics: (1) water use and water resources; (2) major trends in the agricultural production systems with respect to land use, input use, production and economic role; (3) impacts of agricultural and other activities on water quality. This review gives an overview of the available data and literature on these topics and indicates knowledge gaps. The information on the agricultural sector also indicates the districts in Beijing Municipality where the most severe environmental problems due to agriculture (in particular livestock raising and vegetable production) are to be expected.

A few conclusions from this review for Beijing Municipality are: (1) the current water consumption is much larger than the water supply which indicates the need for more efficient water use and for additional water supply; (2) the urban areas have rapidly expanded at the cost of the arable land areas; (3) the intensive forms of agricultural production (vegetable crop and livestock production) have rapidly increased which partly explains the deteriorated water quality. Issues such as intensification of the agricultural production and its impact on water quality, and the competitive demands for the limited water resources will be studied in a case study during the next phase of the project.

1 Introduction

During the 1990s China's urban population has grown by about 10 million per year, to a total which is estimated to be between 400 and 455 million. It has been estimated by some urban planners that by 2015, 40% of the population will be living in urban areas, bringing the total to about 670 million. This urbanisation process and rising incomes are important driving forces behind changes that occur in the agricultural sector, and the impact of this sector on the environment. For example, people living in urban areas, eat on average twice as many eggs and 50% more meat than people in rural areas. The associated increase in animal production may cause pollution of the environment. Also, the increasing production of horticultural crops around urban areas that generally require large fertiliser and biocide applications, may have negative effects on the environment. In this report we give an overview of the main changes due to urbanization, with both a review of the changes which have taken place within the agricultural sector in Beijing Municipality and the effect of these changes on the quality and quantity of water. Beijing is a very interesting case, as it is the second largest city of China and located in an area where clean water is becoming a very scare natural resource.

This study took place within the framework of a research project funded by the International Cooperation (IC) Programme of the Dutch Agricultural Research Foundation (DLO): *Resource Management Options in the Greater Beijing Area* (=RMO-Beijing-project). The aim of this project is to raise awareness among city planners, policymakers and stakeholders (e.g. farmers) in peri-urban Beijing about the impact of different agricultural production systems and technologies on environmental quality, and in particular water quality, in Beijing Municipality and to identify sustainable options for solving such-like problems. This will be achieved by quantifying the impacts of agricultural activities on the degree of pollution and environmental (mainly water) quality, with special attention for the most intensive forms of agriculture such as vegetable and livestock production. The main objectives of the RMO-Beijing-project (Diepen, 2002) are:

(1) to create a knowledge base on agriculture-environment interactions for the main agricultural production systems and on main impacts of agricultural intensification;
(2) to develop tools for analysing alternative land use scenarios;
(3) to evaluate present land use processes and possible future land use changes with respect to their impact on the water system (quality and quantity);
(4) to apply these tools to identify the major constraints to achieve sustainable agricultural production systems and to protect environmental quality;
(5) to explore the agricultural and environmental consequences of changed (e.g. more sustainable) agricultural production systems and land use, and the policy options in close cooperation with the local stakeholders.

A review of the international and national Chinese scientific literature revealed that only few studies have investigated the characteristics of the peri-urban agricultural sector of Beijing. This is in line with earlier reports which pointed out that the urban and peri-urban agricultural sector has been largely ignored by city planners, local and national policymakers and researchers (Pothukuchi & Kaufman, 2000; Drakakis-Smith & Dixon, 1997; Yue-man Yueng, 1993; Hubbard & Onumah, 2001). Only in the last few years the attention has increased to the very specific circumstances in which the agricultural sector is operating in urban and peri-urban zones. For that reason, we decided to give ample attention in this report to describing the general structure of the agricultural sector of Beijing.

This review has the following important aims. First, to review available data and literature on water use and resources (both quality and quantity) in the Beijing Municipality, and second to review available data and literature on agricultural production systems and land use and their developments over the last 10 years. This should give a good overview of the structure and characteristics of the agricultural sector and should indicate knowledge gaps (list in Annex C). Third, the impacts of agricultural activities on the environmental (in particular water) quality within Beijing Municipality are described. This results in a list of main variables (e.g. livestock density, fertiliser use) for identifying the areas with the most severe water pollution by the agricultural sector. For comparison with these agricultural impacts, also the effects of non-agricultural sources on water quality are given. Fourth, for the next phase of the project a case study area is proposed. This study area should be characterized by the main environmental problems that result from intensification and modernization of agriculture. Based on the indicators for severe water pollution (see third point above), a representative area is selected. Fifth, the main stakeholders in water resources and quality are identified. This yields an overview of the main groups that affect water quality through their actions and decisions, and that are affected by these actions and decisions. In the next phases of the project, the research team needs to analyse the results from the case study in close cooperation with the main stakeholders, to explore policy options and possible future changes in agricultural production systems and land use. Finally, the main conclusions from this study are given.

2 Water use and water resources in the Beijing Municipality

2.1 Water supply and use in China

The northern part of China (north of the Yangtze river) is inhabited by 550 million people, has two-thirds of the cropland area in China and only one fifth of the total water supply (Brown, 2001). Hence, the water supply per hectare of cropland in northern China is limited. In the North-China plain, for example, a region that stretches from just north of Shanghai to well north of Beijing and that produces 40% of China's grain, the water table is dropping by on average 1.5 meters per year (Brown, 2001). Farmers in the north are faced with decreasing irrigation water supply due to both aquifer depletion and increased diversion of water to cities and industries.

The northern part of China can be divided into the following three river basins: 1. Yellow (or Huang) river basin; 2 Hai river basin (which contains Beijing Municipality); 3. Huai river basin. In these so-called 3-H basins, 40% of the Chinese population and 40% of the cultivated area is situated. The large majority of China's arable crops is produced here. Economically even more important, 35% of the GDP of China and 31% of the total industrial output value of China is produced here, whereas the 3-H basins only have 10% of the total water resources (World Bank, 2002). This World Bank study estimates that the demand for water in the year 2000 in the 3-H basins (169 billion m^3/year) exceeded supply (132 billion m^3/year). These water shortages are projected to increase over time, although water use efficiency (e.g. for irrigation and urban purposes) is assumed to improve. This indicates that measures should be taken to reduce demands and to augment supplies.

The current 'solution' to deal with these water shortages, is to increase the use of groundwater. Consequently, current water supplies have become strongly dependent on groundwater resources. However, groundwater is a buffer source of water for dry years when surface water supply is more limited,. and this buffer supply has almost disappeared because of its excessive usage. In the Hai-basin, for example, estimates of sustainable groundwater supply are of the order of 17.3 billion m^3/year, whereas groundwater use in 1998 was much larger (i.e. 26.1 billion m^3). As a result, deep and shallow groundwater tables have dropped to 90 and 50 meters, respectively in the Hai-basin. Other side effects of this excess groundwater use are salinity intrusion in coastal provinces and land subsidence of up to several meters in cities like Beijing. This caused damage to building structures in the last decade, reduced flood protection and exacerbated waterlogging in urban areas (World Bank, 2002).

Surface and groundwater quality in China have seriously deteriorated due to pollution from point sources associated with rapid urbanization, industrial development, and rising population and due to diffuse pollution (nutrients, biocides) from agriculture (World Bank, 2002). The current quality status of surface water in the 3-H basins is such that most rivers and lakes fail to meet the state environmental standards: more than 80% is classified as seriously polluted (World Bank, 2002). It has also been estimated that about 25% of all lakes in China are adversely affected by eutrophication (World Bank, 2001).

The agricultural sector has an important impact on both the quantity and the quality of water supply. It has been estimated that agriculture accounts for about 80% of the total water requirements in China, and that 30-40% of this water is lost through non-consumptive uses (World Bank, 2002). Water pollution is mainly caused by both run-off and leaching of pesticides, organic and chemical fertilisers from in particular the intensive (i.e. high input level of fertilisers and biocides) arable and vegetable cropping areas. In addition, the intensive livestock sector and the resulting large manure production are major causes for air, land and water pollution.

Both small and big cities in northern China are surrounded by such intensive vegetable and/or arable production areas with high N-fertiliser applications and by a large number of livestock farms. Hence, in most smaller cities nitrate concentrations in ground and drinking water (derived from local groundwater) exceeded the permitted limit (Zhang et al., 1996). However in large cities such as Beijing, the drinking water is low in nitrate despite high N-applications in neighbouring areas. This drinking water is usually supplied by urban water works, with the water largely derived from protected surface water reservoirs and rivers with little nitrate pollution.

2.2 Water supply and use in the Beijing Municipality

The rapidly expanding Chinese economy is faced with issues that originate from the increasingly competing demands on the natural resource base. Especially around mega-cities such as Beijing, intensification of agricultural production is taking place at an accelerated pace. For instance, demand is rapidly increasing for high quality food products (e.g. vegetables and dairy products), creating incentives for farmers to abandon traditional farming systems and to move to unsustainable management practices, which results in resource degradation and environmental pollution. Such farming systems lead to increased water use, water shortages and to declining quality of surface and groundwater.

Located near the northern tip of the semi-arid North-China plain, Beijing has only 600 mm of annual precipitation. This average amount does not mean much in terms of water supply to the city, as annual precipitation can fluctuate 50% in either direction (Figure 1). In a year of average rainfall, available water resources of Beijing range from 4.2 to 4.5 billion m^3, and in a dry year they are reduced to 3.3 billion m^3, which is already less than the current consumption in Beijing (Chang, 1998).

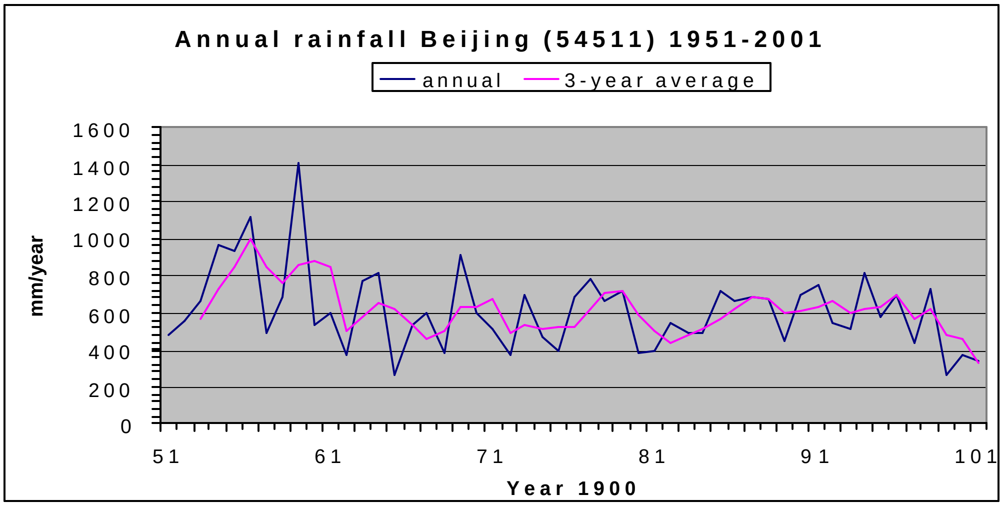

Figure 1 Annual rainfall in Beijing from 1951 to 2001

The weather is characterized by a dry winter and a short rainy period in the warm summer. More than 60% of the annual precipitation is concentrated in the two months of July-August, more than 80% falls within the four months period of June-September. The time series of annual rainfall over the last 50 years (Figure 1) shows that the 10 year average precipitation during the 1950s was clearly higher than in the following 40 years, but in spite of strong year to year variations the 10-year averages are remarkably stable over the period 1961-2000. Figure 1 shows both the year-to-year fluctuations and the moving average over three years. Ten years have annual rainfall below 400 mm, which we may label as dry years. Such dry years did not occur before 1962. The two driest years are 1965 and 1999 with about 260 mm. Two consecutive dry years occurred in 1980-81. Three of the five driest years fell in the period 1999-2001, but it is too early to conclude that this marks the second step towards a drier climate.

In 1995, Beijing Municipality had 85 water reservoirs with a total capacity of 9.3 billion m^3. Of these, Miyun reservoir has a total storage capacity of 4.38 billion m^3 and Guanting reservoir a capacity of 4.16 billion m^3. Miyun reservoir is Beijing's only source of drinking water (Chang, 1998). The fact that farmers along the rivers that feed these reservoirs, are siphoning off more and more water for irrigation, may further reduce future water supply.

More detailed data on water supply and use in the Beijing Municipality in an average year are:

a. Total annual water use (10.86 billion m^3) consists of natural evapo-transpiration (6.76 billion m^3), human consumption (2.3 billion m^3; i.e. all water in agricultural, industrial and domestic use), and outflow leaving Beijing (1.8 billion m^3);
b. Total annual water supply (10.75 billion m^3) is about identical to the total water use, and consists of precipitation (9.55 billion m^3; including the part of precipitation that recharges groundwater) and water inflow (1.2 billion m^3) from the neighbouring province. This indicates that on average there is no surplus water and that in dry years (e.g. 300 mm precipitation results in 5.04 billion m^3)

excessive groundwater extraction is needed. For example, in the dry year 2000, 2.68 billion m^3 groundwater was extracted;

c. Total water supply from surface water inflow (1.2 billion m^3) and from groundwater extraction (2.8 billion m^3) is 4 billion m^3;
d. Water is used (in total 3.54 billion m^3) by: agriculture (1.59 billion m^3), industry (1.05 billion m^3), life (0.86 billion m^3) and environment (0.04 billion m^3). Total reusable water is estimated at 0.7 billion m^3, which results in a human consumption of 2.8 billion m^3 (higher than the value mentioned above);
e. Total storage of Miyun reservoir is 2.5 to 3 billion m^3 and its useful storage 1.5 to 2 billion m^3; total storage of Guanting reservoir is 2 billion m^3 and its useful storage 1 billion m^3.

For drinking water in Beijing Municipality the following is found:

1. In the urban area, drinking water is almost completely extracted from groundwater, whereas in the rural area about 70% originates from groundwater;
2. The distribution of the origins of groundwater as well as the annual extraction rates for urban areas of downtown Beijing and a few districts, are shown in Map 1 (not yet available).

