The Relation among the Water Resources Condition, Grain Production and Human Activities in the North China Plain

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ABSTRACT

The spatial distribution and interannual change of grain production in North China Plain (NCP) in the transect along 38°N latitudinal line are revealed by statistical data analysis, and are examined for interrelationship among grain production, land condition including groundwater resources condition, climate, and socio-economic factors. Grain production at county level varies spatially and temporally.

In the first place, western part in piedmont area of the NCP shows high and stable productivity. The grain production is high and stable. The high productivity results from availability of fresh water from groundwater flow system in alluvial fan. Whereas eastern lowland shows low and unstable productivity. The low productivity is caused by the contrast in high Total Dissolved Solids (TDS) zone in shallow groundwater. The high TDS zone is depended on groundwater flow system corresponding to geomorphologic units that have specific hydrological functions. In the lowland area of eastern NCP, grain
production is sensitive to climatic variation because of low availability of fresh water. The local hydro-geomorphological and hydro-geological characteristics are the keys to understanding grain production.

Secondary, grain production in every county has increasing trend until the middle of 1990's. This corresponds to the increase in productivity per unit area of intensive agriculture. Usage of fertilizers, electricity, and agricultural machines contributed to the increase. The stagnancy of decrease in grain production in late 1990's draws the importance of the cost for grain production. The consistent steady decline of water table will prompt rise in pumping cost. This phenomenon may constitute a limiting factor for grain production in the future when the ultimate level of water stress is reached.

INTRODUCTION

Water problems, especially water shortage, in NCP have been introduced in many literatures as typical (e.g. Kondoh et al. [1]). The earliest warning is made by Brown [2]. He discusses China's water shortage problem in the context of world food security. This is a most pessimistic view and there are many arguments on it. After the publication of Brown [2], grain production in NCP experiences complicated change under the influences of many factors including water resources condition, social system, government policy, and so on. Therefore, holistic view is required to prospect future environments in NCP. The authors first investigate the land condition that is influenced by landforms, geology, and climate to explain the spatial distribution of grain production. Then human activities are included to analyze interrelationship with grain production, and finally were examined about the interaction among groundwater resources condition, grain production, and human activity.

Analysis of interrelationship among grain production and socio-economic factors at provincial level has appeared in some journals (e.g. Xiao and Wang [3]). Because of the large spatial extent of province, county is selected as the spatial unit, which enables detailed analysis of the interaction between physico-natural elements and socio-economic factors. The purpose of the study is to find out the interrelationship among land condition, hydrological cycle, groundwater resource, grain production, socio-economic factors, and human activity.

STUDY AREA

A transect along 38°N line in NCP is an extensive research site (Figure 1a, b). NCP is generally recognized as the area to the north of Huaihe River, but we treat the plain to the north of Huanghe River (Yellow River) because the water problems are more severe in this area (Fei [4]).

The annual precipitation in NCP is around 400mm to 500mm and is unevenly distributed. From the end of June to middle of September is the rainy season and about 70% of annual precipitation is recorded in this period.
Figure 1. The major hydro-geomorphological units of NCP (1a: modified from Wu et al., [5]). The distribution of TDS in shallow groundwater in NCP (1b; modified from Fei [4]).

Figure 1a shows the major hydro-geomorphological units of NCP and (modified from Wu et al., [5]). The western edge of NCP is occupying Taihang Mountains. The major hydro-geomorphological units are piedmont plain, lowland plain and coastal plain (Fei [4]). These units correspond to alluvial fan, flood plain, and delta plain (Wu et al., [5]). Many palaeochannels exist in the lowland form continuous depressions.

Figure 1b shows the distribution of TDS in shallow groundwater in NCP (modified from Fei [4]). High TDS zone are noticed of lowland plain and coastal plain. These are located in the discharge zone of groundwater flow system at the lower end of alluvial fan, and depression in paleochannels. This means that the each geomorphologic unit has peculiar hydrological function to modify groundwater condition in a micro level.

DATA AND METHODOLOGY

Statistical data on agriculture including grain production and socio-economic factors at county level are extracted from Hebei Economic Yearbook [6]. NCP is a typical double cropping area of winter wheat and summer maize. However, due to the limitation of statistical data, we were forced to use grain production data not only of wheat and maize but also other crops. Statistical data of socio-economic factors at province level are extracted from China Statistical Yearbook [7].

At first we collected hardcopy statistical data set and digitized it. Grain production and socio-economic factors from 1984 to 2002, and air temperature and precipitation are employed to analyze interannual change and spatial change at county scale. To determine the main influencing factors for changing of grain production correlation analysis was performed.

**RESULTS AND DISCUSSION**

**Spatial Distribution of Grain production**

Figure 2 shows the grain production rate from 1984 to 2001. Horizontal axis denotes direction from west to east. Lower thin lines shows rate in 1984, and upper thick one denotes the rate in 2001. Almost all the counties experienced increase in grain production during this period.

