Shen J, 2000, Modelling national or regional grain supply and food balance in China, *Environment and Planning A*, 32, 539-557
++

Modelling national/regional grain supply and food balance in China

Jianfa Shen

Department of Geography and the Center for Environmental Studies

The Chinese University of Hong Kong, Shatin, N.T., Hong Kong.

email: jianfa@cuhk.edu.hk

Abstract. This paper used fairly explicit grain production and demand models to analyze the changes in national and regional grain production in China over the period 1990-1997 and the future grain supply and demand up to the year 2087. A decomposition approach was developed on the basis of the grain production model to estimate the impacts of various input factors on the grain production in China. The national grain production, demand and import in the future were modelled. This explicit modelling framework allows projections of the future food situation of China on the basis of various scenarios. The results are fairly transparent and can be easily traced to the conditions of input factors and the level of consumption.

1 Introduction

As the country with the largest population in the world, the food issue and agricultural sector have been the focus of government concern in China. The recent drive to industrialization and urbanization with fundamental impacts on the environment and agriculture has resulted in more and more concerns about China's food security although there were earlier studies on the agricultural instability and food balance (Kueh 1984a; 1984b; 1995). Who will feed China? Can China feed herself? These are important questions facing the world and China.

There has been a hot debate and two opposite views exist (Brown 1995; 1996; Pinstrup-Andersen *et al.*; 1997; Liang 1996; World Bank, 1997).

Based on the industrialization experience of three densely populated countries/regions, Japan, South Korea and Taiwan, Brown (1995) estimated that China's food supply would decline in the future with rapid industrialization and China would import huge amounts of grain from the rest of the world. Lu (1998) found an evolving pattern of exchanging food for food in China. China could be a net food exporter in monetary terms due to its comparative advantage in exporting vegetables and fruits. This has actually been the case in the experience of Taiwan. Other researchers have responded that China will feed herself in the future (Liang 1996). However, many of these discussions are based on past experience and broad qualitative speculations. It is typical that grain output was projected for the future based on various growth rates, and the need to import or export grain varies greatly depending on the growth rates used in such calculations (Kueh 1984b; Liang 1996).

What is missing in the current research is detailed dynamic modelling and analysis to take into account various factors related to China's grain demand and supply. More recently, Huang and Rozelle (1998) conducted a series of research on China's grain economy using econometric analysis and modelling approach. However their research focused mainly on the dynamics of grain yield per ha. and the technical progress in agriculture which had their own merit. In their econometric model for grain demand and supply projections, various growth rates were assumed for urban and rural populations, income per capita, grain and fertilizer prices, and the opportunity cost of land (Huang, Rozelle and Rosegrant 1997). Their model is more sophisticated than previous ones. But no sufficient consideration was given to the dynamics of urban-rural population change, the dynamics of land resources, and geographical variations, which are critical to China's emerging grain issue. Huang (1998) developed a computable general equilibrium model of China's economy that was designed to assess the consequences of various agricultural policy options. The China's economy was disaggregated into 22 economic sectors and 18 products in that model. The model is not a typically dynamic one, but essentially a comparative-static one in nature and it will estimate the changes in the endogenous variables in response to policy changes introduced through exogenous variables at the new equilibrium state of the economy. This is a national level model that is useful for modelling agricultural issues for the country as a whole. Similarly, a recent study on China's food security by the World Bank (1997) focused on the national level and the economic variables. In its projections of future food supplies in China, agricultural growth was driven by investments and total factor productivity while arable land and some other non-economic factors were not explicitly modelled.

China's land resources have also been the focus of recent research. Fischer *et al.*(1998) documented the detailed changes in the cultivated land in China over the period 1988-1995 based on the data from the State Land Administration in China. They reported that 4.804 million ha. of cultivated land was lost and 3.084 million ha. of newly cultivated land was added in the period 1988-1995. The net loss of the cultivated land was 1.722 million ha. in the same period. Heilig (1997) examined the relations between the land use change and various factors in China in recent decades. He identified five major driving forces of land-use changes in China: population growth, urbanization, industrialization, changes in lifestyles and consumption, and shifts in political and economic arrangements and institutions. The impact of environmental degradation on the grain production in China over the period 1975-1990 was also examined (Huang and Rozelle 1998; Rozelle, Veeck and Huang 1997). A provincial level model of grain yield was used to estimate the effect of environmental degradation on grain yield. Again, the research focused on the grain yield rather than the total grain output. The most important issue that the arable land used for grain production may be declining was not taken into account. It is interesting to note that there is no negative impact of environmental degradation on the grain yield over the period 1977-1983 but a significant negative impact over the period 1983-1989. Such kinds of results may need to be further verified by detailed data.

Among various factors which may affect the future grain supply and demand in China, population growth, declining arable land, falling cropping land for grain production, rising demand for meat and the feedgrain are important variables which need to be carefully assessed. Different assumptions on the arable land and the grain yield per hectare will produce significantly different estimates of China's grain import and export to and from the world market (Huang, Rozelle and Rosegrant 1997). Brown (1995) projected that China's grain production will fall by at least 20% by the year 2030 and China will need to import 207 or 369 million tons of grain assuming constant and increasing per capita consumption of food respectively. Huang, Rozelle and Rosegrant (1997) made a more modest projection of China's grain import in the future using a supply and demand projection model. According to their baseline scenario, China may need to import 24, 27 and 25 million tons of grain in 2000, 2010 and 2020 respectively.

The purposes of this paper are to develop an explicit grain production model to analyze the changing grain output in the mainland China and its 30 provincial regions excluding Hong Kong, Macao and Taiwan; to link the grain production model with population projection results to project future grain balance and the needs to import grain from the world market. The grain production system in the period of 1990-1997, 1990-1995 in particular, will be analyzed in detail in the national and regional level to identify the impacts of various agricultural input factors on the grain output. Due to unbalanced economic development in China, the dynamics of grain output in one region is different from others. This will provide more insight on the situation of food issue in China than from the national level or a few regional cases in developed coastal areas of China where the arable land and grain production are shrinking quickly.

Detailed data related to the regional grain production have been collected from the official sources (SSB 1991; 1996; 1998) and calculated for the year 1990, 1995 and 1997. However, the data of regional arable land were not available for 1997. Thus a complete set of data was only available for the period 1990-1995 which will be the main focus of the analysis in this paper. The 1997 data will be used to examine more recent changes in the regional grain production in China. The analysis in this paper will use the regional data in only three years, 1990, 1995 and 1997 instead of the annual data from 1990 to 1997. The main consideration is that there is annual fluctuation in agricultural production or agricultural instability (Kueh 1984a; 1995). Using a period of several years may smooth out such annual fluctuations and more stable trends might be identified. Of course, the choice of the first year and final year in a period may still affect the result. Nevertheless, it is still meaningful to examine the main factors affecting the grain production in various regions in particularly historical periods such as 1990-1995 and 1995-1997. The different results in two periods of 1990-1995 and 1995-1997 may also shed some light on the spatial and temporal instabilities of the contributions of various factors in the grain production.

It is well-known that the official data on arable land were under-reported and this may also be the reason why no data on arable land was released for 1997 in the recent statistical yearbook of China (SSB 1998), anticipating major revisions of such figures. The recent survey of land resources shown that the total arable land in China was 133 million hectares but detailed regional figures are not available yet (People's Daily 1996). The under-reported official arable land data used in this paper have been corrected by a set of regional correction factors cited in Heilig (1997) which is the best at the present. The corrected total arable land is close to the figure of 133 million based on the recent survey of land resources mentioned above. The under-reporting was the most serious in Guizhou, Yunnan and Ningxia but these regions are not the major grain producers in China. Their grain outputs ranked 19th, 17th and 24th among the 30 regions in China respectively in 1997.

The paper is organized as follows. An explicit grain production model will be proposed in the next section. A decomposition approach to measure the contributions of various factors to the grain output will be developed based on the grain production model. The approach will then be used to analyze the dynamics of the national and regional grain production in China over the period 1990-1997 in the next section. A transparent grain supply and demand framework will then be used in the subsequent section to simulate the future grain production, demand and import in China up to the year 2087. The final section concludes the paper.