The main factor underlying the high consumption of water in Beijing Municipality, is its economic structure. In 1985, industrial enterprises in Beijing used 3.9 billion m^3 (much too high compared to figure given above) of water annually, 97% of which was used for production and processing (Chang, 1998). The power industry was the largest user of water, responsible for more than 45% of total water consumed in industry and nearly 55% of total fresh water consumption. Other water-intensive industries include chemicals, ferrous metal processing, petroleum and textiles (Chang, 1998).

Total water consumption in the Beijing Municipality in 1991 was 3.64 billion m^3, of which 2.27 billion m^3 (much higher than figure given above) was used in the agricultural sector (Chang, 1998). It is most likely that the only way to sustain the increasing water demand of the city is modification of the agricultural production systems in the rural areas. Hence, the options are:

1. Replace wetland rice by upland crops. For example, Beijing has already reduced rice fields from 53000 ha in 1980 to 32700 ha in 1990 (Chang, 1998);
2. Replace traditional irrigation methods by sprinkler and drip systems.

More long-term and large-scale operations to sustain the water demand are described in Section 2.5.

2.3 Quality and quantity of groundwater

Total groundwater reserves in Beijing Municipality are estimated at 68 billion m^3, down to the fourth water-bearing stratum. However, the maximum recoverable groundwater supply is estimated at 2.45 billion m^3/year (Chang, 1998), based on the annual recharge rate.

At present, the share of groundwater in the total water supply is 70% (see point c above). With respect to the water supply to agriculture, this completely came from surface water before the 1970s. However, the last decade about 80% of agricultural irrigation water has been extracted from groundwater. The extracted amount of groundwater was very low in the 1950s and 1960s. It was only 0.7 billion m^3 in 1949 and 0.52 billion m^3 in 1961; however in 1971, it amounted to 1.38 billion m^3 and increased rapidly in the following years, and in the 1990s (with more than 40000 wells in Beijing) it reached a level of about 2.7 billion m^3 annually (Chang, 1998). This shows that groundwater extraction continues to increase, and in 2000 the groundwater deficit had accumulated to 5.7 billion m^3. This means that this groundwater extraction is not sustainable. The turning point of the groundwater balance happened at the end of the 1970s when the annual extraction exceeded total recharge. The consequence of this over-pumping is a serious drop in groundwater table depth (from 5 m below surface in the 1950s) in the extraction area (with a radius of 25 km around the city centre of Beijing) with groundwater levels at, on average, 10 to 20 m below soil surface at present and at 50 m below the surface in the most heavily extracted areas (Map 1; not yet available).

Due to this excessive extraction of groundwater and its insufficient protection, the quality of groundwater has deteriorated since the 1980s. According to an investigation in 1994, the amounts detected for volatile phenol, cyanide, mercury, cadmium and arsenic in groundwater increased by 8.6% to 36%, compared to 1985. The frequency of exceedence of environmental standards ranged from 22.5% to 47.4% for water hardness degree, NO_3-N, NO_2-N, and NH_4-N. According to Wu (2000), the area with too high NO_3-N concentrations increased from 72 km^2 in 1981 to 169 km^2 in 2000. Based on a monitoring of the groundwater origin protection zone in 1995, the major pollutant was NO_3-N. Comparing results from 1990 with those from 1986, the NO_3-N concentration increased from 4.5 mg. L^{-1} to 7.0 mg.L^{-1} in a northeastern suburb, whereas in a western suburb the concentrations increased from 11.5 mg.L^{-1} to 13.2 mg.L^{-1}. This corresponds well with the applied amounts of chemical fertiliser, that increased in the protection zones around Beijing during the same period (Table 1).

Table 1 Annual applications of fertiliser nutrients (kg.ha-1) in water protection zones of Beijing

	Fertiliser-N 1981	Fertiliser-N 1991	Fertiliser-P_2O_5 1981	Fertiliser-P_2O_5 1991
Miyun Water reservoir zone	180.0	253.0	39.6	63.3
Huairou Water reservoir zone	190.0	243.0	54.2	62.8
Northeast suburb zone	208.0	291.0	78.8	101.0
West suburb zone	279.0	268.0	86?	122.0

The fraction of groundwater with a good quality is only 42.65% of the total. The area, in which the quality of shallow ground water meets all requirements for producing drinking water, covers only half of the total area.

2.4 Quality and quantity of surface water

The average amount of available surface water is 3.89 billion m^3. However, in recent years due to continuous drought, this amount has strongly decreased (Table 2).

Table 2 Surface water resources of Beijing (billion m^3)

	Amount from inside Beijing Municipality	Inflow (entered from upper-reaches)	Outflow (discharge into lower-reaches)	Total surface water resources
Annual mean	2.178	1.707	1.730	3.885
Year 2000 (dry)	0.634	0.422	1.024	1.056

The inflow into the Miyun water reservoir (previously Huairou water reservoir) in the 1950s was 3.13 billion m^3, but this has decreased to 1.2 billion m^3 from the 1970s. Simultaneously, total inflow from neighbouring areas into Beijing Municipality decreased from 2.5 billion m^3 to 1.0 billion m^3.

The quality of surface water started to deteriorate since 1970 when at the same time precipitation and inflow from the upper-reaches decreased. From 1970 onwards, diffuse pollution (from e.g. agricultural land areas) increased, as well as water use by industry and urban life, however, the treated fraction of sewage waste water was only 20%. Hence, rivers and lakes became severely polluted. According to an investigation of the degree of contamination of 105 major rivers in 1998 (Ni et al., 2000), only 29% were not-polluted. Furthermore, 13% of the rivers were polluted and 58% were severely polluted. Monitoring the quality of the Guanting Reservoir and the Miyun Reservoir showed that for the former reservoir the water quality deteriorated to 'polluted' during the end of 1980s. This means that this water can no longer be used for drinking water. In the latter reservoir, eutrophication is occurring (Zhu et al., 1995).

2.5 Future trend in water supply and consumption

An official program for *'Sustainable application of Water resources during the first decades of the 21st century'* has been set up in 2001 by the Municipal Bureau of Water Conservation. This program is focused on water-saving, pollution control, more efficient water resource exploitation and integrated water utilization.

The main goals for the years 2010 and 2030 are:
In 2010:

1. Water supply and consumption should be brought into equilibrium. This means that the gap of 1.2 billion m^3 should be closed through a series of measures, including water saving especially in agriculture, more wastewater treatment and use of regenerative water, more run-off interception for use, and better protection of waters against pollution. The required investment has been estimated at 17.6 billion Yuan RMB. The measures related to agriculture will be to convert 80,000 hectares of arable land to grasses and fruit land, and to use 0.4 billion m^3 of regenerative water for irrigation;
2. Quality of surface water should be improved considerably. This means that the water quality in the two biggest reservoirs (Guanting, Miyun) as well as the quality of the inflow (entering from upper-reaches) into Beijing Municipality should be improved to 'non-polluted';
3. The gap in the groundwater balance should be closed.

In 2030:

1. The ground water that has already been partly polluted, should be completely recovered to clean;
2. Problem of water resource shortages should be resolved. During the years 2010 to 2030, an additional annual amount of 1.5 billion m^3 water of the Yangtze River will be diverted into Beijing by means of large-scale engineering;
3. Annual consumption of water should maintain a constant level, i.e. 3.57 billion m^3. The share of water use by agriculture will be reduced to 0.7 billion m^3, which requires a strong reduction in comparison to the present water use of 2.0 billion m^3.

3 Major agricultural production systems in Beijing Municipality

3.1 General introduction

Beijing has a very long and rich history. The city originates from settlements founded more than 3000 years ago, and grew from a population of 58,000 during the Liao Dynasty (916-1125) to 4 million inhabitants in 1947. Today, as the capital of the People's Republic of China, Beijing is one of the four "independent municipalities" (Chang, 1998), which directly fall under the jurisdiction of the central government. Consequently, it has the same status as a province in the Chinese central bureaucracy, with its Mayor having a cabinet-level rank (LNV, 2001). With a total permanent resident population of 11 million (in the year 2000: Table 3), and almost 2 million migrant workers, Beijing has become the 11th largest city in the world, and the second largest in China.

Figure 2 Map of Beijing Municipality and its borders

As can be seen in Figure 2, the urban district of Beijing Municipality (BM) is located in the Southern part of Beijing Municipality, of which 38% is plain and 62% is mountainous.

3.1.1 Present area and population

Beijing Municipality has a total area of about 16,808 km^2, and is divided into a city centre, near suburbs, outer suburbs and counties (Table 3). The 13 urban districts have a population of 10.8 million, with the other 2.0 million living in the five counties (Beijing Municipal Statistical Bureau, 2001). The population density of the whole municipality is 760 persons per km^2, ranging from 111 in Huairou county to 30,574 persons per km^2 in the city. For the whole of Beijing Municipality, the main part of the permanent population can be considered as non-agricultural residents (69%), however, in the outer suburbs 64% of the permanent population is defined as agricultural and in the counties this figure is even 73% (Table 3). With regard to the land distribution, Table 4 shows that the counties cover the largest part of the total land area of Beijing Municipality followed by the outer suburbs. The main part of the population of Beijing Municipality is living in the city centre and the near suburbs (Table 4).

Table 3 Area and Population of districts of Beijing Municipality in the year 2000

District	Land Area (km^2)	Total population (persons)	Population density (pers./km^2)	Permanent population (persons)	Temporary residents (persons)	Permanent non agricul-tural residents (persons)	Permanent agricultural residents (persons)
Beijing Municipality	**16,808**	**12,780,000**	**760**	**11,075,000**	**1,705,000**	**7,607,000**	**3,468,000**
City Proper	**87**	**2,663,000**	**30,574**	**2,382,000**	**281,000**	**2,382,000**	**0**
Dongcheng	25	713,000	28,866	626,000	87,000	626,000	0
Xicheng	30	856,000	28,533	781,000	75,000	781,000	0
Chongwen	16	462,000	29,057	413,000	49,000	413,000	0
Xuanwu	17	632,000	38,303	562,000	70,000	562,000	0
Near Suburbs	**1,283**	**5,373,000**	**4,188**	**4,292,000**	**1,081,000**	**3,819,000**	**473,000**
Chaoyang	471	1,897,000	4,029	1,522,000	375,000	1,335,000	187,000
Fengtai	304	1,103,000	3,626	822,000	281,000	675,000	147,000
Shijingshan	82	415,000	5,073	332,000	83,000	316,000	16,000
Haidian	426	1,958,000	4,596	1,616,000	342,000	1,493,000	123,000
Outer Suburbs	**6,478**	**2,778,000**	**429**	**2,539,000**	**239,000**	**912,000**	**1,627,000**
Mentougou	1,331	255,000	192	234,000	21,000	153,000	81,000
Fangshan	1,867	783,000	419	743,000	40,000	270,000	473,000
Tongzhou	870	652,000	749	597,000	55,000	191,000	406,000
Changping	1,430	495,000	346	428,000	67,000	180,000	248,000
Shunyi	980	593,000	605	537,000	56,000	118,000	419,000
Counties	**8,960**	**1,966,000**	**219**	**1,862,000**	**104,000**	**494,000**	**1,368,000**
Daxing	1,012	589,000	582	528,000	61,000	156,000	372,000
Pinggu	1,075	399,000	371	387,000	12,000	97,000	290,000
Huairou	2,557	283,000	111	263,000	20,000	82,000	181,000
Miyun	2,336	422,000	181	415,000	7,000	97,000	318,000
Yanqing	1,980	273,000	138	269,000	4,000	62,000	207,000

Source: Compiled by authors from data of the Beijing Statistical Office, 2001

Table 4 District areas and population relative to totals for Beijing Municipality in the year 2000

District	Land Area (km²)	Total population (persons)	Permanent population (persons)	Temporary residents (persons)	Permanent non agricultural residents (persons)	Permanent agricultural residents (persons)
Beijing Municipality	**100.0%**	**100%**	**100%**	**100%**	**100%**	**100%**
City Proper	**0.5%**	**21%**	**22%**	**16%**	**31%**	**0%**
Dongcheng	0.1%	5.6%	6%	5.7%	5.1%	8.2%
Xicheng	0.2%	6.7%	7%	7.1%	4.4%	10.3%
Chongwen	0.1%	3.6%	4%	3.7%	2.9%	5.4%
Xuanwu	0.1%	4.9%	5%	5.1%	4.1%	7.4%
Near Suburbs	**7.6%**	**42%**	**39%**	**63%**	**50%**	**14%**
Chaoyang	2.8%	15%	14%	22%	18%	5%
Fengtai	1.8%	9%	7%	16%	9%	4%
Shijingshan	0.5%	3%	3%	5%	4%	0%
Haidian	2.5%	15%	15%	20%	20%	4%
Outer Suburbs	**38.5%**	**22%**	**23%**	**14%**	**12%**	**47%**
Mentougou	7.9%	2%	2%	1%	2%	2%
Fangshan	11.1%	6%	7%	2%	4%	14%
Tongzhou	5.2%	5%	5%	3%	3%	12%
Changping	8.5%	4%	4%	4%	2%	7%
Shunyi	5.8%	5%	5%	3%	2%	12%
Counties	**53.3%**	**15%**	**17%**	**6%**	**6%**	**39%**
Daxing	6.0%	5%	5%	4%	2%	11%
Pinggu	6.4%	3%	3%	1%	1%	8%
Huairou	15.2%	2%	2%	1%	1%	5%
Miyun	13.9%	3%	4%	0%	1%	9%
Yanqing	11.8%	2%	2%	0%	1%	6%

Source: Compiled by authors from data of the Beijing Statistical Office, 2001

3.1.2 Trends in land use and population

The main impact of urbanisation on the agricultural sector is the loss of arable land areas due to conversion to urban areas. With regard to Beijing this process was described by Lu (1999). He calculated the expansion rate of the city centre from historical times. From the Qing dynasty (1644-1911) to the revolution in 1949, the city has grown with about 0.76 km^2 per year. In the period from 1947 until 1997 annual expansion was about 8.1 km^2. In addition to the city centre growth, urbanization of the Beijing suburbs (the near and outer suburbs) and counties rapidly took place. Whereas there were only 38 small towns in 1953, in 1993 the suburbs have developed into 78 small towns, 14 satellite-towns and 26 so-called “developing areas” (Lu, 1999). These latter areas are urban areas under construction. As a consequence, the area of arable land declined by 204 thousand hectares since 1949 (Table 5). The largest area losses occurred during the periods 1953-1960 and 1990-1997, resulting in only 0.03 hectares of arable land per capita at present.