The counties with large production are located in the piedmont plain (left-hand side of Figure 2), and lowland region (right-hand side) has low production rate. Luancheng County in piedmont plain attained 8.97x10^3 kg/ha in production rate in 2001. High productivity in piedmont area is observed due to the availability of fresh groundwater in alluvial fan. Such groundwater flow system in alluvial fan is delineated by isotope concentration (Shimada et al., [10]).

Low production rate in lowland region is due to high TDS contents in shallow groundwater. The policy prohibiting use of canal water for irrigation in eastern part of Hebei province has also resulted further shortage of water for irrigation. Although there is fresh water in deep aquifer, the high pumping cost make farmers to hesitate to use deep groundwater. These factors lead to the very low production rate in lowland region. High TDS restricting the grain production in lowland region is caused by discharge from local groundwater system.

This idea suggests that the arrangement of geomorphologic units determines the groundwater flow system, and it influences the local land condition. Land condition further determines the grain production in NCP. There exists a strong interaction among geomorphology, hydrological cycle and grain production in NCP.
Relation between Grain production Rate and Meteorological Conditions

Figure 3 shows the changing rate of grain yield per unit cultivated area and anomaly of annual precipitation of Luancheng. The fluctuation of grain production in Nanpi County located in lowland region is very large. On the contrary, the production is very stable in Luancheng County in piedmont plain.

Little precipitation generally causes favorable energy condition for the grain production due to the prolonged sunshine duration. There is a tendency that these year with large precipitation lead to low increase rate of grain production in Luancheng County. Since groundwater irrigation is variable in Luancheng, low precipitation is not the determining factor to grain production.

In case of Nanpi County, high productivity corresponds to large annual precipitation, and vice versa. Weather condition is crucial factor in lowland region because freshwater resource is limited by high TDS. Lowland region is vulnerable to weather condition due to its land condition. Availability of fresh water resources influences the interannual variation of grain production.

Time Changes in Grain production

Figure 4 shows interannual changes in grain production in three selected counties. Grain production had been increasing since 1984 until middle of 1990's, however, it stagnated or decreased in late 1990's.

Figure 5 shows the changes in agricultural data in the three counties. Cultivated land area is nearly stable. There is increase in grain production corresponding to increase in grain yield per unit area. Such increase also correspond to the increases in fertilizers, electric, an machine usages. The growth in agricultural production is accomplished by intensive agriculture.
In the latter half of 1990's, grain production was either at the steady or decreasing rate. One of the reasons was the change in the price of farm products.

Figure 6 shows the general purchasing price index of farm products. The value is the rate when price level in 1978 set to 100.

The sharp increase in grain yield from 1992 to 1996 is recognized especially at Shenzhou and Nanpi counties (Figure 4). This increase is parallel to the rise in purchasing price. After 1996, increasing trend in grain production changes to constant or decreasing trend. This means that the cost of agricultural practices becomes significant factor for grain production. At Luancheng County, amount of fertilizers decreases. Although it is not obvious in Shenzhou and Nanpi County, Shen [11] clearly demonstrates that the increasing trend of the cost for unit production turns to constant or decreasing after 1996.

Long term decline in groundwater table corresponding to increasing grain production has long been noticed as concern for future food security. Water table fall lead to increase in pumping cost. The fact that the fall in purchasing price promotes the reduction of grain production, suggests that further decline in water table control the grain production in view of pumping cost.

CONCLUSIONS

Grain productions at county level vary spatially and temporally. The reason of high and stable productivity in piedmont plain is the availability of fresh water resources from the groundwater flow system in alluvial fan. In contrast, low and unstable productivity in lowland region is due to high TDS contents in shallow groundwater. The high TDS distribution located in discharge areas, created by each groundwater flow systems.
occurrence of groundwater flow systems depend on hydro-geomorphological units that have specific hydrological functions. The local hydro-geomorphological and hydro-geological characteristics are the keys to understanding grain production.

In the lowland region of NCP, grain productivity is sensitive to climatic variation because of low availability of fresh water due to high TDS contents in shallow groundwater. Availability of fresh water resources influences the interannual variation of grain production.

The grain production in every county along 38°N latitudinal line in NCP has increasing trend until the middle of 1990’s, while changes in cultivated area is small. This is caused by the increase in productivity per unit area of intensive agriculture. That is, interannual and spatial change in grain production seems also strongly affected by some socio-economic factors, e.g. change of government food policy, improvement of technology and the cost of production (usage of chemical fertilizers, groundwater pumping and agricultural machines). The stagnancy of decrease in grain production in late 1990’s suggests the importance of the cost for grain production. The consistent steady decline of water table will prompt rise in pumping cost. This phenomenon may constitute a limiting factor for grain production in the future when the ultimate level of water stress is reached.

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