2 Modelling grain supply and factor contributions

Grain production is a complicated system. Various factors such as the arable land, the proportion of cropped land for grain production, capital investment in agriculture and the shifting of rural labour from agriculture to non-agricultural sector may all affect the grain production. These are related to the processes of industrialization, urbanization, agricultural and economic development in a country or region.

Most concerns in the grain production and food security are the impact of industrialization and urbanization on the land resources and the subsequent declining of arable land. This section thus will attempt to build a deterministic structural model to link various input variables to the grain output. The model can then be used to assess the different contributions of various factors in the change of the grain output in a particular country or region in a specific period. The model could also be used to project future grain output under certain assumptions of input factors. Figure 1 presents the grain supply and demand framework. A similar analytic approach was used by Bongaarts (1996) in the study of the food supply system in the developing world. But the framework used in this paper is extended to include the grain demand as well. Kueh (1995) used an approach to examine the contributions of the reductions in the cropped area and the grain yield to the losses in the grain output in China as a whole in selected years of great agricultural instability over the period 1931-1991. His approach is similar to the model here but with only two variables.

The grain supply model could be expressed as follows:

$$O_{it} = Y_{it} G_{it} I_{it} L_{it} \quad (1)$$

Here O is the grain output; L is the arable land; I is the cropping index which is the ratio of the total cropped area to the arable land reflecting the intensity of land use; G is the proportion of the cropped area for grain production in the total cropped area which reflects the relationship between the grain and non-grain agricultural production, and finally, Y is the grain yield per hectare of the cropped area which will in tern be affected by various input factors such as the soil property, labour input and the use of fertilizer. Subscript i and t refer to region i and time t respectively.

It is possible to decompose the change in grain output over a period to four components due to four factors mentioned above. The method is to estimate the impact of one factor's change over the period t1-t2 while other factors are hold constant at either t1 or t2 respectively. The estimation takes place recursively. Those factors whose impacts have been estimated will use their values at time t1 while other factors whose impacts remain to be estimated will use their values at time t2. The following equations can be obtained. For simplicity, the regional subscript i is dropped in the following.

The total change in the grain output $O_{Tt1\text{-}t2}$ is:

$$O_{Tt1-t2} = O_{t1} - O_{t2} \quad (2)$$

The change in the grain output due to the change in the grain yield $O_{Yt1\text{-}t2}$ is:

$$O_{Yt1-t2} = (Y_{t2} - Y_{t1}) G_{t2} I_{t2} L_{t2} \quad (3)$$

The change in the grain output due to the change in the proportion of the cropped area for the grain production $O_{Gt1\text{-}t2}$ is:

$$O_{Gt1-t2} = Y_{t1}(G_{t2} - G_{t1})I_{t2}L_{t2} \qquad (4)$$

The change in the grain output due to the change in the cropping index $O_{It1\text{-}t2}$ is:

$$O_{It1-t2} = Y_{t1}G_{t1}(I_{t2} - I_{t1})L_{t2} \qquad (5)$$

The change in the grain output due to the change in the arable land $O_{Lt1\text{-}t2}$ is:

$$O_{Lt1-t2} = Y_{t1}G_{t1}I_{t1}(L_{t2} - L_{t1}) \qquad (6)$$

It is easy to prove that the total change in the grain output is the sum of the contributions of four factors:

$$O_{Tt1-t2} = O_{Yt1-t2} + O_{Gt1-t2} + O_{It1-t2} + O_{Lt1-t2} \qquad (7)$$

It is noticed that all three variables did not used values at the same time t1 or t2 in estimating the impact of one factor. Indeed, it is possible to estimate two sets of contributions of various factors by using the values of other variables at t1 and t2 respectively. But the total of such contributions will not equal to the total change in equation (2). A number of small components due to the interaction of two or three factors will need to be added. This will make the decomposition procedure much more complicated but with little gain. For simplicity, the above decomposition of the grain output change into four components is preferred. The approach will produce one component for each factor and the sum of all components is equal to the total change in grain output.

3 Regional changes in grain production

The method developed in the previous section will be used in this section to analyze the contributions of various factors on the grain output for China as a whole and in 30 provincial regions in mainland China over the period 1990-1997. As mentioned before, the data of arable land in 1997 were not available yet, so the analysis will be focused on the period 1990-1995.

As shown in table 1, there have been significant changes in the grain production condition and output over the period 1990-1997 in China. In the period 1990-1995, the total arable land declined from 137.8 million hectare to 136.8 million hectare at the rate of -202.2 thousand ha. per year. The proportion of the cropped area for grain production declined from 76% to 73% at the rate of -0.6% per year. However, the cropping index increased slightly from 1.55 to 1.58 over the same period. The grain yield per hectare of the cropped land also increased from 2.73 ton in 1990 to 2.94 ton in 1995 at the rate of 0.042 ton per ha.. As a result of these mixed positive and negative effects, the total grain output in China increased from 446 million ton in 1990 to 467 million ton by 1995. Because of the multiplicative nature of the grain production model represented as equation (1), the percentage change of each input factor is a good indicator of the degree of influence on the grain output. According to table 1, the grain yield per ha. in China increased by 7.69% over the period 1990-1995. This was the largest increase among four input factors in model (1). On the other hand, the proportion of cropped area for grain production was decreased by -3.95% in the same period and it is was the largest decrease among input factors. The cropping index was increased by 1.94% contributing to an increase in the grain output. In contrary to common expectations, the arable land was declined by only 0.73% in the period and was the least important factor in the change of the grain output in the period 1990-1995.

In the period of 1995-1997, the proportion of the cropped area for the grain production remain unchanged at 73%, partly due to strong government measures in the agricultural sector (Ash 1997). As a result of this and other factors, the grain output in China further increased from 467 million in 1995 to 494 million ton in 1997.

There are variations of the impacts of various input factors among various regions in China. Table 2 presents the situation of the grain production by region in 1990, 1995 and 1997 respectively. The top nine regions with about 20 million ton or more grain output were the same in 1990, 1995 and 1997. These regions are Sichuan (46 million ton in 1997), Shandong (39 million ton in 1997), Henan (39 million ton in 1997), Jiangsu (36 million ton in 1997), Heilongjiang (31 million ton in 1997), Hunan (28 million ton in 1997), Anhui (28 million ton in 1997), Hebei (27 million ton in 1997), Hubei (26 million ton in 1997). Only Hubei experienced a slight decline in annual grain output over the period 1990-1995 while the grain output in other eight regions increased in the same period. Except Jiangsu, the grain yield per hectare of the cropped area in these main grain producing regions increased over the period 1990-1995. In the period 1995-1997, all regions except Shandong experienced an increase in grain output. The grain output of Shandong in 1997 was smaller than that of 1995 but still greater than that of 1990.

The bottom nine regions with an annual grain output less than 8.3 million ton also remain unchanged over the period 1990-1997. These regions were Xinjiang (8.3 million ton in 1997), Gansu (7.7 million ton in 1997), Ningxia (2.6 million ton in 1997), Beijing (2.4 million ton in 1997), Shanghai (2.3 million ton in 1997), Tianjin (2.1 million ton in 1997), Hainan (2.1 million ton in 1997), Qinghai (1.3 million ton in 1997), Xizang (0.8 million ton in 1997). Three of these regions, Gansu, Beijing and Shanghai, experienced a decline of grain output over the period 1990-1995. Tianjin and Hainan experienced a decline in the grain yield per hectare of the cropped area over the period 1990-1995. But only Beijing and Tianjin experienced a decline of the grain output over the period 1995-1997.

There have been significant changes in the grain production factors in various regions over the period 1990-1997. This section will focus on two out of four input factors at the regional scale for the period 1990-1995 as the data on arable land were not available for 1997. Table 2 also presents the grain yield per ha. and the arable land in 1990 and 1995. The grain yield in 25 regions increased but decreased in 5 regions. The arable land declined in 20 regions but increased in 9 regions over the same period. There was no change in arable land in Xizang.