Table 5 Trends in total land area, total population and per capita area of arable land in Beijing Municipality

Year	Area of arable land (ha)	Population	Arable land per capita (ha/person)
1949	573,480	4,140,000	0.14
1953	644,400	5,024,000	0.13
1960	469,440	7,321,000	0.06
1980	459,864	8,857,000	0.05
1990	445,752	10,322,000	0.04
1997	369,720	10,855,000	0.03

Source: Lu, 1999.

Table 6 Land use for non-agricultural and agricultural functions in the year 1991 and the year 2001 in the different districts of Beijing Municipality and the change in land use over this time period

	1991			2001			Difference
District	Non-agricultural land (ha) [1]	Agricultural land (ha) [2]	Total land area (ha)	Non-agricultural land (ha) [1]	Agricultural land (ha) [2]	Total land area (ha)	Agricultural land (ha)
Near suburbs	**77,884**	**50,396**	**128,280**	**104,359**	**23,921**	**128,280**	**-26,475**
Chaoyang	26,112	20,968	47,080	38,356	8,724	47,080	-12,244
Fengtai	18,576	11,844	30,420	24,447	5,973	30,420	-5,871
Shijingshan	6,891	1,289	8,180	7,566	614	8,180	-675
Haidian	26,305	16,295	42,600	33,990	8,610	42,600	-7,685
Outer suburbs	**428,215**	**219,585**	**647,800**	**455,826**	**191,974**	**647,800**	**-27,611**
Mentougou	124,275	8,855	133,130	125,256	7,874	133,130	-981
Fangshan	139,951	46,719	186,670	140,410	46,260	186,670	-459
Tongzhou	24,760	62,240	87,000	32,574	54,426	87,000	-7,815
Changping	103,718	39,282	143,000	108,169	34,831	143,000	-4,451
Shunyi	35,512	62,488	98,000	49,417	48,583	98,000	-13,905
Counties	**685,996**	**209,994**	**895,990**	**704,175**	**191,815**	**895,990**	**-18,179**
Daxing	34,481	66,719	101,200	46,885	54,315	101,200	-12,404
Pinggu	70,737	36,763	107,500	74,846	32,654	107,500	-4,109
Huairou	233,251	22,479	255,730	235,248	20,482	255,730	-1,997
Miyun	191,994	41,566	233,560	188,528	45,032	233,560	3,466
Yanqing	155,533	42,467	198,000	158,668	39,332	198,000	-3,135
Beijing Municipality	**1,192,094**	**479,976**	**1,672,070**	**1,264,360**	**407,710**	**1,672,070**	**-72,266**

Source: Compiled by authors from data of the Beijing Statistical Office, 1992 and 2002

1) Non-agricultural land consists out of land use for residential areas, roads, factories etc. This category also contains mountainous land that cannot be used for agriculture because it is too steep.

2) Agricultural land area covers the following categories: cultivated land (food crops, cash crops, vegetables), orchards and fish ponds.

Analysing the land use changes between 1991 and 2001 in more detail, shows that the non-agricultural land areas in Beijing Municipality were about 1.2 million hectares in 1991 and increased to 1.3 million hectares in 2001 (i.e. from 71 to 76% of the total land area (Table 7)). These figures clearly show how much the agricultural sector is under pressure from increasing claims for non-agricultural land uses. Within a period of ten years, more than 72 thousand hectares of land have changed from an agricultural function to a non-agricultural function (Table 6). Not surprisingly, the relatively strongest changes occurred in the near suburbs, where 20% (Table 7: from 39% in 1991 to 19% in 2001) of the total land area was converted to a non-agricultural function. In addition to the districts in the near suburbs, a rapid conversion of land areas from agricultural to non-agricultural function also took place in Shunyi and Daxing. The only exception to this trend of agricultural land conversion is Miyun county, where the area of agricultural land increased by more than three thousand hectares.

Table 7 Relative land use for non-agricultural and agricultural functions in the year 1991 and the year 2001 in the different districts of Beijing Municipality and the change in relative land use over this time period.

	1991		2001		Difference
District	Non-agricultural land (ha) [1]	Agricultural land (ha)	Non-agricultural land (ha) [1]	Agricultural land (ha)	Agricultural land (ha)
Near suburbs	**61%**	**39%**	**81%**	**19%**	**-20%**
Chaoyang	55%	45%	81%	19%	-26%
Fengtai	61%	39%	80%	20%	-19%
Shijingshan	84%	16%	92%	8%	-8%
Haidian	62%	38%	80%	20%	-18%
Outer suburbs	**66%**	**34%**	**70%**	**30%**	**-4%**
Mentougou	93%	7%	94%	6%	-1%
Fangshan	75%	25%	75%	25%	0%
Tongzhou	28%	72%	37%	63%	-9%
Changping	73%	27%	76%	24%	-3%
Shunyi	36%	64%	50%	50%	-14%
Counties	**77%**[1]	**23%**	**79%**	**21%**	**-2%**
Daxing	34%	66%	46%	54%	-12%
Pinggu	66%	34%	70%	30%	-4%
Huairou	91%	9%	92%	8%	-1%
Miyun	82%	18%	81%	19%	1%
Yanqing	79%	21%	80%	20%	-2%
Beijing Municipality	**71%**	**29%**	**76%**	**24%**	**-4%**

Source: Compiled by authors from data of the Beijing Statistical Office, 1992 and 2002

1) The high percentage of non-agricultural land use in these counties is due to the mountainous areas that cannot be used for agriculture, therefore, they have been classified in the non-agricultural land category.

3.2 Arable production systems in Beijing Municipality

3.2.1 Land use

The area of agricultural land in Beijing Municipality declined by more than 72 thousand hectares from 1991 to 2001 (Table 6). This corresponds to an annual rate of decline of 1.6%. In this section, we look at the different agricultural land uses in more detail. The total agricultural land area is defined as the total of arable land, land in use for orchards and aquaculture. Table 8 shows that the decline in agricultural land area completely took place in the arable land category, and that this land was converted to orchards or non-agricultural land use. In the year 1991 orchards covered 10% of the total area of agricultural land, whereas in the year 2001 the relative area with orchards had increased to 21% (Table 9). Also the absolute area increase of orchards was considerable: over 35 thousand hectares. This enlarged area of orchards is a direct response to the higher demand for fruits from the urban consumers. At the same time these changes are also stimulated by the Chinese government, by subsidising the conversion of arable land to perennial crop lands such as orchards. The government is stimulating this conversion, assuming that farmers will not be able to compete with their grain crops on the world market, and that orchards will better serve the objectives of sustainable land use (including water and soil conservation and sufficient farmers' income) and meet the demands of urban consumers.

The main part of the total orchard area is situated in the counties (58% of the total in year 2001 (Table 8)). Especially in the counties Pinggu and Miyun and in the outer suburb Changping, the largest share of the total orchard area growth took place (Table 8). Miyun is a special case because the government has assigned the upper stream of the Miyun reservoir as a water protection area. To prevent sedimentation and eutrophication of the reservoir farmers are no longer allowed to produce annual crops (Decision of Beijing Municipality, 2001 ?)

Table 8 Distribution of total agricultural land over different land use types in years 1991 and 2001 in the different districts of Beijing Municipality and the change in land use over this time period

District	1991 Arable land (ha)	1991 Orchards (ha)	1991 Aquaculture (ha)	2001 Arable land (ha)	2001 Orchards (ha)	2001 Aquaculture (ha)	Difference 1991 – 2001 Arable land (ha)	Difference 1991 – 2001 Orchards (ha)	Difference 1991 – 2001 Aquaculture (ha)
Near suburbs	**43,555**	**5,174**	**1,667**	**20,206**	**2,526**	**1,189**	**-23,349**	**-2,648**	**-478**
Chaoyang	19,438	480	1,050	7,697	278	749	-11,741	-202	-301
Fengtai	10,376	1,331	137	5,322	587	64	-5,054	-744	-73
Shijingshan	874	408	7	340	274	0	-535	-134	-7
Haidian	12,867	2,955	474	6,847	1,387	376	-6,020	-1,567	-98
Outer suburbs	**196,827**	**17,359**	**5,398**	**153,924**	**33,025**	**5,024**	**-42,903**	**15,666**	**-375**
Mentougou	7,549	1,157	149	3,036	4,588	251	-4,513	3,430	102
Fangshan	40,237	6,030	452	39,776	5,956	528	-461	-74	76
Tongzhou	59,078	1,558	1,604	48,721	4,190	1,515	-10,358	2,632	-89
Changping	32,552	5,407	1,323	22,323	11,622	886	-10,229	6,214	-437
Shunyi	57,410	3,206	1,871	40,068	6,671	1,844	-17,342	3,465	-28
Counties	**167,672**	**27,201**	**15,121**	**126,426**	**49,439**	**15,950**	**-41,245**	**22,238**	**828**
Daxing	60,312	5,891	515	46,010	7,940	364	-14,302	2,049	-151
Pinggu	29,149	6,677	937	14,571	16,883	1,199	-14,578	10,207	262
Huairou	18,708	2,906	865	14,937	4,655	890	-3,771	1,749	25
Miyun	25,458	6,492	9,617	18,804	15,961	10,267	-6,653	9,469	650
Yanqing	34,044	5,236	3,188	32,104	3,999	3,229	-1,940	-1,236	42
Beijing Municipality	**408,054**	**49,735**	**22,187**	**300,557**	**84,991**	**22,162**	**-107,497**	**35,256**	**-24**

Source: Compiled by authors from data of the Beijing Statistical Office, 2002

The total area of land that is used for arable cropping, can be divided over the following categories:

- food crops (wheat, rice, maize, millet, sorghum, tubers, beans)
- cash crops (cotton, peanut, sesame, sunflower, tobacco)
- vegetables
- flowers, nurseries and others (e.g. forage crops and grassland)

Table 10 shows considerable differences in land use change for these categories during the time period 1991-2001. The area of grain crops strongly decreased. Surprisingly, the area of flowers and nurseries also declined. With rising incomes and urbanisation one would expect that the land area in use for the ornamental sector would increase instead of decrease. A possible explanation is the strong reduction in the arable land area (Table 8) due to the rapid urbanization.

Table 9 Relative agricultural land use in the years 1991 and 2001 as fraction of total area of agricultural land in different districts of Beijng Municipality and the change in relative land use over this time period

	1991			2001			Difference 1991 - 2001		
District	Arable land (ha)	Orchards (ha)	Aquacul-ture (ha)	Arable land (ha)	Orchards (ha)	Aquacul-ture (ha)	Arable land (ha)	Orchards (ha)	Aquacul-ture (ha)
Near suburbs	**86%**	**10%**	**3%**	**84%**	**11%**	**5%**	**-2%**	**0%**	**2%**
Chaoyang	93%	2%	5%	88%	3%	9%	-4%	1%	4%
Fengtai	88%	11%	1%	89%	10%	1%	1%	-1%	0%
Shijingshan	68%	32%	1%	55%	45%	0%	-13%	13%	-1%
Haidian	79%	18%	3%	80%	16%	4%	1%	-2%	1%
Outer suburbs	**90%**	**8%**	**2%**	**80%**	**17%**	**3%**	**-9%**	**9%**	**0%**
Mentougou	85%	13%	2%	39%	58%	3%	-47%	45%	2%
Fangshan	86%	13%	1%	86%	13%	1%	0%	0%	0%
Tongzhou	95%	3%	3%	90%	8%	3%	-5%	5%	0%
Changping	83%	14%	3%	64%	33%	3%	-19%	20%	-1%
Shunyi	92%	5%	3%	82%	14%	4%	-9%	9%	1%
Counties	**80%**	**13%**	**7%**	**66%**	**26%**	**8%**	**-14%**	**13%**	**1%**
Daxing	90%	9%	1%	85%	15%	1%	-6%	6%	0%
Pinggu	79%	18%	3%	45%	52%	4%	-35%	34%	1%
Huairou	83%	13%	4%	73%	23%	4%	-10%	10%	0%
Miyun	61%	16%	23%	42%	35%	23%	-19%	20%	0%
Yanqing	80%	12%	8%	82%	10%	8%	1%	-2%	1%
Beijing Municipality	**85%**	**10%**	**5%**	**74%**	**21%**	**5%**	**-11%**	**10%**	**1%**

Source: Compiled by authors from data of the Beijing Statistical Office, 2002

Table 10 Distribution of arable land area over different crop categories in the years 1991 and 2001 in the different districts of Beijing Municipality and the change over this time period

	1991				2001				Change between 1991 and 2001			
District	Food crops (ha)	Cash crops (ha)	Vegetables (ha)	Others, flowers and nurseries (ha)	Food crops (ha)	Cash crops (iha)	Vegetables(ha)	Other, flowers and nurseries (ha)	Food crops (ha)	Cash crops (ha)	Vegetables (ha)	Other, flowers and nurseries (ha)
Near suburbs	**19,265**	**105**	**2,180**	**22,005**	**6,295**	**45**	**6,076**	**7,790**	**-12,970**	**-60**	**3,896**	**-14,215**
Chaoyang	9,856	75	1,414	8,093	2,434	45	3,079	2,139	-7,421	-30	1,664	-5,954
Fengtai	3,195	30	234	6,917	1,710	0	2,054	1,558	-1,485	-30	1,820	-5,359
Shijingshan	121	0	0	753	0	0	103	236	-121	0	103	-517
Haidian	6,093	0	532	6,242	2,151	0	840	3,856	-3,942	0	308	-2,386
Outer suburbs	**151,388**	**5,333**	**4,569**	**35,536**	**67,483**	**7,326**	**36,495**	**42,621**	**-83,906**	**1,993**	**31,925**	**7,085**
Mentougou	4,578	7	73	2,890	2,047	2	609	377	-2,531	-5	536	-2,514
Fangshan	32,808	1,556	638	5,235	17,106	2,278	5,488	14,903	-15,702	722	4,851	9,668
Tongzhou	44,417	2,548	494	11,620	18,353	3,251	11,264	15,853	-26,063	703	10,770	4,233
Changping	23,440	125	1,442	7,545	11,494	84	4,020	6,725	-11,946	-40	2,577	-820
Shunyi	46,145	1,097	1,923	8,246	18,482	1,710	15,113	4,763	-27,663	613	13,191	-3,483
Counties	**117,600**	**10,674**	**4,804**	**34,593**	**63,486**	**11,148**	**35,463**	**16,330**	**-54,114**	**473**	**30,659**	**-18,264**
Daxing	37,933	4,668	4,252	13,459	19,207	4,658	18,962	3,184	-18,726	-11	14,710	-10,275
Pinggu	19,415	1,157	181	8,397	7,672	955	4,471	1,473	-11,743	-202	4,290	-6,923
Huairou	14,372	806	21	3,510	6,897	1,663	2,029	4,349	-7,475	857	2,007	840
Miyun	18,759	3,959	26	2,714	9,101	3,742	4,301	1,660	-9,657	-217	4,275	-1,054
Yanqing	27,121	85	324	6,514	20,609	131	5,700	5,663	-6,512	46	5,376	-851
Beijing Municipality	**288,254**	**16,112**	**11,554**	**92,135**	**137,264**	**18,519**	**78,033**	**66,741**	**-150,989**	**2,407**	**66,480**	**-25,394**

Source: Compiled by authors from data of the Beijing Statistical Office, 2002

The area under vegetables strongly increased in accordance with our expectations. Over the period 1991-2001 the vegetable area grew by 19% per year, increasing in total by 66 thousand hectares (Table 10). This has changed the arable land use distribution considerably. In 1991 the share of vegetables in the total arable land use was only 3% with grain crops dominating (71%). However in 2001, the area fraction with vegetables had increased to 26%, and the relative area with grain crops had decreased to 46% (Table 10).

Table 11 Relative arable land use in the different districts of Beijing Municipality in years 1991 and 2001 as fraction of the total land use for each crop category

	1991				2001			
District	Food crops (ha)	Cash crops (ha)	Vegetables (ha)	Others, flowers and nurseries (ha)	Food crops (ha)	Cash crops (ha)	Vegetables (ha)	Others, flowers and nurseries (ha)
Near suburbs	**7%**	**1%**	**19%**	**24%**	**5%**	**0%**	**8%**	**12%**
Chaoyang	3%	0%	12%	9%	2%	0%	4%	3%
Fengtai	1%	0%	2%	8%	1%	0%	3%	2%
Shijingshan	0%	0%	0%	1%	0%	0%	0%	0%
Haidian	2%	0%	5%	7%	2%	0%	1%	6%
Outer suburbs	**53%**	**33%**	**40%**	**39%**	**49%**	**40%**	**47%**	**64%**
Mentougou	2%	0%	1%	3%	1%	0%	1%	1%
Fangshan	11%	10%	6%	6%	12%	12%	7%	22%
Tongzhou	15%	16%	4%	13%	13%	18%	14%	24%
Changping	8%	1%	12%	8%	8%	0%	5%	10%
Shunyi	16%	7%	17%	9%	13%	9%	19%	7%
Counties	**41%**	**66%**	**42%**	**38%**	**46%**	**60%**	**45%**	**24%**
Daxing	13%	29%	37%	15%	14%	25%	24%	5%
Pinggu	7%	7%	2%	9%	6%	5%	6%	2%
Huairou	5%	5%	0%	4%	5%	9%	3%	7%
Miyun	7%	25%	0%	3%	7%	20%	6%	2%
Yanqing	9%	1%	3%	7%	15%	1%	7%	8%
Beijing Municipality	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

Source: Compiled by authors from data of the Beijing Statistical Office, 1992 and 2002

If we look at the location of the different types of arable land use, it is clear that most arable land uses are moving away from the near suburbs to the more distant zones (Table 11). Flowers and nurseries are moving from both the near suburbs and counties towards the outer suburbs. In 1991 and 2001, the largest share of vegetable production was located in Daxing county (Table 11), however, its dominance decreased, as in other districts the area of the arable land allocated to vegetable production increased faster. For example in Tongzhou, Huairou and Miyun, annual rates of increase in vegetable area were between 31 and 51%.

3.2.2 Input use

Water quality is strongly affected by the magnitude of fertiliser and biocide use. Tables 12 and 13 give the total use of fertilisers and biocides in respectively the years 1991 and 2001. Over this period of ten years, total fertiliser use increased by only 1% per year. However, as simultaneously the arable land area decreased by 108 thousand hectares (-26 %; Table 8), total fertiliser use per hectare considerably increased: from 351 kg/ha to 522 kg/ha on average for Beijing Municipality as a whole. Fertiliser use within Beijing Municipality per hectare varied in 1991 between 85 and 511 kg/ha, and in 2001 between 158 and 1060 kg/ha. Note that these high fertiliser rates on arable land areas may partly be explained by fertiliser use on orchard area which is not considered in the arable land area.

Table 12 Use of fertilisers and biocides in the year 1991 on arable land areas in Beijing Municipality

	Fertiliser use in effective components				Fertiliser use per hectare of arable land				Total biocide use	
	Total (tons)	Nitrogen (tons)	Phospho-rus (tons)	Potassium (tons)	Total (kg/ha)	Nitrogen (kg/ha)	Phosphorus (kg/ha)	Potassium (kg/ha)	(tons)	(kg/ha)
Near suburbs	**11,060**	**8,682**	**1,640**	**739**	**254**	**199**	**38**	**17**	**843**	**19**
Chaoyang	4,927	4,021	626	281	253	207	32	14	211	11
Fengtai	2,932	2,103	568	262	283	203	55	25	293	28
Shijingshan	168	132	24	13	192	150	27	14	12	14
Haidian	3,033	2,427	422	184	236	189	33	14	327	25
Outer suburbs	**79,076**	**55,503**	**15,853**	**7,720**	**401**	**282**	**80**	**39**	**1,462**	**7**
Mentougou	645	510	89	46	85	68	12	6	40	5
Fangshan	12,283	8,922	2,373	988	305	222	59	25	232	6
Tongzhou	28,342	20,360	5,574	2,409	478	343	94	41	403	7
Changping	8,429	6,075	1,566	788	259	187	48	24	312	10
Shunyi	29,377	19,636	6,252	3,489	511	342	109	61	475	8
Counties	**53,488**	**43,197**	**7,817**	**2,475**	**318**	**257**	**47**	**15**	**1,324**	**8**
Daxing	19,715	14,918	4,003	795	326	247	66	13	469	8
Pinggu	10,445	8,500	1,339	606	357	291	46	21	429	15
Huairou	6,099	4,798	876	426	326	256	47	23	134	7
Miyun	6,807	5,564	831	412	267	218	33	16	222	9
Yanqing	10,422	9,417	769	236	306	276	23	7	70	2
Beijing Municipality	**143,624**	**107,382**	**25,309**	**10,934**	**351**	**263**	**62**	**27**	**3,629**	**9**

Source: Compiled by authors from data of the Beijing Statistical Office, 1992

In both the years 1991 and 2001, the largest part of the total fertiliser application consists of nitrogen (Tables 12 and 13). In 1991 the contribution of nitrogen to total fertiliser consumption was 75%, and in 2001 66%.

Total biocide use annually increased with about 2%. Biocide consumption per hectare increased more rapidly, from 9 kilogram in 1991 to 15 kilogram in 2001. Remarkably, biocide use per hectare decreased in the near suburbs, whereas the relative share of biocide intensive crops such as vegetables, has increased. However, the areas with orchards (Table 8), flowers and nurseries (Table 10) have clearly decreased, which may be the explanation.

Table 13 Use of fertilisers and biocides in the year 2001 on arable land areas in Beijing Municipality

	Fertiliser use in effective components				Fertiliser use per hectare of arable land				Total biocide use	
	Total (tons)	Nitrogen (tons)	Phosphorus (tons)	Potassium (tons)	Total (kg/ha)	Nitrogen (kg/ha)	Phosphorus (kg/ha)	Potassium (kg/ha)	(tons)	(kg/ha)
Near suburbs	**5,329**	**3,802**	**1,051**	**477**	**264**	**188**	**52**	**24**	**287**	**14**
Chaoyang	2,758	1,850	619	290	358	240	80	38	106	14
Fengtai	1,411	1,006	289	117	265	189	54	22	43	8
Shijingshan	78	64	11	4	230	188	31	11	3	9
Haidian	1,082	883	133	67	158	129	19	10	135	20
Outer suburbs	**79,471**	**49,638**	**19,940**	**9,894**	**516**	**322**	**130**	**64**	**1,755**	**11**
Mentougou	490	281	148	61	161	93	49	20	44	14
Fangshan	14,917	8,346	4,497	2,075	375	210	113	52	328	8
Tongzhou	6,700	4,838	1,359	504	300	217	61	23	356	16
Changping	31,551	19,942	7,670	3,939	648	409	157	81	593	12
Shunyi	25,813	16,232	6,266	3,316	644	405	156	83	434	11
Counties	**71,981**	**49,851**	**14,576**	**7,455**	**569**	**394**	**115**	**59**	**2,431**	**19**
Daxing	30,528	22,096	5,590	2,843	664	480	121	62	942	20
Pinggu	15,477	10,095	3,561	1,821	1,062[1]	693[1]	244	125	722	50[1]
Huairou	7,254	5,191	1,505	558	486	348	101	37	318	21
Miyun	8,766	5,486	1,917	1,364	466	292	102	73	203	11
Yanqing	9,956	6,983	2,004	869	310	218	62	27	246	8
Beijing Municipality	**156,781**	**103,291**	**35,566**	**17,826**	**522**	**344**	**118**	**59**	**4,473**	**15**

Source: Compiled by authors from data of the Beijing Statistical Office, 2002
[1] This high number may be explained by fertiliser and biocide use on orchard area which is not considered in the arable land area.

Another very important input is water. An indicator for the use of water is the area of irrigated land. This area has considerably decreased in the ten years since 1991. Compared to 1991, the irrigated area in 2001 was 94 thousand hectares smaller (Table 14). Moreover, the fraction of the total arable land area that was irrigated, decreased from 70% in 1991 to 60% in 2001. This decline in irrigated area resulted in a reduction in total water use for irrigation. Only in Changping more irrigation water was used in 2001 than in 1991. Changping, Shunyi and Daxing use the largest amounts of irrigation water. Together, these districts consumed in the year 2001 about 48% of the total irrigation water use in Beijing Municipality.

Table 14 Area of irrigated land and use of irrigation water in the different districts of Beijing Municipality in the years 1991 and 2001 and their change over this time period

	1991			2001			Difference	
	Irrigated area (ha)	Share irrigated land of total arable land	Irrigation water use (billion m^3)	Irrigated area (ha)	Share irrigated land of total arable land	Irrigation water use (billion m^3)	Irrigated area (ha)	Irrigation water use (billion m^3)
Near suburbs	**33,287**	**66%**	**0.237**	**13,799**	**58%**	**0.07**	**-19,488**	**-0.17**
Chaoyang	15,769	75%	0.107	7,697	88%	0.03	-8,072	-0.08
Fengtai	6,632	56%	0.048	3,347	56%	0.02	-3,285	-0.03
Shijingshan	485	38%	0.005	245	40%	0.00	-240	0.00
Haidian	10,401	64%	0.076	2,510	29%	0.02	-7,891	-0.06
Outer suburbs	**175,665**	**80%**	**0.932**	**132,856**	**69%**	**0.58**	**-42,809**	**-0.35**
Mentougou	2,132	24%	0.016	1,981	25%	0.02	-151	0.00
Fangshan	38,858	83%	0.180	32,712	71%	0.12	-6,146	-0.06
Tongzhou	54,527	88%	0.320	37,591	69%	0.09	-16,937	-0.23
Changping	24,642	63%	0.139	16,587	48%	0.18	-8,055	0.04
Shunyi	55,505	89%	0.277	43,985	91%	0.18	-11,520	-0.10
Counties	**127,750**	**61%**	**0.630**	**96,338**	**50%**	**0.57**	**-31,412**	**-0.06**
Daxing	55,035	82%	0.261	45,252	83%	0.23	-9,783	-0.04
Pinggu	24,295	66%	0.119	13,933	43%	0.12	-10,362	0.00
Huairou	17,889	80%	0.073	10,826	53%	0.04	-7,063	-0.03
Miyun	17,820	43%	0.089	13,404	30%	0.09	-4,417	0.00
Yanqing	12,710	30%	0.088	12,923	33%	0.10	212	0.01
Beijing Municipality	**336,701**	**70%**	**1.799**	**242,993**	**60%**	**1.22**	**-93,708**	**-0.58**

Source: Compiled by authors from data of the Beijing Statistical Office, 1992 and 2002

3.3 Animal production systems in Beijing Municipality

3.3.1 General

From 1978, when China adopted ‘open and reform’ policy, animal husbandry systems developed very quickly. Backyard rearing played an important role in livestock production. Upon entering the 1980s, an official government-supported campaign was launched to guarantee the supply of animal/poultry produce to the urban residents. To realize this target, advanced technology of intensified, mechanized, and confinement rearing has been introduced. A large number (more than 3,000) of big and medium sized livestock farms were established. For example in 1990, there were already 1254 large-scale swine farms (each farm with more than 100 head of sows and with an annual production of about 1500 pigs). These state-owned livestock farms have made a large contribution to livestock production. However, due to their central planning system and out-dated management, the majority of these livestock farms works at a loss, even though they get considerable subsidies from the municipal government. A new, household responsibility system has been introduced around 1992. Since then, a large proportion of the state-owned livestock farms changed to collectively-owned or to specialized rearing household-owned farms. In 1997, the Beijing municipal government decided to promote the so-called 'small rearing plot'. Such plots comprise several specialized rearing households and receive subsidies from the government for their technical innovation. As a result, the current fraction of farms with backyard rearing has decreased to below 10% of the total. Also, the number of large-scale livestock farms has strongly been reduced to 897 (swine and poultry) in 2001, from 1,445 farms in 1997 and more than 2,300 in 1990. Simultaneously, the number of 'small rearing plots' has grown quickly and amounted to 1928 in 2001, and the number of specialized rearing households reached 159,000.