Now the decomposition method can be applied first to the national and regional grain output systems over the period 1990-1995. As mentioned before, only the data in 1990 and 1995 were used in the decomposition to smooth out the annual fluctuations. As the changes of four factors were different in various regions, different regional impacts of these factors can be estimated for various regions. The results in table 3 and figures 2-6 present a clear picture of how the national and regional grain outputs have been affected by four factors.

According to table 3, China's grain output was increased by 33.770 million ton due to the increased grain output per hectare and by 7.836 million ton due to the increased cropping index over the period 1990-1995. But China's grain output was decreased by 17.957 million ton due to the declined proportion of cropped area for grain production and by 3.274 million ton due to the loss of arable land. Thus it is clear that the main gain in the grain output came from the increase in the grain yield per capita (the land productivity) and the main loss came from the loss of cropping area for other non-grain crops rather than the decline of arable land. This is the overall situation for the country as a whole. Various regions have experienced different changes of grain production under the influence of various factors.

According to figures 2 and 3, generally, the grain yield per hectare and the cropping index had positive impact on the grain output in most regions. The positive impact of the grain yield on the grain production was the most impressive in the several regions in the eastern part of China. Only five regions including Liaoning and Jilin in the northeastern part of China and Shanxi, Shaanxi and Gansu in the northern and western parts of China experienced a decline in the grain yield per hectare over the period 1990-1995. Some nine regions in the northern and eastern parts of China have experienced a smaller cropping index while 21 regions have increased their grain output by raising the cropping index. The positive impact of the cropping index on the grain production was the most impressive in the southwestern part of China.

On the other hand, according to figures 4 and 5, the proportion of the cropped area for the grain production and the arable land had negative impacts on the grain output in most regions. Only four regions including Jilin, Heilongjiang, Hebei and Shandong in the northeastern and northern parts of China have gained an increase in the grain output by raising the ratio of the cropped area for the grain production in the period 1990-1995. Some nine regions including Nei Mongol, Jilin, Heilongjiang, Guangxi, Yunnan, Gansu, Qinghai, Ningxia and Xinjiang in sparsely populated regions in the northeastern, northern, western and southwestern parts of China have managed to increase their arable land. Other regions in the densely populated and/or more developed regions have more or less experienced a decline in arable land.

According to figure 6, there were 11 regions had a smaller grain output in 1995 than in 1990. There was no clear spatial concentration of such regions as the change in the total grain output of a region was a result of various positive and negative impacts. The main contributing factor in Shanghai, Zhejiang and Guangdong is the declining arable land. Rapid industrialization and urbanization in these regions are taking away substantial arable land. The main contributing factor in Jiangxi and Hubei is the declining proportion of the cropped area for the grain production indicating the impact of non-grain crops on the grain production. In Jilin, Shaanxi and Gansu, the main reason for the decline in the grain output is the fall in the grain yield per hectare. Three or four factors are responsible for the decline in the grain output in Beijing (except the positive impact of grain yield per hectare), Shanxi and Liaoning (except the positive impact of cropping index).

According to table 3 and figures 2-6, for 16 out of 19 regions whose grain outputs have been increased over the period 1990-1995, the main contributing factor is the rising grain yield per hectare. For Fujian and Guizhou, raised cropping index is also an important factor for the increase of the grain output. Rising cropping index is the main contributing factor for the increase in the grain output in Sichuan and Ningxia. Increasing arable land is the main contributing factor for the increase in the grain output in Nei Mongol.

As the data of arable land for 1997 were not available, it is not possible to conduct a precise decomposition of the changes in grain production for the period 1995-1997. The total change in the grain output and the impact of the proportion of the cropped area for the grain production on the grain output can be estimated for each region precisely using the available data. The impacts of the changes in the grain yield and the cropping index on the grain output could also be estimated if no change in the arable land was assumed in each region over the period 1995-1997. In reality, it is unlikely that there was no change in the area of arable land over the period 1995-1997. But such change was likely to be much smaller in the period of 1995-1997 than that in the period of 1990-1995 due to tightened agricultural measures since the mid-1990s (Ash 1997).

Table 4 and figures 6 and 7 presents the estimated impacts of various factors assuming there was no change in the arable land in each region over the period 1995-1997. If there was a decrease in the arable land in a region, then the impacts of the changes in the grain yield and the cropping index on the grain output in that region would have been underestimated. If there was an increase in the arable land in a region, then the impacts of the changes in the grain yield and the cropping index in that region would have been overestimated. Here I will focus on the estimated impacts of the proportion of the cropped area for the grain production and the total grain output changes in various regions that are no affected by the previous assumption.

Over the period 1995-1997, the grain output for China as a whole was reduced by 0.643 million ton due to a slight decline of the proportion of the cropped area used for the grain production. According to figure 6, only Hebei, Heilongjiang and Jiangsu gained an increase of over 0.5 million tons of grain while Shandong and Guangxi experienced a decrease of over 0.5 million tons of grain due to this factor in the period 1995-1997. Comparing these impacts in 1995-1997 in figure 6 to those in 1990-1995 of the same factor in figure 3, it is clear that there are similarities and differences in terms of the spatial incidences of positive and negative impacts. Table 5 presents the number of regions with positive and negative impacts on the grain output by the proportion of cropped area for the grain production in the periods 1990-1995 and 1995-1997 respectively. 15 out of 30 regions had the same positive (12 regions) and negative impacts (2 regions) in these two periods. 14 regions changed from negative impacts to positive impacts and one region changed from a positive impact to a negative impact. Overall, more regions had positive impacts, which means that more regions have used more arable land for grain production in 1997 than in 1995. Thus there is no evidence to support consistent spatial impacts of this factor on grain production in the two periods 1990-1995 and 1995-1997. The correlation coefficient between the impacts in these two periods is only 0.081 and neither positive nor negative significant correlation exists.

Figure 8 presents the changes in the total grain output in various regions over the period 1995-1997. Only six regions experienced a decline in the grain output in this period and this number was much smaller than 11 regions in the period 1990-1995. Comparing figure 8 with figure 5, it is noticeable that the trend of the grain output was reversed from decline to growth in Shanghai, Zhejiang, Guangdong and Shaanxi. Table 5 also presents the number of regions with positive and negative changes in the total grain output in the periods 1990-1995 and 1995-1997 respectively. 21 out of 30 regions had the same positive (17 regions) and negative growth (4 regions) in these two periods. 7 regions changed from negative growth to positive growth and two regions changed from positive growth to negative growth. Overall, more regions had positive growth in the period 1995-1997. Again, there is no strong evidence to support a consistent spatial pattern of the grain output changes in the two periods 1990-1995 and 1995-1997. The correlation coefficient between the total grain output changes in these two periods is only –0.232 and not significant at 0.05 level.

4 Modelling grain supply and demand in future

Various factors may affect the future grain supply and demand in China. Different estimates of China's grain import and export to and from the world market have been produced (Huang, Rozelle and Rosegrant 1997; Brown 1995). The major reasons for the huge difference in various estimates are the different assumptions of the changing arable land, the grain yield per hectare and the level of grain consumption per capita.

This section will attempt to construct various scenarios of grain supply and demand based on an explicit and fairly transparent framework (Figure 1). Before doing that, it is interesting to note that China's grain output statistics covers more crops than the definition used in international statistics and usually refers to raw grain rather than milled grain. Thus China' official grain output figures which are used in this section are 25% larger than the figures based on the international definition.

Future grain demand will be projected by the total population and the per capita consumption of grain. A series of urban-rural population and urbanization projections of China have been made in earlier research (Shen and Spence 1995; 1996) assuming different fertility rates in urban and rural areas. Year 1987 was used as the base year for these projections. According to a projection scenario assuming constant fertility rates in urban and rural areas from 1987, China's population will increase from about 1229 million in 1995 to 1604 million by 2040 (see table 6). About 400 million more population will be added to the current huge population in China. The projected total population will be used to estimate the grain demand in the future.