However, as the negative environmental effects of farms with conventional modernized rearing systems were not taken into consideration, no equipment for waste treatment was included in the construction plans of these big and medium-sized livestock farms. Consequently, these rapid developments in the livestock sector have already caused severe pollution problems.

As livestock production is regarded as the best way for increasing farmers' incomes, the Beijing government decided in 2001 that the proportion of livestock production value should increase from 50% (of total agricultural production value) at present to 60% in the year of 2010. Simultaneously, the government emphasized the importance of so-called 'green animal husbandry', which should in the future result in less pollution of the environment.

In 1996, the Municipal government decided to move the livestock farms that were located within the Fourth Ring Road (near suburbs) into the outer suburban areas. The next step will be the removal of all livestock farms located within the Fifth Ring Road and the Fourth Ring Road. This means that livestock production will disappear from the near suburban districts.

3.3.2 Production and consumption

In a review of the livestock sector in Beijing (Ke, 1998) the growing demand for meat in Beijing is clearly indicated (Table 15), as well as the resulting increase in production. Following a more than tenfold increase in per capita income in the period 1980 to 1995, more and more people can afford to buy meat. In combination with the large population growth in Beijing, this has resulted in a booming livestock sector around the city.

Table 15 Mean annual per capita consumption (kg) of livestock products in urban and rural areas of Beijing

	Year					
	1985		1990		1995	
	urban	rural	urban	rural	urban	rural
Red meat	26.0	9.8	30.6	11.5	34.5	12.8
Poultry	3.0	0.3	4.0	0.6	7.8	1.6
Eggs	14.0	5.6	15.5	5.8	16.6	5.8
Milk / products	14.0	0.0	15.6	0.0	15.1	1.5

Source: Ke, 1998

According to Ke (1998) the demand for meat has increased at an annual rate of 9%, bringing enormous pressure on local production to attain self-sufficiency, which is estimated for meat in Beijing at around 60%. Table 16 shows these rapid increases in meat production, i.e. a doubling of the pork production, an increase in poultry production by a factor of 3.7 and a twelve-fold increase in beef production. Ke states that this production growth was achieved through improved production technology, such as the introduction of high yielding animal breeds and the use of modern feed processing.

Table 16 Increase in livestock production in Beijing from the year 1985 to the year 1995

	Livestock production (x 1 000 tons)					
	Pork	Poultry	Mutton	Beef	Eggs	Milk
1985	131.7	22.3	3.8	1.5	116.5	128.4
1995	258.2	104.9	10.9	20.4	279.2	206.0
Growth %	96.1	370.4	186.8	1260.0	139.7	60.4

Source: Ke, 1998

For the livestock production in Beijing Municipality as a whole, total feed input consisted of 2.3 million tons of concentrates, 2.8 million tons of corn silage (fresh weight), 0.44 million tons of alfalfa (dry) and 0.40 million tons of hay (dry) in the year 2001 (?). This was associated with a production of 312.0, 258.9, 30.2, 43.4, 155.6 and 429.0 thousand-tons of pork, poultry, mutton, beef, eggs and milk, respectively in the year 2001.

3.3.3 Livestock numbers and density

Data used in this study indicate that the rate of growth in number of livestock has declined in recent years for pigs (only 0.2 % per year at present), but that rates for cattle, poultry and sheep are still high at 7%, 7% and 30% per year, respectively. This growth has resulted in nearly 7 million pigs, 195 million poultry birds, more than 2 million sheep and 434 thousand cattle in the year 2001 (Table 17).

Differences in growth rates among the various districts are considerable. For all livestock types, except for sheep (as a strong increase in the number of sheep is found in all districts), the growth rates were negative for the near suburbs, very high for the outer suburbs and high for cattle and poultry (but not for pigs) in the counties (Table 17). Especially in Shunyi, located in the outer suburbs, the growth in number of livestock was very high: annual growth rate of 26% for cattle, 9% for swine, 36% for sheep, and 16% for poultry. Growth of poultry production was even slightly higher in Fangshan, Yanqing and Miyun (about 17% per year).

Table 17 Livestock in the various districts of Beijing Municipality in the years 1994 and 2001 and the change over this time period

District	1994 (livestock numbers x 1000)					2001 (livestock numbers x 1000)					Difference (livestock numbers x 1000)				
	Cattle	Swine	Goats	Sheep	Poultry	Cattle	Swine	Goats	Sheep	Poultry	Cattle	Swine	Goats	Sheep	Poultry
Near suburbs	**17**	**1,124**	**15**	**14**	**14,580**	**11**	**468**	**11**	**53**	**2,392**	**-6**	**-656**	**-5**	**39**	**-12,187**
Chaoyang	10	469	12	11	4,599	8	296	0	31	238	-3	-173	-12	19	-4,361
Fengtai	2	228	2	1	3,879	2	80	1	14	959	0	-148	-1	13	-2,920
Shijingshan	1	43	0	0	1,394	0	16	0	0	133	0	-27	0	0	-1,262
Haidian	4	384	2	1	4,708	2	76	10	8	1,063	-3	-308	8	7	-3,645
Outer suburbs	**119**	**3,474**	**711**	**194**	**55,203**	**234**	**4,117**	**702**	**1,221**	**109,980**	**115**	**643**	**-9**	**1,027**	**54,777**
Mentougou	2	83	49	1	1,143	2	63	151	49	738	1	-19	102	48	-404
Fangshan	14	545	211	46	6,158	35	543	324	194	19,144	21	-2	113	148	12,986
Tongzhou	59	986	231	76	10,860	45	741	55	205	12,880	-14	-246	-176	128	2,020
Changping	18	501	49	26	13,958	22	319	60	383	13,396	4	-182	12	357	-562
Shunyi	26	1,359	170	44	23,084	129	2,452	111	391	63,822	103	1,092	-59	346	40,738
Counties	**138**	**2,240**	**509**	**162**	**47,296**	**189**	**2,363**	**411**	**1,066**	**83,220**	**50**	**123**	**-98**	**903**	**35,925**
Daxing	47	660	265	105	15,046	48	803	57	562	25,966	1	143	-207	458	10,920
Pinggu	26	553	118	23	13,219	22	494	75	129	14,389	-5	-59	-43	107	1,170
Huairou	20	308	27	9	8,107	37	297	36	56	9,029	17	-12	9	47	922
Miyun	16	477	67	18	7,953	49	542	189	226	24,359	33	65	122	208	16,406
Yanqing	29	243	33	8	2,970	33	228	54	91	9,477	4	-15	21	83	6,507
Beijing Municipality	**274**	**6,838**	**1,235**	**370**	**117,078**	**434**	**6,948**	**1,123**	**2,340**	**195,592**	**159**	**110**	**-112**	**1,970**	**78,514**

Source: Compiled by authors from data ?

Table 18 shows that of the different districts in Beijing Municipality, Shunyi produces the largest part of cattle, pigs, and poultry. Compared to 1994, the production in Shunyi has strongly increased, so that at present one third of the total number of cattle, pigs and poultry in Beijing Municpality is located here. Table 18 also shows that livestock is moving from the near suburbs to the outer suburbs.

Table 18 Shares of different districts in the total number of livestock (specified per animal category) in Beijing Municipality in the years 1994 and 2001 and the change over this time period

	1994					2001					Difference				
District	Cattle	Swine	Goats	Sheep	Poultry	Cattle	Swine	Goats	Sheep	Poultry	Cattle	Swine	Goats	Sheep	Poultry
Near suburbs	**6%**	**16%**	**1%**	**4%**	**12%**	**3%**	**7%**	**1%**	**2%**	**1%**	**-4%**	**-10%**	**0%**	**-1%**	**-11%**
Chaoyang	4%	7%	1%	3%	4%	2%	4%	0%	1%	0%	-2%	-3%	-1%	-2%	-4%
Fengtai	1%	3%	0%	0%	3%	0%	1%	0%	1%	0%	0%	-2%	0%	0%	-3%
Shijingshan	0%	1%	0%	0%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%	-1%
Haidian	2%	6%	0%	0%	4%	0%	1%	1%	0%	1%	-1%	-5%	1%	0%	-3%
Outer suburbs	**43%**	**51%**	**58%**	**52%**	**47%**	**54%**	**59%**	**62%**	**52%**	**56%**	**11%**	**8%**	**5%**	**0%**	**9%**
Mentougou	1%	1%	4%	0%	1%	1%	1%	13%	2%	0%	0%	0%	9%	2%	-1%
Fangshan	5%	8%	17%	12%	5%	8%	8%	29%	8%	10%	3%	0%	12%	-4%	5%
Tongzhou	22%	14%	19%	21%	9%	10%	11%	5%	9%	7%	-11%	-4%	-14%	-12%	-3%
Changping	7%	7%	4%	7%	12%	5%	5%	5%	16%	7%	-1%	-3%	1%	9%	-5%
Shunyi	9%	20%	14%	12%	20%	30%	35%	10%	17%	33%	20%	15%	-4%	5%	13%
Counties	**50%**	**33%**	**41%**	**44%**	**40%**	**44%**	**34%**	**37%**	**46%**	**43%**	**-7%**	**1%**	**-5%**	**2%**	**2%**
Daxing	17%	10%	21%	28%	13%	11%	12%	5%	24%	13%	-6%	2%	-16%	-4%	0%
Pinggu	10%	8%	10%	6%	11%	5%	7%	7%	6%	7%	-5%	-1%	-3%	-1%	-4%
Huairou	7%	5%	2%	2%	7%	9%	4%	3%	2%	5%	1%	0%	1%	0%	-2%
Miyun	6%	7%	5%	5%	7%	11%	8%	17%	10%	12%	6%	1%	11%	5%	6%
Yanqing	11%	4%	3%	2%	3%	8%	3%	5%	4%	5%	-3%	0%	2%	2%	2%
Beijing Municipality	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**0%**	**0%**	**0%**	**0%**	**0%**

Source: Compiled by authors from data ?

Table 19 gives the livestock density, i.e. the number of animals per hectare of total agricultural land (Table 8). In the year 1994, highest livestock densities were observed in the near suburbs, in particular for pigs and poultry. In the period 1994 to 2001, livestock densities in the near suburbs decreased, and in the outer suburbs strongly increased (Table 19). Also in the counties livestock densities increased, however, to a lesser extent. Consequently, in the year 2001 livestock densities were highest in the outer suburbs. In particular in Shunyi, densities for cattle, pigs and poultry have become very high. These strong increases in livestock density are the result of both the strong increases in number of livestock (Table 17: mainly cattle, sheep and poultry) and the decrease in total agricultural land area (Table 8).

Table 19 Livestock density in number of animals per hectare of agricultural land in the years 1994 and 2001 in the different districts of Beijing Municipality and the change over this time period

District	1994 (animals/ha)[1]					2001 (animals/ha)					Difference (animals/ha)				
	Cattle	Swine	Goats	Sheep	Poultry	Cattle	Swine	Goats	Sheep	Poultry	Cattle	Swine	Goats	Sheep	Poultry
Near suburbs	**0.4**	**26.5**	**0.4**	**0.3**	**343.4**	**0.5**	**19.6**	**0.4**	**2.2**	**100.0**	**0.1**	**-6.9**	**0.0**	**1.9**	**-243.4**
Chaoyang	0.6	27.1	0.7	0.6	265.9	0.9	34.0	0.0	3.5	27.3	0.3	6.9	-0.7	2.9	-238.6
Fengtai	0.2	22.6	0.2	0.1	384.7	0.3	13.4	0.2	2.4	160.5	0.1	-9.2	0.0	2.3	-224.2
Shijingshan	0.9	39.6	0.0	0.0	1283.6	0.8	25.4	0.0	0.0	215.8	-0.1	-14.2	0.0	0.0	-1067.8
Haidian	0.3	27.4	0.1	0.1	336.5	0.2	8.8	1.1	0.9	123.4	-0.1	-18.6	1.0	0.8	-213.1
Outer suburbs	**0.6**	**16.4**	**3.4**	**0.9**	**261.3**	**1.2**	**21.4**	**3.7**	**6.4**	**572.9**	**0.6**	**5.0**	**0.3**	**5.5**	**311.6**
Mentougou	0.2	9.7	5.7	0.1	133.5	0.3	8.0	19.2	6.2	93.8	0.1	-1.7	13.5	6.1	-39.7
Fangshan	0.3	11.7	4.5	1.0	132.2	0.8	11.7	7.0	4.2	413.8	0.5	0.0	2.5	3.2	281.6
Tongzhou	1.0	16.5	3.9	1.3	181.3	0.8	13.6	1.0	3.8	236.6	-0.2	-2.9	-2.9	2.5	55.3
Changping	0.5	13.2	1.3	0.7	367.8	0.6	9.1	1.7	11.0	384.6	0.1	-4.1	0.4	10.3	16.8
Shunyi	0.4	23.3	2.9	0.8	395.8	2.7	50.5	2.3	8.0	1,313.7	2.3	27.2	-0.6	7.2	917.9
Counties	**0.7**	**11.0**	**2.5**	**0.8**	**231.2**	**1.0**	**12.3**	**2.1**	**5.6**	**433.9**	**0.3**	**1.3**	**-0.4**	**4.8**	**202.7**
Daxing	0.7	10.5	4.2	1.7	238.8	0.9	14.8	1.1	10.4	478.1	0.2	4.3	-3.1	8.7	239.3
Pinggu	0.7	15.6	3.3	0.6	372.1	0.7	15.1	2.3	4.0	440.7	0.0	-0.5	-1.0	3.4	68.6
Huairou	0.9	14.1	1.2	0.4	370.5	1.8	14.5	1.8	2.8	440.8	0.9	0.4	0.6	2.4	70.3
Miyun	0.4	11.2	1.6	0.4	186.7	1.1	12.0	4.2	5.0	540.9	0.7	0.8	2.6	4.6	354.2
Yanqing	0.7	5.9	0.8	0.2	71.5	0.8	5.8	1.4	2.3	240.9	0.1	-0.1	0.6	2.1	169.4
Beijing Municipality	**0.6**	**14.9**	**2.7**	**0.8**	**255.5**	**1.1**	**17.0**	**2.8**	**5.7**	**479.7**	**0.5**	**2.1**	**0.1**	**4.9**	**224.2**

[1] Livestock density is calculated for the total agricultural area in 1994 which was derived by linear interpolation between the agricultural areas in the years 1991 and 2001 (Table 8).

3.4 Economic role of the agricultural sector

The two most important objectives of the agricultural sector are to (i) generate income and (ii) supply food.

3.4.1 Income generation

The contribution of the primary sector[1] to the gross domestic product (GDP)[2] of Beijing Municipality has considerably decreased since 1991 and appears to be relatively small in 2001 (Table 20). Only 3% of the total GDP is generated by the agricultural sector which, however, still generated employment for about 11% of the total working force in Beijing Municipality. The relatively low productivity of the primary sector is reflected in the value of GDP per employed person, which was about US$ 1,637[3] in 2001, i.e. one third of that in the other sectors.

1 The primary sector is defined by the Beijing Statistical Office to contain all following agricultural activities: farming, forestry and fishery.

2 GDP is the value (at market prices) of all outputs minus the value of all non-fixed inputs that are used.

3 Based on the following exchange rate: 8 Chinese Yuan equals US$ 1.

Table 20 Economic structure of Beijing Municipality in the years 1991 and 2001

	Employment				GDP					
	persons		% of total		US$ billion		% of total		US$ per employed person	
	1991	2001	1991	2001	1991	2001	1991	2001	1991	2001
Primary sector	907,998	710,763	14%	11%	0.6	1.2	8.6%	3.3%	628	1,637
Secondary sector	2,796,866	2,159,241	44%	34%	3.6	12.9	51.4%	36.2%	1,303	5,967
Tertiary sector	2,635,352	3,418,755	42%	54%	2.8	21.5	40%	60.5%	1,051	6,296
All sectors	**6,340,216**	**6,288,759**	**100%**	**100%**	**7.0**	**35.6**	**100%**	**100.0%**	**2,982**	**5,656**

Source: Compiled by authors from data of the Beijing Statistical Office, 1992 and 2002

Within the primary sector the largest shares are contributed by the farming sub-sector which includes both arable cropping and fruit tree cultivation, and the animal husbandry sub-sector. This latter shows the highest labour productivity, generating US$ 4,748 per person-year, and currently employs only 13% of the total number of persons active in the agricultural sector (Table 21). The farming sub-sector, showing a four times lower labour productivity, still employs the largest share of the agricultural workforce.

Table 21 Economic structure of the agricultural sub-sectors in Beijing Municipality in year 2001

	Gross Domestic Product (at current prices)			Employment		GDP per employed person	
	(million Yuan)	(million US$)	%	(persons)	%	(Yuan/person)	(US$/person)
Farming[1]	4,866	608	52%	526,230	74%	9,247	1,156
Forestry	433	54	5%	76,576	11%	5,654	707
Animal Husbandry	3,604	451	39%	94,886	13%	37,984	4,748
Fishery	405	51	4%	13,072	2%	30,988	3,873
All agricultural sub-sectors	**9,308**	**1,163**	**100%**	**710,763**	**100%**	**13,096**	**1,637**

Source: Compiled by authors from data of the Beijing Statistical Office, 2002

[1] Farming consists of arable cropping (grains, oil crops, fibre crops and horticulture) and fruit tree cultivation.

For the farming sub-sector the relative contributions to the total gross output value are given for the main crop categories (Table 22). Between 1991 and 2001 total output of all farming activities increased by 42%, to which all crops contributed except for the cereals. Vegetable production contributes most to the total value of outputs in the farming sub-sector, followed by fruits and cereals.

Table 22 Contribution of products from different crop categories to total farming gross output value in Beijing Municipality in 1991 and 2001

	Gross Output Value of Farming (at 1990 constant prices)					
	1991		2001		Change	
	(million US$)	%	(million US$)	%	(millionUS$)	%
All output	**478**	**100%**	**680**	**100%**	**202**	**42%**
Cereal	181	38%	72	11%	-109	-60%
Beans	3	1%	8	1%	5	167%
Cash crops	10	2%	27	4%	17	170%
Vegetable and melon	196	41%	386	57%	190	97%
Fruit and mulberry	58	12%	122	18%	64	110%
Others	31	6%	65	10%	34	110%

Source: Compiled by authors from data of the Beijing Statistical Yearbook, 1992 and 2002

3.4.2 Food supply

The agricultural sector in Beijing Municipality plays a major role in the supply of food products to the population of Beijing. Tables 23, 24 and 25 give an overview of the total production of the most important agricultural products in the different districts of Beijing Municipality, expressed as total production per district, production per capita of the total population in each district, and the relative contribution of each district to the total production of Beijing Municipality, respectively.

The data in Tables 23 and 24 indicate that the municipality can be regarded as self-sufficient in vegetable production. The large variation in per capita production among the districts of Beijing Municipality (Table 24) indicates which areas produce surplus vegetables and can supply other areas. For example, Daxing, Shunyi and Tongzhou, with only 15% of the total population, produce 62% of the total vegetable production in Beijing Municipality. Overall, Tongzhou, Shunyi, Daxing and Pinggu produce the largest shares of most agricultural products in Beijing Municipality (Table 25). The only exception is cow milk, of which 42% is still produced by the Municipal farms. This large production of cow milk at state farms is an inheritance of the pre-reform time, when all the dairy cattle in Beijing were raised at state and collective farms. Individual farmers were not allowed to raise large animals, with the exception of the Northwestern and Southwestern nomadic regions where each household was permitted to rear one or two head for family needs (Ke, 1998).

Table 23 Production of various food products by the agricultural sector in the different districts of Beijing Municipality in the year 2000

	Vegetable production (ton)	Fresh eggs production (ton)	Cow milk production (ton)	Dry and fresh fruits (ton)	Fish (ton)	Slaughtered pigs (head)	Hens production (10,000 heads)
Beijing Municipality	**4,891,457**	**160,165**	**303,312**	**609,721**	**75,044**	**4,156,079**	**1,406**
Near Suburbs	**434,142**	**9,007**	**16,904**	**17,882**	**8,361**	**400,679**	**66**
Chaoyang	174,157	491	8,058	924	5,271	251,753	5
Fengtai	143,524	4,718	4,205	4,772	340	67,223	39
Shijingshan	9,148	1,586	2,022	999	40	28,667	9
Haidian	107,313	2,212	2,619	11,187	2,710	53,036	13
Outer Suburbs	**2,265,166**	**57,147**	**77,608**	**217,004**	**38,340**	**2,486,076**	**533**
Mentougou	21,878	1,096	4,123	6,461	450	33,022	9
Fangshan	239,703	14,048	12,181	67,480	2,100	344,896	169
Tongzhou	866,332	13,725	22,919	42,441	11,669	443,301	96
Changping	127,478	6,938	17,595	55,005	8,048	246,146	60
Shunyi	1,009,775	21,340	20,790	45,617	16,073	1,418,711	199
Counties	**2,191,649**	**91,996**	**81,916**	**372,592**	**28,343**	**1,324,159**	**794**
Daxing	1,112,582	29,441	27,847	95,488	4,813	395,543	209
Pinggu	360,682	22,666	1,055	150,145	14,365	260,623	237
Huairou	54,240	7,648	19,339	45,818	2,045	195,410	75
Miyun	183,116	19,549	10,679	35,905	4,309	320,078	181
Yanqing	481,029	12,692	22,996	45,236	2,812	152,505	93
Municipal Farm Bureau	**500**	**2,015**	**126,884**	**2,243**		**45,165**	**13**

Source: Compiled by authors from data of the Beijing Statistical Office, 2002

Table 24 Production per capita of various food products by the agricultural sector in the different districts of Beijing Municipality in the year 2000

	Vegetable production (kg/capita/year)	Fresh eggs production (kg/capita/year)	Cow milk production (kg/capita/year)	Dry and fresh fruits (kg/capita/year)	Fish (kg/capita/year)	Slaughtered pigs (head/capita/year)	Hens production (head/capita/year)
Beijing Municipality	**382.7**	**12.5**	**23.7**	**47.7**	**5.9**	**0.33**	**1.10**
Near Suburbs	**80.8**	**1.7**	**3.1**	**3.3**	**1.6**	**0.07**	**0.12**
Chaoyang	91.8	0.3	4.2	0.5	2.8	0.13	0.03
Fengtai	130.1	4.3	3.8	4.3	0.3	0.06	0.35
Shijingshan	22.0	3.8	4.9	2.4	0.1	0.07	0.23
Haidian	54.8	1.1	1.3	5.7	1.4	0.03	0.07
Outer Suburbs	**815.4**	**20.6**	**27.9**	**78.1**	**13.8**	**0.89**	**1.92**
Mentougou	85.8	4.3	16.2	25.3	1.8	0.13	0.36
Fangshan	306.1	17.9	15.6	86.2	2.7	0.44	2.16
Tongzhou	1,328.7	21.1	35.2	65.1	17.9	0.68	1.47
Changping	257.5	14.0	35.5	111.1	16.3	0.50	1.20
Shunyi	1,702.8	36.0	35.1	76.9	27.1	2.39	3.35
Counties	**1,114.8**	**46.8**	**41.7**	**189.5**	**14.4**	**0.67**	**4.04**
Daxing	1,888.9	50.0	47.3	162.1	8.2	0.67	3.54
Pinggu	904.0	56.8	2.6	376.3	36.0	0.65	5.94
Huairou	191.7	27.0	68.3	161.9	7.2	0.69	2.64
Miyun	433.9	46.3	25.3	85.1	10.2	0.76	4.30
Yanqing	1,762.0	46.5	84.2	165.7	10.3	0.56	3.40

Source: Beijing Statistical Office, 2001

Table 25 Relative production in the different districts and counties of Beijing Municipality in the year 2000 as fraction of the total production for each food product category

	Vegetable production	Fresh eggs production	Cow milk production	Dry and fresh fruits	Fish	Slaughtered pigs	Hens production
Beijing Municipality	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**
Near Suburbs	**9%**	**6%**	**6%**	**3%**	**11%**	**10%**	**5%**
Chaoyang	4%	0%	3%	0%	7%	6%	0%
Fengtai	3%	3%	1%	1%	0%	2%	3%
Shijingshan	0%	1%	1%	0%	0%	1%	1%
Haidian	2%	1%	1%	2%	4%	1%	1%
Outer Suburbs	**46%**	**36%**	**26%**	**36%**	**51%**	**60%**	**38%**
Mentougou	0%	1%	1%	1%	1%	1%	1%
Fangshan	5%	9%	4%	11%	3%	8%	12%
Tongzhou	18%	9%	8%	7%	16%	11%	7%
Changping	3%	4%	6%	9%	11%	6%	4%
Shunyi	21%	13%	7%	7%	21%	34%	14%
Counties	**45%**	**57%**	**27%**	**61%**	**38%**	**32%**	**56%**
Daxing	23%	18%	9%	16%	6%	10%	15%
Pinggu	7%	14%	0%	25%	19%	6%	17%
Huairou	1%	5%	6%	8%	3%	5%	5%
Miyun	4%	12%	4%	6%	6%	8%	13%
Yanqing	10%	8%	8%	7%	4%	4%	7%
Municipal Farm Bureau	**0%**	**1%**	**42%**	**0%**	**0%**	**1%**	**1%**

Source: Beijing Statistical Office, 2001

Comparing the major agricultural production data for Beijing Municipality (BM) in 2001 with consumption (Table 26) of 2001, shows that in general terms the agricultural sector in BM appears to be self sufficient. For vegetables and meat there even seems to be an oversupply and only for aquatic products, the agricultural sector of BM cannot meet the demand. This is not surprising as BM is not located near the sea and hence all marine products have to be transported to BM. Of course, these figures are rough and lack detail, such as, for example, the types of vegetables and the kinds of meat. Hence, there might be a shortage of certain types of vegetables (in a certain season) or meat.

Table 26 Comparison of production of agricultural outputs and consumption in Beijing Municipality (BM) in 2001

	Total consumption (kg)	Total production (kg)	Self sufficiency in agricultural products (%)
Grain	1,148,638,380	1,049,169,000	91%
Vegetable	1,151,079,020	5,228,671,000	454%
Pork, beef, mutton	190,960,940	382,244,000	200%
Milk	343,043,320	429,004,000	125%
Fresh Eggs	151,679,860	155,587,000	103%
Aquatic products	128,349,360	74,302,100	58%

Source: Beijing Statistical Office, 2002

4 Impact of agricultural activities on water quality in Beijing Municipality

4.1 General

The agricultural sector has a strong impact on both the quantity and the quality of water resources. It is estimated that agriculture accounts for about 80% of the total water requirements in China, and that 30-40% of this water is lost to non-consumptive uses (World Bank, 2002). Water pollution is mainly caused by both run-off and leaching of pesticides, organic and chemical fertilisers from in particular the intensive (i.e. high input levels of fertilisers and biocides) arable and vegetable cropping areas. In addition, the livestock sector and the associated manure production are major causes for air, land and water pollution.

Increasing fertiliser application rates in northern China result in N-pollution of ground-water. Zhang et al. (1996) showed that nitrate pollution of ground and surface water has become a serious problem. In more than half of their measuring points, nitrate concentrations exceeded the permitted limit (50 mg/L) for drinking water. Critical situations were found particularly in the vegetable-production areas, with nitrate concentrations in ground- and drinking water up to 300 mg/L. Results from this study (Zhang et al., 1996) showed that at all locations showing excessive nitrate concentrations, high N-fertiliser doses exceeding 500 kg N/ha, were applied whereas the fraction of applied N taken up by the crop was below 0.4. This indicates that N fertiliser management should urgently be improved and total N-application in chemical fertilisers and manure should be reduced in the near future. Such improved N-management might include (1) split application at lower rates; (2) slow release fertilisers; (3) site-specific fertiliser application in dependence of growing conditions, indigenous soil supply and crop demand; (4) growing catch crops after vegetable crops; (5) removing high-N crop residues; (6) reduction in vegetable crop production; (7) reduction in intensive livestock sector and manure production; (8) improved practices for fertiliser and manure application such as e.g. no application near water courses, on steep slopes, and on flooded or frozen soils.