It has been estimated that the direct grain consumption per capita was 235kg and the feedgrain per capita for the production of other foods was 65.8kg in 1993 (Liang 1996). This gave a total of 300.8kg grain consumption per capita. The actual grain per capita available was 379kg in 1993, part of which was used as seed. Thus 26% more grain needs to be available than the actual amount of grain consumption. This parameter will be used in the estimation of the grain demand.

The grain output in China will be estimated using assumed arable land, cropping index, proportion of cropped area for grain production and the grain yield per hectare in equation (1). The projected net import is the difference between the grain demand and the grain output.

Four sets of grain production, demands and import projections A, B, C and D will be estimated using various assumptions on the level of grain per capita and input factors for grain production. These have been presented in table 6. The period 1990-1995 was used as a reference in the construction of various scenarios as the data set for 1997 was not complete. The projections go to the year 2087, but the period 2000-2040 will be the focus of discussion here.

Scenario A assumes that the future grain consumption per capita and production parameters remain the same as in 1995 (table 6). There is neither any decline in the arable land nor any increase in the grain yield per hectare. Any increase in the grain demand is the result of population change. Thus China's grain output will remain at the 1995 level of 466.62 million ton a year. The grain demand will increase to 497.26 million ton in 2020 and 607.78 million ton in the year 2040.

According to scenario A, China's net import of grain will be 30.64 million ton in 2000, 113.35 million ton in 2020 and will reach the peak of 141.16 million ton by the year 2040 due to population growth. The 2040 figure of grain import accounts for 70% of the current total grain export in the world. This scenario clearly shows the consequences of further population growth in China. However, the grain production parameters and the level of grain consumption per capita are likely to change in the future which will be simulated in other scenarios.

The same grain demand assumption for scenario A will be used in scenario B, but the four production parameters will change at the actual rate over the period 1990-1995 (table 6). The arable land will decrease by 0.20 million hectare a year and there will be only 127.66 million hectare of arable land by the year 2040. The cropping index will increase from 1.58 in 1995 to 1.83 in 2040, at the rate of 0.0055 a year. The proportion of the cropped land for grain production will decrease from 73% in 1995 to 46% in 2040, at the rate of 0.006 a year. The grain yield per hectare will increase from 2.94 ton per hectare in 1995 to 4.83 ton per hectare by the year 2040. Under these assumptions, China's grain output will increase from 466.62 million ton in 1995 to the peak of 527.63 million ton in 2030 and then it will decline to 517.98 million ton in 2040. China's net import of grain will be 14.00, 55.27 and 89.80 million ton in 2000, 2020 and 2040 respectively. These projected imports are smaller than those in scenario A.

It is not realistic to assume constant rates of change in the grain production parameters and a constant level of grain consumption. Scenario C will use a larger proportion of the cropped land for grain production. It will only decline to 70% in the year 2000 and then will remain unchanged. Other production parameters in scenario C are assumed to the same as in scenario B (table 6). According to one projection by CAAS (Chinese Academy of Agricultural Sciences), the direct grain consumption per capita in China will decline to 223kg and 214kg in 2000 and 2010 respectively and the feedgrain per capita for the production of other foods will increase to 83.8kg and 112.9kg in 2000 and 2010 respectively (Liang 1996). These projections will be used as the basis to estimate the grain demand in China in scenario C. The constant increase rate of 2kg a year of the grain consumption per capita including feedgrain in the period 2000-2010 will also apply to the rest of the projection period. The grain consumption per capita will be 346.8kg and 386.8kg in 2020 and 2040 respectively. According to the projection result of scenario C, China's grain demand will increase to 507.18, 668.66 and 781.54 million ton in 2000, 2020 and 2040 respectively. China's grain output will be 483.26, 634.49 and 792.11 million ton respectively in these years. China's grain import will be much smaller in this scenario and China may even become a major grain exporter from year 2040. The peak of the grain import will be only 34.17 million ton in the year 2030. This means that if a high proportion of cropped land (70%) can be used for grain production in the future, then China will only need to import a modest amount of grain.

Scenario D attempts to assess China's position of the grain production if the arable land will be lost at a faster rate. The main assumptions are as follows. The arable land in China will be decreased by 0.40 million hectare a year. The proportion of the cropped land for grain production will decline to 58% in the year 2020 before it is stabilized. Other assumptions in scenario D are the same as in scenario C (table 6). According to this scenario D, China's grain output will be 476.06, 500.53 and 603.16 million ton in 2000, 2020 and 2040 respectively. Due to faster decline of the arable land and smaller proportions of the cropped land for grain production, China will need to import more grain from the world market. The projected grain import will be 31.12, 168.13 and 178.8 million ton in 2000, 2020 and 2040 respectively.

5 Conclusion

This paper has used fairly explicit grain production and demand models to analyze the changes in the national and regional grain productions in China over the period 1990-1997 and the future grain supply and demand up to the year 2087. A decomposition approach was developed on the basis of the grain production model to estimate the impacts of various input factors on the grain production in China. On contrary to the common expectation, declining arable land only play a minor role in the change of the grain output for China as a whole in the period 1990-1995. At the regional scale, the arable land became an important factor in the decline of the grain output in economically fast growing regions such as Shanghai, Zhejiang and Guangdong. Some preliminary comparisons between two periods 1990-1995 and 1995-1997 show that there is no consistent spatial pattern of growth or decline of regional grain output. The growing or declining trend of the grain output was reversed in some regions in these two periods. All these findings mean that the regional grain output is much unstable than the aggregated national total.

The national grain production, demand and import were modelled. The projection of the grain production was based on the grain production model (1) with four input factors. The projection of the grain demand was based on externally projected population total and the grain consumption per capita. The grain import is the balance between the grain production and demand. This explicit modelling framework allows projections of the future food situation of China on the basis of various scenarios. The results are fairly transparent and can be easily traced to the conditions of input factors and the level of consumption.

Four simulation scenarios show that there are many options for China to choose to import small or large amount of grain from the world market. Further increase in the grain yield per hectare is essential to produce sufficient grain to support its still expanding population. Loss of arable land and the transfer of the arable land from the grain production for other agricultural use should also be controlled to avoid importing large amount of grain from the world market.

On the upper limit, China's annual loss of the arable land should be less than 0.4 million hectare a year and more than 60% of the cropped land should be used for grain production in the long term. Only modest increase in the grain consumption per capita should be allowed.

Acknowledgement

This paper is the result of a research project supported by a Direct Research Grant of the Chinese University of Hong Kong. Project code 2020400. Helpful comments of two anonymous referees are also gratefully acknowledged.

References

Ash R F, 1997, The grain issue in China: domestic and international perspectives. In: Brosseau M, Kuan H C and Kueh Y Y (eds), *China Review 1997*. pp.135-160. Hong Kong: The Chinese University Press.

Bongaarts J 1996, Population pressure and the food supply system in the developing world, *Population and Development Review*, 22, 483-503.

Brown L 1995. *Who Will Feed China? Wake-up Call for a Small Planet*. London: Earthscan Publications Ltd.

Brown L, 1996, Who will feed China? *The Futurist*, 30, 14-18.

Fischer G, Chen Y and Sun L, 1998, The Balance of cultivated land in China during 1988-1995, *Interim Report*, IR-98-047, Laxenburg: International Institute for Applied Systems Analysis.

Heilig G K, 1997. Anthropogenic factors in land-use change in China. *Population and Development Review* 23(1): 139-168.

Huang J and Rozelle S, 1998, *China's Grain Economy to the Twenty-First Century*, Beijing: China Agriculture Press.

Huang, Jikun; Rozelle, Scott; and Rosegrant, Mark W, 1997, China's food economy to the twenty-first century: supply, demand, Trade. *Food, Agriculture, and the*

Environment Discussion Paper 19. International Food Policy Research Institute, Washington, D.C.

Huang, Yiping, 1998, *Agricultural Reform in China: Getting Institutions Right*. Cambridge: Cambridge University Press.

Kueh Y Y, 1984a, A weather index for analysing grain yield instability in china, 1952-1981, *China Quarterly*, 97 (March), 68-83.

Kueh Y Y, 1984b, China's food balance and the world grain trade: projections for 1985, 1990 and 2000, *Asian Survey*, 24, 1247-74.

Kueh Y Y, 1995, *Agricultural Instability in China 1931-1991*. Oxford: Clarendon Press.

Liang Y(ed), 1996, *Can China Feed Herself*? Beijing: Economic Science Press (in Chinese).

Lu F, 1998, Grain versus food, a hidden issue in China's food policy debate, *World Development*, 26(9), 1641-1652.

Pinstrup-Andersen P, Pandya-Lorch R and Rosegrant M W, 1997, *The World Food Situation: Recent Developments, Emerging Issues, and Long-Term Prospects*, Washington D.C.: International Food Policy Research Institute.

People's Daily, 1996, June 24, 1996.

Rozelle S, Veeck G and Huang J, 1997, The impact of environmental degradation on grain production in China, 1975-1990, *Economic Geography*, 73, 44-66.

Shen J and Spence N A, 1995, Trends in labour supply and the future employment in China. *Environment and Planning C*, *Government and Policy*,13, 361-377.

Shen J and Spence N A, 1996, Modelling urban-rural population growth in China, *Environment and Planning A*, 28, 1417-1444.

SSB, 1991, *China Statistics Yearbook 1991*. State Statistical Bureau. Beijing: China Statistics Press.

SSB, 1996, *China Statistics Yearbook 1996*. State Statistical Bureau. Beijing: China Statistics Press.

SSB, 1998, *China Statistics Yearbook 1998*. State Statistical Bureau. Beijing: China Statistics Press.

World Bank, 1997, *At China's Table: Food Security Options*. Washington D. C.

Table 1 Grain output and production factors in China in 1990, 1995 and 1997

Year	Arable land (1000 ha.)	Croppin g index	Proportion of cropping area for grain	Grain yield per hectare (ton)	Grain output (1000 Ton)
1990	137769	1.55	76%	2.73	446243
1995	136758	1.58	73%	2.94	466618
1997	NA	NA	73%	NA	494173
1990-1995 Total change	-1011	0.03	-3%	0.21	20375
1990-1995 Annual change	-202.2	0.006	-0.6%	0.042	4075
1990-1995 Percentage change	-0.73%	1.94%	-3.95%	7.69%	4.57%

Source: SSB (1991; 1996; 1998)

Table 2 Grain output by region in 1990, 1995 and 1997

Region	Arable land 1990 (1000 ha.)	Arable land 1995 (1000 ha.)	Grain yield per hectare 1990 (ton)	Grain yield per hectare 1995 (ton)	Grain output 1990 (1000 Ton)	Grain output 1995 (1000 Ton)	Grain output 1997 (1000 Ton)
Total	137769	136758	2.73	2.94	446243	466618	494173
Beijing	520	503	4.34	4.75	2646	2598	2375
Tianjin	595	588	2.99	3.39	1889	2075	2062
Hebei	7474	7430	2.93	3.52	22769	27390	27467
Shanxi	6019	5942	1.81	1.79	9690	9171	9014
Nei Mongol	6902	7633	1.81	1.83	9730	10554	14210
Liaoning	4369	4271	3.80	3.73	14947	14235	13135
Jilin	5279	5297	4.33	4.16	20465	19924	18083
Heilongjiang	11215	11424	2.45	2.68	23125	25521	31045
Shanghai	368	331	5.04	5.37	2395	2104	2302
Jiangsu	5424	5293	4.27	4.80	32308	32863	35638
Zhejiang	2533	2378	3.30	3.46	15861	14309	14935
Anhui	6024	5922	2.85	3.20	24572	25807	28027
Fujian	1620	1577	3.23	3.48	8796	9199	9618
Jiangxi	2749	2701	3.83	3.91	16582	16074	17677
Shandong	8908	8705	3.17	4.02	33549	42464	38522
Henan	8805	8643	2.79	3.10	33037	34665	38947
Hubei	4311	4164	3.84	4.16	24750	24638	26344
Hunan	4935	4842	3.32	3.53	26514	26916	28019
Guangdong	4570	4194	2.62	2.76	18969	17348	18977
Guangxi	4387	4418	2.22	2.44	13631	15082	15448
Hainan	787	777	1.65	1.94	1696	2018	2139
Sichuan	11023	10832	2.48	2.51	42668	43650	46190
Guizhou	4858	4821	1.08	1.26	7210	9489	10259
Yunnan	5918	5971	1.40	1.57	10572	11889	12719
Xizang	378	378	1.70	2.19	555	700	773
Shaanxi	5441	5226	1.68	1.56	10707	9134	10444
Gansu	5840	5851	1.43	1.31	6907	6442	7662
Qinghai	947	967	1.74	1.81	1140	1142	1276
Ningxia	1838	1865	1.14	1.15	1901	2032	2566
Xinjiang	4075	4129	2.75	3.40	6662	7185	8300

Source: SSB (1991; 1996; 1998)

Table 3 Changes of regional grain output by factor 1990-1995 (1000 Ton)

Region	Impact of grain yield per ha.	Impact of proportion of cropped area for grain	Impact of cropping index	Impact of arable land	Total grain output change
Total	33770	-17957	7836	-3274	20375
Beijing	227	-109	-81	-85	-48
Tianjin	246	-58	22	-23	186
Hebei	4615	178	-38	-135	4621
Shanxi	-110	-117	-167	-124	-519
Nei Mongol	149	-61	-294	1030	824
Liaoning	-278	-454	354	-334	-712
Jilin	-837	195	29	72	-541
Heilongjiang	2146	10	-190	430	2396
Shanghai	129	-83	-92	-246	-291
Jiangsu	3641	-1716	-593	-777	555
Zhejiang	641	-523	-698	-972	-1552
Anhui	2783	-1668	539	-419	1235
Fujian	671	-553	517	-231	403
Jiangxi	344	-1406	845	-290	-508
Shandong	8999	56	627	-767	8915
Henan	3423	-2481	1294	-607	1628
Hubei	1903	-2191	1022	-846	-112
Hunan	1638	-864	129	-500	402
Guangdong	866	-1259	329	-1558	-1621
Guangxi	1366	-1517	1507	96	1451
Hainan	300	-78	124	-23	322
Sichuan	522	-783	1984	-741	982
Guizhou	1368	-347	1313	-55	2279
Yunnan	1256	-1038	1005	94	1317
Xizang	155	-25	15	0	145
Shaanxi	-726	-47	-376	-423	-1573
Gansu	-594	-181	298	12	-465
Qinghai	48	-96	26	24	2
Ningxia	30	-43	116	27	131
Xinjiang	1369	-1004	68	90	523

Source: Calculated by the author

Table 4 Changes of regional grain output by factor 1995-1997 (1000 Ton)

Region	Impact of grain yield per ha.*	Impact of proportion of cropped area for grain	Impact of cropping index*	Total grain output change
Total	15463	-643	12735	27555
Beijing	-166	24	-82	-223
Tianjin	0	-1	-12	-13
Hebei	-1005	652	430	77
Shanxi	-89	98	-166	-157
Nei Mongol	1712	367	1577	3656
Liaoning	-1129	16	13	-1100
Jilin	-1926	47	37	-1841
Heilongjiang	3845	547	1132	5524
Shanghai	65	94	39	198
Jiangsu	1409	1126	240	2775
Zhejiang	329	220	77	626
Anhui	1435	369	416	2220
Fujian	310	-243	352	419
Jiangxi	1249	119	235	1603
Shandong	-3689	-825	572	-3942
Henan	4007	-125	400	4282
Hubei	861	-237	1082	1706
Hunan	894	-370	579	1103
Guangdong	1347	-395	678	1629
Guangxi	54	-888	1200	366
Hainan	113	-95	103	121
Sichuan	1814	-172	898	2540
Guizhou	561	-445	653	770
Yunnan	582	-390	639	830
Xizang	39	5	30	73
Shaanxi	1301	-6	15	1310
Gansu	1325	-79	-26	1220
Qinghai	103	33	-2	134
Ningxia	481	7	46	534
Xinjiang	750	32	333	1115

Source: Calculated by the author

Note: The impacts of the grain yield per ha. and the cropping index on the grain production were estimated assuming that there was no change in the arable land over the period 1995-1997 in various regions. The data on the change of the arable land are not available for the period 1995-1997. Such impacts would be consistently underestimated/overestimated if the arable land in a region was decreased/increased in reality in this period.