4.2 Vegetable crop production

The relationship between application level of chemical fertilisers and the degree of ground water pollution has been studied in three areas in North China Plain, i.e. Beijing Municipality, Tianjin Municipality, and Tangshan Municipality (Zhang et al., 1995). From the collected samples of drinking water and ground water, 73% showed nitrate concentrations above the permitted level (i.e. 50 $mg.L^{-1}$) for drinking water. Highest nitrogen application was recorded in Qinshuiyin village, Daxing County, Beijing in a rotation of cucumber and spinach, i.e. 558 $kg.ha^{-1}.yr^{-1}$, and the nitrate concentration in shallow ground water exceeded 500 $mg.L^{-1}$. In another study on the impact of excessive use of nitrogen fertiliser in vegetable fields on nitrate concentration in ground water (in Haidian District, Beijing; Chen & Zhang, 1996), average annual nitrogen fertiliser rate was 780 $kg.ha^{-1}.yr^{-1}$. Average doses of nitrogen, phosphorus (probably P_2O_5) and potassium fertiliser in the whole Beijing Municipality were 674, 460 and 211 $kg.ha^{-1}.yr^{-1}$, respectively. Nitrate concentrations in shallow groundwater under one fourth of the vegetable plots in Beijing Municipality exceeded the permitted level (50 $mg.L^{-1}$) for drinking water.

4.3 Livestock production

According to the statistics of the Ministry of Agriculture (1997), total animal manure production in Beijing Municipality was 11.93 million tons, containing 243,000 tons of COD, 183,000 tons of BOD, 17,000 tons of phosphorus, and 59,000 tons of total nitrogen. Average manure excretion per ha of agricultural land (figure for year 2001 from Table 6) was 29 tons. Only 3% of this livestock excretion has been treated to prevent pollution. Pollution from 7 livestock farms has been investigated in the year 2000 by the Section of Rural energy and Environment of the Beijing Municipal Bureau of Agriculture. Table 27 presents the degree of pollution in the water discharged from these farms.

Table 27 Pollutants in the discharged water from livestock farms (mg.L-1)

	Total P	Total N	Chlorides	Cd	COD[1]	BOD[2]
Gaolianghe	12.0	474	145	0.317	11,000	?
Luxin	18.8	50.3	105	1.10	10,240	?
Baofang	1.90	10.9	232	0.760	32,600	675
Nengda	10.7	12.7	582	0.070	4,820	3,420
Jinjiawu	8.15	14.6	70	? 0.004	4,580	1,800
Dadong	9.89	10.2	276	0.070	3,560	4,200
Zhangziying	0.14	11.8	125	? 0.004	3,780	4,150

[1] Chemical oxygen demand
[2] Biological oxygen demand

Among the different types of livestock and poultry production systems, the strongest pollution comes from swine production, as swine farms adopted the so-called ‘wet cleaning method for excretion’. The shortcomings of this method are first that the mixture of swine urine and faeces drop through the slatted floor, and second that the manure is washed by running water into ponds. All other livestock and poultry farms adopted the dry cleaning method to collect manure which causes much less pollution. According to the statistics of the Livestock section of the Beijing Municipal Bureau of Agriculture, annual discharge of COD from pig farms reached 103,000 tons, which accounts for 54% of the total COD produced by the whole livestock sector.

Livestock in the Beijing Municipality consumes 25.6 million m^3 of water annually, and produces 15.7 million m^3 of waste water. For each ton of pork produced, 200 m^3 of water is needed. According to monitoring by the Municipal Bureau of Environment Protection, the annual increase in ground water pollution from diffuse sources of pollutants (from agricultural activities) amounts to 28.8% in recent years.

Due to the rapidly expanding and industrialized livestock production sector which also uses large amounts of raw materials for animal feeding from other regions, the mean nitrogen and phosphorus loads on agricultural land in Beijing Municipality have strongly increased. This leads to enhanced levels of nitrate and phosphate in ground and surface water. In addition, the use of high supplementary levels of copper and zinc in the feeds may lead to unacceptable soil accumulation and leaching of these heavy metals.

Although much effort has been put into the treatment of excreta from livestock, no ideal method has been identified. Even if a relatively good method is available, such as the separation of the solid fraction from the liquid fraction in the waste water, the solid fraction being used for making organic fertiliser and the liquid fraction anaerobic-fermented in a biogas generator, this method for discharge treatment cannot be applied. The reason is that first the investment and maintenance costs are too high and second the relevant laws appear not to be compulsory. Hence, in the foreseeable future the pollution problems from the livestock production sector will not be easily solved. A plan for 'green animal husbandry' was outlined by the Municipal Government which should result in 100 livestock farms with wastewater treatment equipment in the coming 5 years. Considering the current number of large-scale livestock farms (897), however, the resulting abatement of water pollution from the livestock sector is expected to be small.

4.4 Degree of water pollution in Beijing Municipality and selection of study area

4.4.1 Approach for indicating degree of water pollution

Water pollution in Beijing Municipality is mainly caused by the high input use in arable and vegetable crop production and the high manure production by the livestock sector. Hence, the following criteria can be applied for selecting districts with strongest water pollution:

1. livestock density in Tropical Livestock Units (TLU) /ha
2. (inorganic) fertiliser use in kg/ha
3. biocide use in kg/ha
4. fractional area of vegetable crops in total agricultural land use.

Based on these criteria, a most interesting district, Shunyi, was selected for the next phase of the project. This district strongly shows the effects of intensification of agricultural production systems on the water quality in Beijing Municipality. For example, in Shunyi one third of the total livestock in Beijing Municipality (Table 18) is located and the livestock density is highest of Beijing Municipality (Table 19). Moreover, fertiliser use per hectare is one of the highest of all districts in Beiijing Municipality (Table 13). Manure application per hectare of land is very high and amounted to 60 tons.

4.4.2 Characteristics of Shunyi and case study

Shunyi is characterized by agricultural modernization and intensification and urbanization, and shows all the negative effects of a too rapid transition. The prevailing cropping system was winter wheat followed by summer maize. Recently, intensive vegetable crop production has become very important (Table 10). Agriculture is technologically advanced with high land and labour productivity. One third of the total livestock in Beijing Municipality is located in this district, which results in nitrate pollution of groundwater. Land prices are rising sharply. The annual rate of conversion from agricultural land to urban areas is 2% per year (Table 7). The city is expanding (Table 6) and townships are disappearing. Water supply is based on extraction of groundwater.

The case study will focus on the most pressing issues in Shunyi. These are in particular the intensification of agricultural production (i.e. vegetable crop and livestock production) and its impact on water quality and the competitive demands (i.e. from agriculture and urban areas) on the limited water resources. This indicates the need for water-saving and for environment-friendly agricultural production systems. LUPAS (Land Use Planning and Analysis System) will be applied to Shunyi to analyse the consequences of present and alternative land use scenarios for the agricultural production system, water resources, water quality, etc. These alternative scenarios include for example changes in production technologies and/or in relative priorities of policy objectives. Promising options for future development, as based on this analysis, and supportive policies will be developed in close interaction with stakeholders (Section 6).

5 Impact of non-agricultural activities on water quality in Beijing Municipality

The main sources of non-agricultural water pollution are industrial water use and domestic water use and discharge. Both sources tend to increase with increasing population and industrialization. Beijing discharges 1.2 billion m^3 of waste water annually, of which about 0.9 billion m^3 is from urban areas. 42% of this urban discharge was treated in waste water treatment plants (Guo, 2000). Untreated water is discharged to rivers and water ponds and to groundwater through seepage, which causes surface and groundwater pollution. The proportion of industrial waste water passing through waste water treatment plants increased during the 1990s, but the efficacy of the treatment process declined. This suggests that while the regulatory system provides incentives for installing treatment facilities, it provides less incentives to operate them effectively (World Bank, 2002).

In the Hai river basin (which includes Beijing Municipality), the major pollution comes from urban industry, urban municipality, livestock and rural municipality (Table 28). Over 50% of the total chemical oxygen demand (COD) in the Hai river basin comes from the urban municipality and industries. In Beijing Municipality, this fraction is of course higher and the total COD load is about 200.000 ton/yr (World Bank, 2002). An important source of pollution is the urban-based paper industry which contributes 25% to total pollution in the Hai river basin. Other highly polluting industries include: (a) chemical; (b) brewing and distillation; (c) food; (d) pharmaceutical; (e) textile (World Bank, 2002). Toxic pollution loads are undocumented but are estimated at about 1.7% of total COD loads, presenting a significant threat to public health and aquatic systems.

Table 28 Sources of pollution in the Hai river basin in year 2000

	Total COD (1000 ton/yr)	Total COD (%)
Rural municipality	254	5
Rural industry	1607	31
Livestock	633	12
Urban municipality	488	9
Urban industry	2213	43
Total	5195	100

Source: adapted from World Bank (2002)

COD loads are projected to decrease by 25% in the year 2020 (compared to the data in Table 28) under the current government program, mainly because of improved waste water treatment, modernization of production technology and waste water reuse, which is driven by the severe water scarcity. It is expected that the other half of the total water pollution that comes from the rural areas (i.e. rural municipality and industry and livestock), is not affected by these regulations and remains essentially uncontrolled by this government program (World Bank, 2002). For two other possible programs including more strict regulations and accelerated implementation, future COD loads have also been calculated. The relative contributions of different sources of pollution (Table 28) to the total future COD-loads in the Hai-river basin for both the current and the two more strict programs, are also determined (World Bank, 2002).

Waste water recycling is an efficient technology to improve water use efficiency. In Beijing, a large fraction of wastewater is still discharged without treatment. If wastewater is treated to the Irrigation standard, this water could be used again, resulting in additional water resources (Guo, 2000). If waste water is used for irrigation without treatment, it presents severe health risks.

Results from a study on heavy metal contamination in suburban areas around four large cities (e.g. Beijing) in China (Wang et al., 2001) showed that the levels of cadmium (Cd), mercury (Hg) and lead (Pb) in soils and sometimes also in (vegetable and arable) crops were higher than Governmental Standards. Untreated sewage water irrigation was the major cause of increasing heavy metal concentrations in soils and crops. Moreover, atmospheric deposition, application of industrial and municipal wastes and sewage sludge, and phosphate fertilisers sometimes contributed to the increase in heavy metal-concentrations.

6 Stakeholders in water management

6.1 Water management

The complex situation of water management in China was reviewed by Lohmar et al. (2001). In theory, water policy is developed and implemented by the Ministry of Water Resources (MWR). The role of MWR is to develop and implement national price and allocation policies for water, and supervise water conservation investments. Although much of China's water is still used by farmers in agriculture, the nation's water policy is becoming increasingly focused on industrial interests. Acting in line with the Water Law, MWR gives priority to the domestic and industrial sectors (over agriculture) in water allocation. Provincial governments also have the power to allocate water, based on their local priorities, a provision that has led many provinces to give industry a particularly high priority (Lohmar et al., 2001).

Under the 1988 Water Law, not only MWR is responsible for all water related policies, but other ministries in China also influence water policies for both rural and urban areas. In the use of agricultural water, MWR shares its responsibilities with the Ministry of Agriculture, particularly in developing local delivery plans and extending water saving technology. In urban areas, Urban Construction Commissions (or Bureaus) are charged with managing the delivery of water to urban industrial and domestic users. Urban Construction Commissions also have taken responsibility for managing groundwater resources below the municipality's land area (Lohmar et al., 2001). China's State Environmental Protection Agency has the responsibility for managing industrial waste water and for municipal sewage treatment. Apart from the central government, many sub-national management institutions influence water policy. Linked vertically to the MWR, provinces, prefectures and county governments all have Water Resource Bureaus (WRB). Formally, the sub-national offices are charged with implementing the rules and policies imposed by the national authorities. In reality, the heads of local WRB's are appointed by and report to the heads of their own jurisdictions (e.g. provincial governor, county magistrates). As these horizontal ties frequently dominate the vertical ones, WRB's also develop and implement water policy and regulations based on the need of their own jurisdiction, resulting in a considerable degree of heterogeneity in water policies across regions (Lohmar et al., 2001). Finally, each of China's 7 major river basins has a National River Basin Commission, functioning directly under MWR, to manage the basin's water resources.

Intensification of agricultural production and its impact on water quality and the competitive demands (i.e. from agriculture and urban areas) on the limited water resources are the main topics of the present study. Changes in water supply or demand in Beijing Municipality and changes in the degree of water pollution by agriculture, industries and urban areas can only be achieved by changes in, for example, agricultural production systems and the associated diffuse pollution, construction of purification systems of sewage-water from industries and urban areas, etc. Such possible future system changes and their consequences for agricultural production, land use, water supply and demand and water quality will be analysed in a case study using LUPAS (Section 4.4.2). Promising options for future development as based on this analysis, and supportive policies will be developed in close interaction with stakeholders.

6.2 Stakeholders

Stakeholders can be defined as the persons, groups or institutions with interests in the topics of this study (i.e. water supply/demand, water quality and pollution). This includes both the *active* stakeholders that by their operations affect the topics of this study and the *passive* stakeholders that are affected by these operations. The main groups of stakeholders, as already discussed above (Section 6.1), are:

- Government institutions: Ministry of Water Resources, Ministry of Agriculture, State Environmental Protection Agency, Hai River basin Commission
- Beijing Municipality institutions: Urban Construction Commission, Water Resources Bureau, Commission for Rural Development, Agriculture Bureau, Environmental Protection Bureau (for the complete list of institutions, see Annex A)
- Farmers organisations: unions, representative for different type of farmers (arable, vegetable, and livestock)
- Non-agricultural water users: industries, domestic users
- International organizations and donors: Asian Development Bank, World Bank, etc.

The main ideas, aspirations, objectives, intentions and interests of the stakeholders should be identified. These characteristics should result in identification of a range of present and possible future policies. Subsequently, the consequences of the different present and future scenarios for agricultural, industrial and urban development will be analyzed in the case study, in close cooperation with the stakeholders. These analyses should indicate the range of possible policies, future options for urban, industrial and agricultural development, possible conflicting interests (e.g. urban versus agricultural water demand) of the policies, and the resulting land use pattern, soil and water pollution (e.g. heavy metal concentration in soil or nitrate concentration in groundwater), water quality, water supply and demand in the case study area for the different policies. An inventory of the current legislation on these agricultural and environmental subjects should be compiled. These current policies should be considered in these analyses, to project their future efficacy in, for example, limiting water use or reducing water pollution. These analyses may also indicate the need for new legislation on, for example, more environment-friendly land use, maximum levels of fertiliser and manure application, maximum livestock density, maximum nutrient levels in raw materials or complete feeds, maximum water use for irrigation or by industries, etc.