Table 5 Number of regions with positive and negative impacts in periods 1990-1995 and 1995-1997

Indicator	Impact in 1990-1995	Positive impact 1995-1997	Negative impact 1995-1997
Proportion of cropped area for grain production	Positive	12	1
Proportion of cropped area for grain production	Negative	14	3
Total Grain output	Positive	17	2
Total Grain output	Negative	7	4

Source: Calculated by the author

Table 6 Projected grain output, demand and import in scenario A, B, C and D

Year	Population (million)	Grain consumption per capita (kg / person)	Arable land (million Ha)	Cropping index	Proportion of cropping area for grain	Grain yield (Ton/ Ha.)	Grain demand (million ton)	Grain output (million ton)	Net import (million ton)
	Scenario A								
2000	1312	300.80	136.758	1.58	73%	2.94	497.26	466.62	30.64
2010	1428	300.80	136.758	1.58	73%	2.94	541.08	466.62	74.46
2020	1530	300.80	136.758	1.58	73%	2.94	579.97	466.62	113.35
2030	1595	300.80	136.758	1.58	73%	2.94	604.37	466.62	137.75
2040	1604	300.80	136.758	1.58	73%	2.94	607.78	466.62	141.16
2060	1540	300.80	136.758	1.58	73%	2.94	583.83	466.62	117.21
2087	1370	300.80	136.758	1.58	73%	2.94	519.07	466.62	52.45
	Scenario B								
2000	1312	300.80	135747	1.61	70%	3.15	497.26	483.26	14.00
2010	1428	300.80	133725	1.66	64%	3.57	541.08	509.70	31.38
2020	1530	300.80	131703	1.72	58%	3.99	579.97	524.69	55.27
2030	1595	300.80	129681	1.77	52%	4.41	604.37	527.63	76.73
2040	1604	300.80	127659	1.83	46%	4.83	607.78	517.98	89.80
2060	1540	300.80	123615	1.93	34%	5.67	583.83	459.03	124.80
2087	1370	300.80	118156	2.08	17%	6.80	519.07	291.47	227.60
	Scenario C								
2000	1312	306.80	135747	1.61	70%	3.15	507.18	483.26	23.92
2010	1428	326.90	133725	1.66	70%	3.57	588.02	557.97	30.05
2020	1530	346.80	131703	1.72	70%	3.99	668.66	634.49	34.17
2030	1595	366.80	129681	1.77	70%	4.41	736.98	712.59	24.38
2040	1604	386.80	127659	1.83	70%	4.83	781.54	792.11	-10.56
2060	1540	426.80	123615	1.93	70%	5.67	828.39	954.55	-126.16
2087	1370	480.80	118156	2.08	70%	6.80	829.68	1178.70	-349.02
	Scenario D								
2000	1312	306.80	133725	1.61	70%	3.15	507.18	476.06	31.12
2010	1428	326.90	129681	1.66	64%	3.57	588.02	494.29	93.74
2020	1530	346.80	125637	1.72	58%	3.99	668.66	500.53	168.13
2030	1595	366.80	121593	1.77	58%	4.41	736.98	552.54	184.44
2040	1604	386.80	117549	1.83	58%	4.83	781.54	603.16	178.38
2060	1540	426.80	109461	1.93	58%	5.67	828.39	698.99	129.40
2087	1370	480.80	98542	2.08	58%	6.80	829.68	812.94	16.75

Source: Calculated by the author

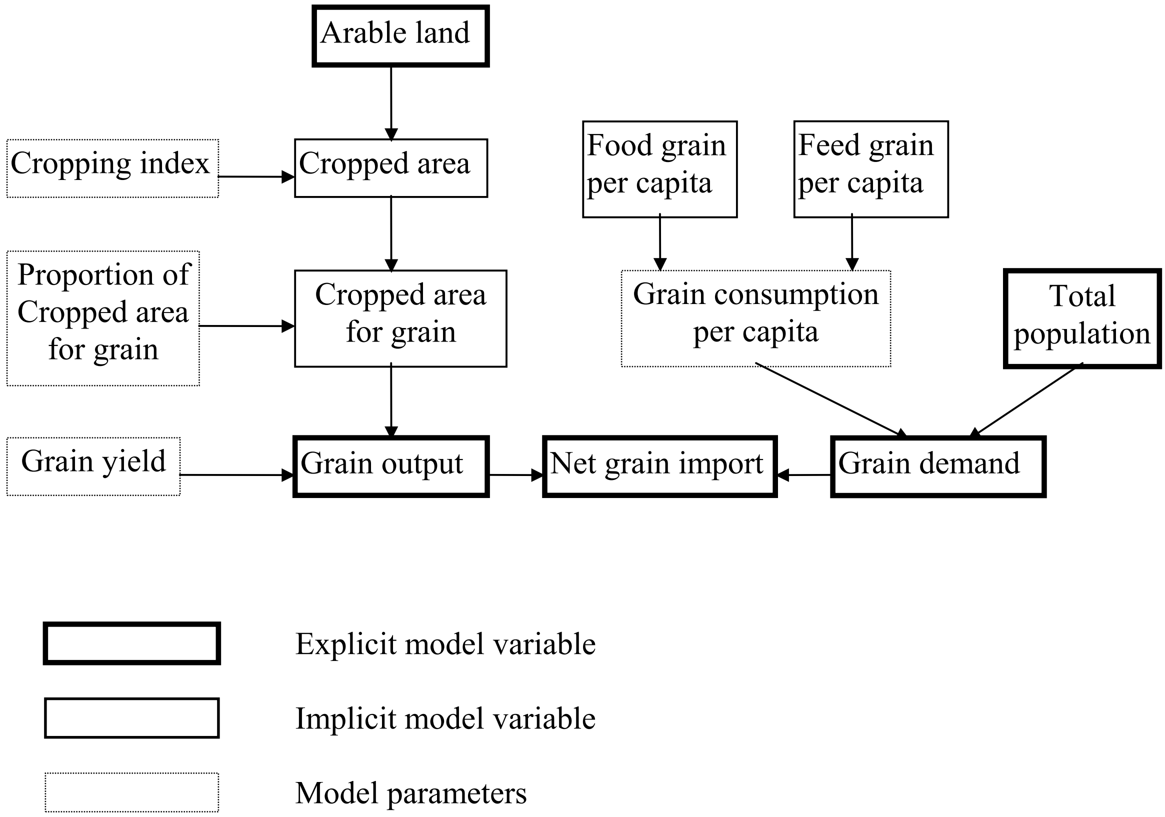

Figure 1 Grain supply and demand framework

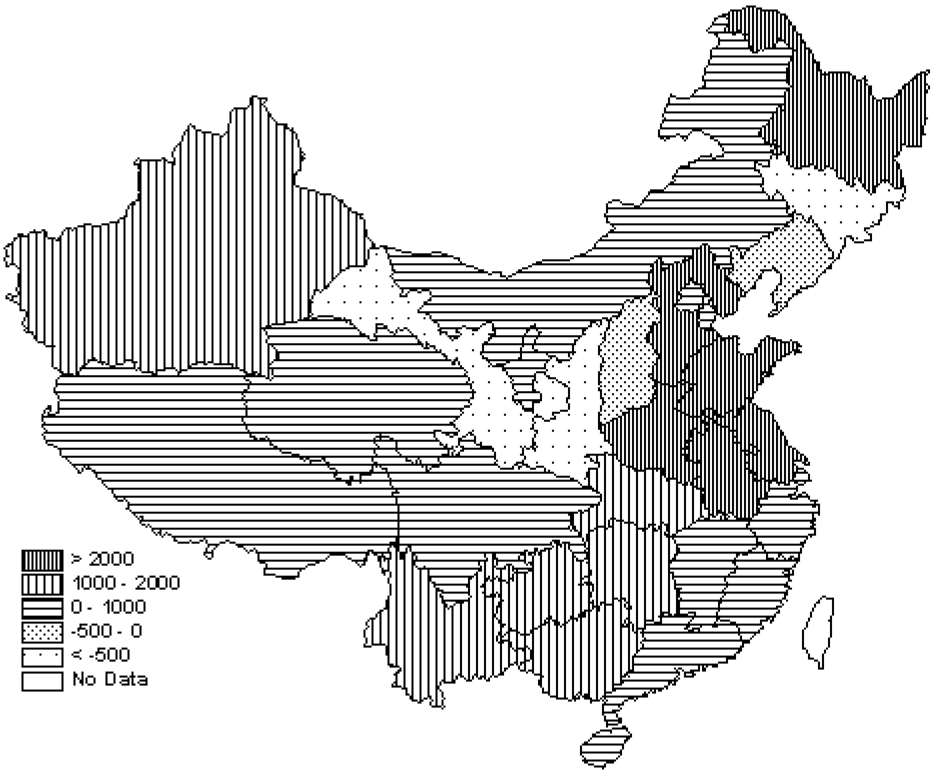

Figure 2 Impact of the grain yield per hectare on the grain output 1990-1995 (1000 Ton)

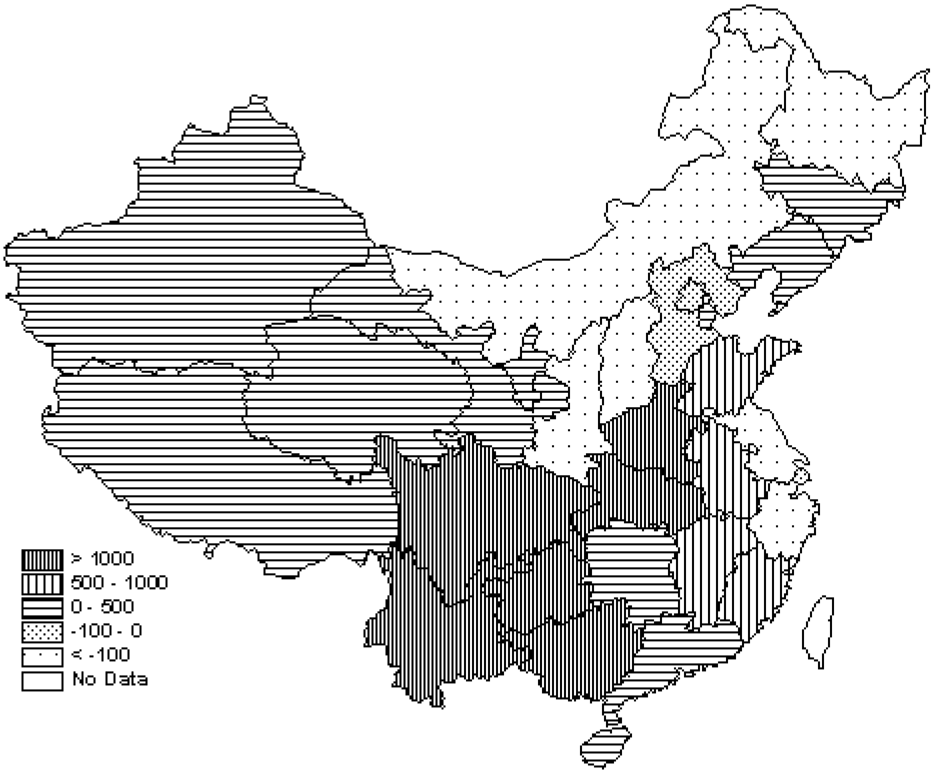

Figure 3 Impact of the cropping index on the grain output 1990-1995 (1000 Ton)

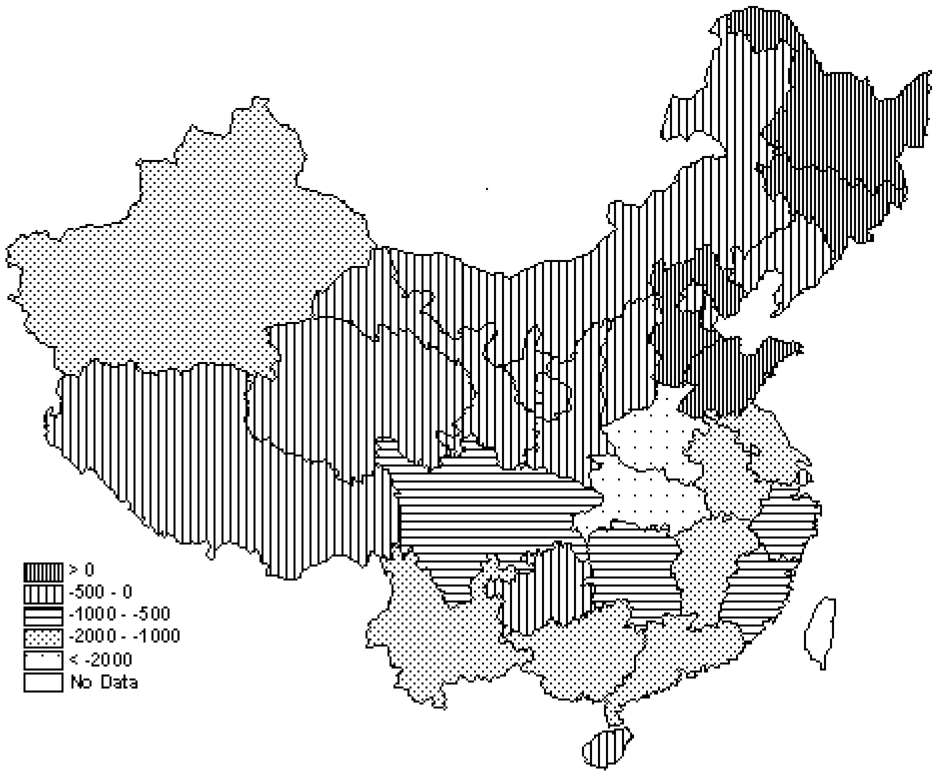

Figure 4 Impact of the proportion of the cropped area for the grain production on the grain output 1990-1995 (1000 Ton)

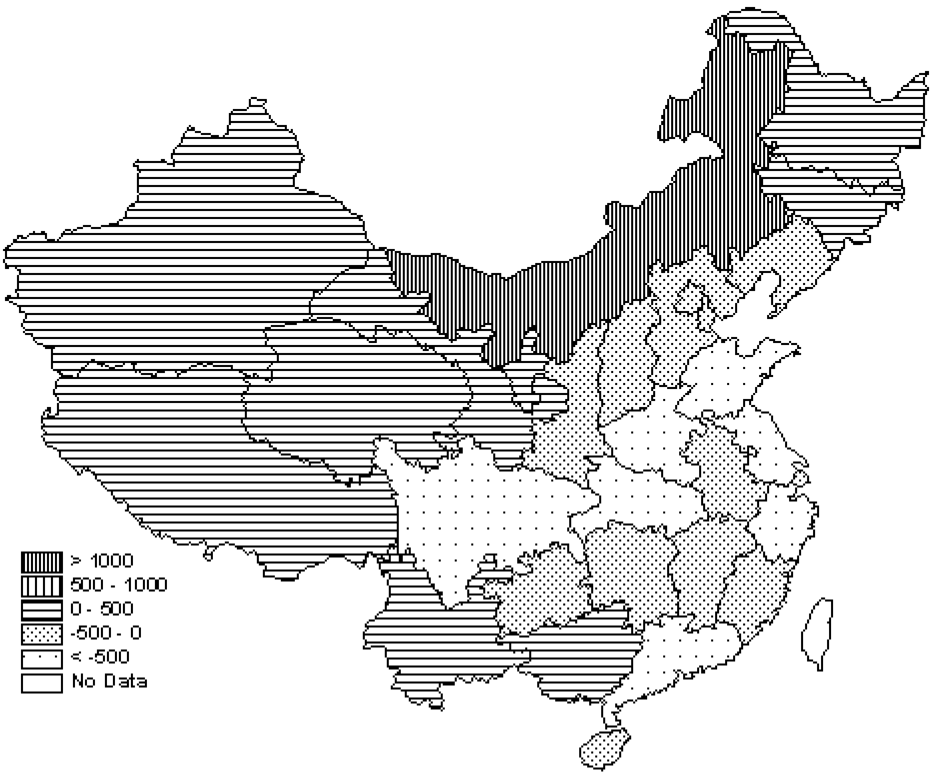

Figure 5 Impact of the arable land on the grain output 1990-1995 (1000 Ton)