7 Conclusions

For Beijing Municipality the quantity of available water resources and the quality of the available water have become matters of concern. This is caused by the rapid urbanization and the strong intensification of the agricultural sector. The aim of the RMO-Beijing project is to raise awareness on these matters and on the impact of different agricultural production systems on environmental quality, and in particular water quality, in Beijing Municipality, and to identify possible sustainable solutions for these problems. This will be achieved in next phases of the project by quantifying the impact of current and possible future agricultural activities on available water resources, the degree of pollution and environmental quality, with special attention for the most intensive forms of agriculture such as vegetable crop production and livestock raising.

Only few studies give attention to the peri-urban agricultural sector of Beijing. As the conditions in which the agricultural sector is operating in urban and peri-urban zones is quite specific, and as the impacts of urbanization and agriculture on the water supply and quality are the main subjects of the RMO-Beijing project, this literature review providing basic information for next phases of this project, covers for Beijing Municipality the following main topics : (1) water use and water resources; (2) major trends in the agricultural production systems with respect to land use, input use, production and economic role; (3) impacts of agricultural and other activities on water quality. This review gives an overview of the available data and literature on these topics, which also indicates the knowledge gaps (Annex C). The information on the agricultural sector indicates the districts in Beijing Municipality where the most pressing environmental problems due to agriculture (in particular due to livestock raising and vegetable crop production) are to be expected.

The review of water use and water resources indicates that current water consumption is much higher than water supply and that consequently groundwater levels have strongly dropped. This indicates the need for changes such as water saving especially in agriculture, more wastewater treatment and use of regenerative water, and more run-off interception for use. In the long term, the water supply may be increased by water diversion from the Yangtze river.

The main changes in the agricultural production systems in Beijing Municipality during the last decade are: (1) loss of arable land areas due to conversion to urban areas; (2) rapid reduction in arable land areas and rapid increase in orchards; (3) rapid reduction in grain crop area and rapid increase in vegetable crop area; (4) strong increase in fertiliser use per hectare; (5) strong reduction in total water use for irrigation; (6) shift in livestock from the near-suburbs to the outer sub-urbs and counties; (7) rapid increase in livestock numbers, in particular cattle, sheep and poultry.

The quality of surface water has deteriorated since the 1970s when the diffuse pollution (from agricultural land areas) increased, as well as total water use by industry and urban life. However, the treated fraction of sewage waste was low and hence, rivers and lakes became severely polluted. The quality of groundwater has deteriorated since the 1980s. The frequency that environmental standards for groundwater were exceeded, was high, in particular for nitrate. Water pollution from agricultural activities is mainly caused by both run-off and leaching of pesticides, organic and chemical fertilisers from in particular the intensive (i.e. characterized by high input levels of fertilisers and biocides) arable and vegetable cropping areas. In addition, the intensive livestock sector and the associated large manure production are major causes for water pollution.

In the next phase of the project, a case study will be executed on pressing issues in Beijing Municipality. These issues are in particular the intensification of agricultural production (i.e. vegetable crop and livestock production) and its impact on water quality and the competitive demands (i.e. from agriculture and urban areas) on the limited water resources. In this case study, consequences of present and alternative future land use scenarios for agricultural production systems, water resources, water quality, etc. will be analyzed. Results of such an analysis may indicate the need for changes in land use, water-saving, improved production technologies and more environment-friendly agricultural production systems. For this case study, a most interesting district of Beijing Municipality, Shunyi, was selected. This district strongly shows at present the effects of intensification of agricultural production systems (Section 4.4.1: high livestock density, high level of fertiliser use) on environmental quality.

Promising options for future development as based on the case study analyses, and supportive policies will be developed in close interaction with stakeholders (Section 6.2). These analyses should indicate the range of possible policies, the future options for urban, industrial and agricultural development, possible conflicting effects of the policies, and the resulting land use, soil and water pollution, water quality, water supply and demand in the case study area for the different policies.

Literature

Beijing Municipal Statistical Bureau, 2002. Beijing Statistical Yearbook 2001, China Statistical Publishing House, Beijing, China.

Beijing Municipal Statistical Bureau, 2001. Beijing Statistical Yearbook 2000, China Statistical Publishing House, Beijing, China.

Beijing Municipal Statistical Bureau, 1992. Beijing Statistical Yearbook 1991, China Statistical Publishing House, Beijing, China.

Brown, L. 2001. Falling water tables in China may soon raise food prices everywhere. From: http://www.earth-policy.org/Alerts/Alert1.htm

Chang, S.-D., 1998. Beijing: perspectives on preservation, environment, and development. Cities 15: 13-25.

Chen, X.-P., Zhang, F.-S., 1996. The problems and countermeasures of vegetable fertilization in Beijing. Journal of China Agricultural University 1 (5): 63-66.

Diepen, C.A. van, 2002. Project description and workplan 2002 of project 'Resource Management Options (RMO) Beijing'. A Dutch-Chinese Research project of DLO research programme International Cooperation North-South. Alterra, Wageningen, Netherlands.

Drakakis-Smith, D., Dixon, C., 1997. Sustainable urbanization in Vietnam. Geoforum 28 (1): 21-38.

Guo, H., 2000. Beijing and Tianjin sustainable development with water resources. p. 349-356. In: Proceedings of international conference 'Guarantee of Water Resources for the Sustainable Development of Big Cities in Early 21st century'. May 8-10, 2000, Tianjin, China.

Hubbard, M., Onumah, G., 2001. Improving urban food supply and distribution in developing countries: the role of city authorities. Habitat International 25: 431-446.

Ke, B., 1998. Area-wide integration of crop and livestock: case study Beijing. Regional workshop on area-wide integration of crop-livestock activities, 18-20 June, 1998. FAO Regional Office, Bangkok, Thailand.

LNV, 2001. Beijing report. Mimeo.

Lohmar, B., Wang, J., Rozelle, S., Huang, J., Dawe, D., 2001. Investment, conflicts and incentives in China's water crisis: the role of institutions and policies. Mimeo.

Lu, Q., 1999. Historical perspectives of land-use and land-cover changes in Beijing. Mimeo.

Ni et al., 2000. Internal report.

Pothukuchi, K., Kaufman, J.L., 2000. The food system: a stranger to planning. Journal of the American Planning Association 66(2): 113-124.

Wang, Q., Dong, Y., Cui, Y., Liu, X., 2001. Instances of soil and crop heavy metal contamination in China. Soil and Sediment Contamination 10(5): 497-510.

World Bank, 2001. China: Air, land and water. Environmental priorities for a new millennium. World Bank, Washington D.C.

World Bank, 2002. Agenda for water sector strategy for North China. Summary report. Report No. 22040-CHA, World Bank, Washington D.C.

Wu, 2000. Internal report.

Yue-man Yueng. 1993. Urban agriculture research in East and Southeast Asia: Record, Capacities and Opportunities. Cities Feeding People, report 6. IDRC.

Zhang et al., 1995. Internal report.

Zhang, W.L., Tian, Z.X., Zhang, N., Li, X.Q., 1996. Nitrate polution of groundwater in northern China. Agric.Ecosys. Environ. 59:223-231.

Zhu et al., 1995. Internal report.

Abbreviations

Alterra	'Green World' Research Institute, Wageningen UR, Wageningen
BM	Beijing Municipality
BAAS	Beijing Academy of Agricultural and Forestry Sciences
BOD	Biological Oxygen Demand
CAS	Chinese Academy of Sciences
CAU	China Agricultural University, Beijing
COD	Chemical Oxygen Demand
ID	Institute for Animal Science and Health, Wageningen UR, Lelystad
IGSNRR	Institute of Geographical Sciences and Natural Resources Research, Beijing
LEI	Agricultural Economics Research Institute, Wageningen UR, The Hague
LUPAS	Land Use Planning and Analysis System
MWR	Ministry of Water Resources, P.R. China
PRI	Plant Research International, Wageningen UR, Wageningen
RMO-Beijing	project 'Resource Management Options in the Greater Beijing Area'
TLU	Tropical Livestock Unit
WRB	Water Resource Bureau

Annex A List of Beijing government institutions

1. Bureau of Agriculture: management and supervision of livestock, cropping and grassland
2. Office for the Capital Greening Committee: forest management and protection, afforestation
3. Bureau of Gardening: creation of green belts
4. Bureau of Water Resources
5. Environmental Protection Agency: water and soil conservation, monitoring of water and air pollution, standard of green food
6. Bureau of Land and Resources and Estate Management: farm land protection, mineral resource management, build up land approval
7. Bureau of Agriculture: quarantine of crop, livestock and fishery products. Standard of agro-products and agro-production materials
8. Bureau of Tourism: sight-seeing plots management
9. Trade Committee: trade of agro-products
10. People's Congress: local regulations, supervision
11. Consultive Committee:advice, suggestions, political consultation
12. Bureau of Miyun Reservoir
13. Development and Planning Committee: general and strategic plan of socio-economic development
14. Bureau (Committee) of Construction

Annex B List of Chinese scientific research institutions and collaborative research teams

Institutions

1. Beijing Academy of Agricultural and forestry Sciences, Institute of Integrated Development of Agriculture (BAAS)
2. Beijing Academy of Water Sciences
3. Beijing Academy of Environmental Protection
4. China Agricultural University, College of Rural Development / Center for Integrated Agricultural Development (CAU)
5. Chinese Academy of Agricultural Sciences (CAAS)
6. Beijing Centre of Rural Development
7. Beijing Agricultural College
8. Chinese Academy of Agricultural Mechanization
9. Agricultural input companies
10. Institute of Geographical Sciences and Natural Resources Research, Chinese Academy of Sciences (IGSNRR-CAS)
11. Chinese Academy of Meteorological Sciences, Research Center for Agrometeorology Application (CAMS)
12. Chinese Institute of Water resources and Hydropower Research (CIWHR)

Chinese research teams within RMO-Beijing project

1. IGSNRR-CAS

a. Prof. Zhang Yi-Li
b. Prof. Li Xiubin
c. Dr. Lu Changhe
d. Dr. Wang Xiuhong
e. Dr. Zhang Ming

2. CAU

a. Prof. Cheng Xu
b. Dr. Chang Xin
c. Mr. Qiu Hua Jiao
d. Ms. Guo Shu Min
e. Mr. Zhu Wabin
f. Mr. Wu Quanzhong

3. BAAS

a. Prof. Wen Hua
b. Dr.Hu Yanxia

Collaborative research teams

1. CAMS

a. Prof. Wang Futang

b. Prof. Wang Shili
c. Prof. Jiahua Zhang
d. Dr. He Yanbo

2. CIWHR
a. Prof. Gao Zhanyi

Annex C List of knowledge gaps

The presented literature review covers the general structure of the agricultural sector in Beijing Municipality (BM) and the impacts of urbanization and agriculture on the water resources and quality. This review gives an overview of the available data and literature and also indicates the knowledge gaps for next phases of the project. In particular for the intended case study for the Shunyi district (Section 4.4.2), the following information from Beijing Municipality (BM) and in more detail from Shunyi (SH) should be collected:

1. Water availability (contradictory data in review) : a. present groundwater deficit; b. potential extraction of groundwater and rechargeable amount (mean and variation in dependence of annual rainfall etc.); c. total water supply from surface water (water inflow from neighbouring province and from reservoirs); d. potential reuse of water; e. distribution of available water over BM; f. water availability for SH

2. Water demand (contradictory data in review) : a. total water use in BM and in SH and water use per sector such as agriculture, industry, etc.; b. agricultural water use per land use type (dependent on crop type and land with or without irrigation (total areas in Table 14)) per ha; c. domestic water use per capita; d. industrial water use per sector; e. distribution of water use over BM and over SH as dependent on distribution of land use types, industries and urban areas (mainly based on 2b, 2c and 2d)

3. Water quality of groundwater and surface water: a. present distribution of water quality over BM and SH and main polluted areas; b. change in water quality with time in ground and surface waters

4. Manure production: a. manure production per animal type (cattle, pigs, goats, sheep, poultry); b. composition of manure per animal type and livestock farm type (dry matter, organic matter, nitrogen, phosphorus, potassium (COD, N, P, K) etc. contents); c. distribution of manure applications and resulting nutrient applications over BM and SH (mainly based on 4a and 4b and livestock density (Tables 17 and 19))

5. Nutrient loading: a. distribution of inorganic fertiliser use over BM and SH (total fertiliser use in Table 13) in dependence of crop and land type; b. distribution of nutrient loading (i.e. nutrient inputs minus outputs in topsoil) over BM and SH (based on manure (see 4c) and inorganic fertiliser applications (see 5a) minus crop uptake)

6. Water pollution by nutrients (COD, N, P, K): a. distribution of diffuse pollution from agriculture over BM and SH (based on nutrient loading, see 5b) ; b. pollution from point sources in BM and SH such as industries and sewage water from urban areas, and in surface water inflow

7. Water pollution by other pollutants: a. main types of biocides and their use over BM and SH (total use in Table 13); b. main sources of heavy metals and their distribution over BM and SH (e.g. due to irrigation with untreated sewage water, and application of industrial and municipal wastes and of sewage sludge) ; c. other pollutants and their distribution over BM and SH

8. Soil pollution: a. phosphate fixation in topsoils over BM and SH at present; b. fixation of heavy metals in topsoils over BM and SH at present (see 7b); c. biocide accumulation

9. Possibilities for improving nutrient (in particular N) management to reduce nutrient leaching and water pollution: a. effects of split application of fertilisers; b. effects of site-specific nutrient application; c. effects of growing catch crops after vegetable crops; d. effects of other improved measures (see Section 4.1 for improved N-management)

10. Possibilities for manure storage and treatment to reduce nutrient leaching and water pollution

11. Possibilities for reduced water pollution from non-agricultural sources in BM and SH by: a. improved waste water treatment; b. modernization of production technologies in main industries in SH; c. treatment and re-use of waste water

12. Possibilities for reduced water use in BM and SH: a. by agriculture (e.g. reduced irrigated cropping area, improved irrigation methods, other crop types); b. by industries; c. by domestic users.