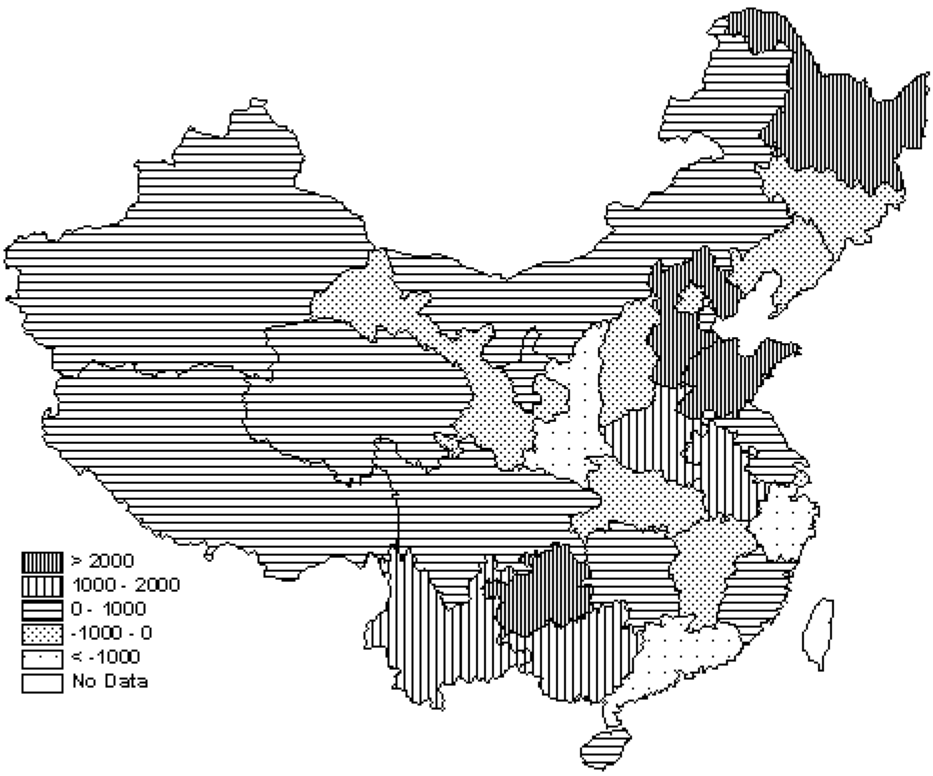

Figure 6 Changes of the regional grain outputs 1990-1995 (1000 Ton)

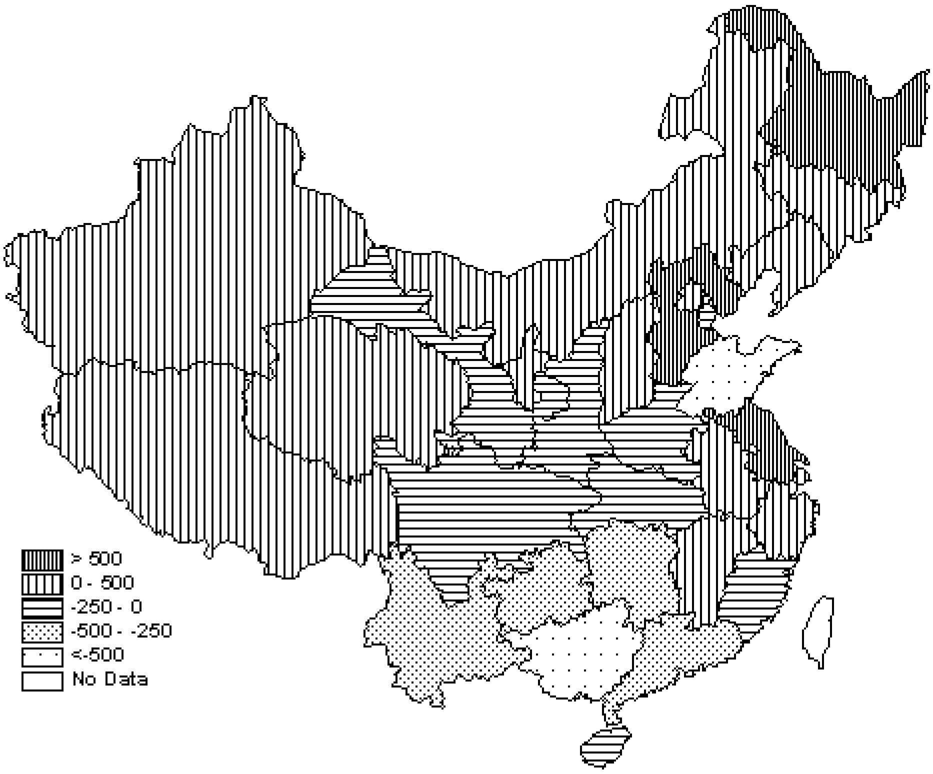

Figure 7 Impact of the proportion of the cropped area for grain production on the grain output 1995-1997 (1000 Ton)

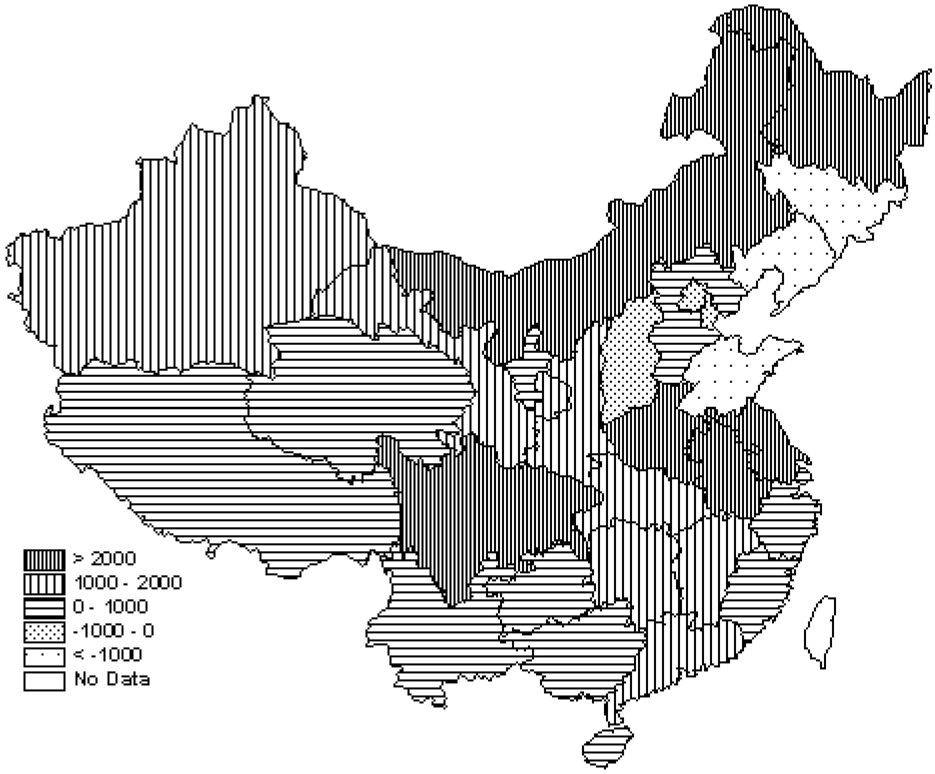

Figure 8 Changes of the regional grain outputs 1995-1997 (1000 Ton)