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Influences of greenhouse effect on agricultural production in China

Gao Suhua[1], Ding Yihui[1], Pan Yaru[1] and Zhao Zongci[1]

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Abstract— An obvious warming in China induced by doubled carbon dioxide (CO_2) as simulated by the climatic models have been found. It is also noticed that there might be drying or wetting in some parts of China induced by doubled CO_2 as simulated by the general circulation models(GCMs). Agricultural productivity mainly depends on the temperature, rainfall and soil moisture in China. The changes of agricultural productivity in the different parts of China induced by doubled CO_2 have been estimated in this paper. It is shown that the greenhouse effect might cause increasing production in some parts of China and decreasing production in other parts of China.

Keywords: greenhouse effect; agricultural productivity; doubled CO_2; GCMs; climatic productivity force.

INTRODUCTION

The global surface air mean temperature has increased by about 0.5°C for the last 100 years. A warming of about 1°C in the continental regions of the Norther Hemisphere has been observed. The trends of change of temperature in China are similar to those in the Northern Hemisphere (Zhang, 1989).

Greenhouse effect influences on the change of temperature. An obvious warming of about 1.5–4.5°C induced by doubled CO_2 as simulated by the GCMs has been shown. In turn, this warming would influence on the ecosystem and social-economic systems.

It is difficult to estimate the changes of agricultural production induced by doubled CO_2. A few researches try to address this problem in China(Zhang, 1988). In this paper we attempt to show some preliminary estimated results.

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[1]Academy of Meteorological Science, State Meteorological Administration, Beijing 100081, China.

POSSIBLE INFLUENCE ON AGRICULTURAL CLIMATIC RESOURCES IN CASE OF DOUBLED CO_2

The growth and development of crops depend on the accumulated temperature and growing period. The accumulated temperature is defined as a sum of daily mean temperature which is higher than 0°C or 10°C in China. They are expressed as $\Sigma T0$ and $\Sigma T10$.

The correlations between $\Sigma T10$ (or $\Sigma T0$) and the annual mean temperature have been calculated. There are the significant linear relationships between both variables. Some results are shown in Table 1.

Table 1 Relationships between $\Sigma T10$, $\Sigma T0$ and annual mean air temperature

Stations	Items	Equations	Significant level
Jinzhou	$\Sigma T10$	$Y = 209.16X + 1659.51$	0.01
	$\Sigma T0$	$Y = 160.74X + 2533.60$	0.01
Zunhua	$\Sigma T10$	$Y = 185.60X + 2035.63$	0.01
	$\Sigma T0$	$Y = 231.68X + 1922.80$	0.01
Linyi	$\Sigma T10$	$Y = 231.70X + 1342.12$	0.01
	$\Sigma T0$	$Y = 313.12X + 780.13$	0.01
Kunming	$\Sigma T10$	$Y = 474.13X - 2468.50$	0.01
	$\Sigma T0$	$Y = 364.74X + 15.25$	0.01

Table 2 Changes of annual mean temperature (T, °C), annual mean precipitation (P, mm and annual mean soil moisture (SM, mm) in whole China and several parts of China induced by doubled CO_2 as simulated by the OSU AGCM/mixed-layer ocean model

Areas items	T	P	SM
China	2.69	146.4	0.05
Northeast China	2.72	77.8	-1.93
Huabei	2.56	98.2	-2.23
Yangtze River Valley	2.52	190.4	1.52
Huanan	2.42	251.5	2.44
Southwest China	3.04	140.2	0.00
Northwest China	3.02	77.0	-0.95

The results induced by doubled CO_2 as simulated by the OSU atmospheric GCM(AGCM) coupled to a mixed-layer ocean model (Schlesinger, 1989) have been used in our analyses. Table 2 shows the changes of annual mean surface air temperature, precipitation and soil moisture in whole China and several parts of China induced by doubled CO_2 as simulated by the OSU

AGCM/mixed-layer ocean model. It is noticed in Table 2 that the warming of about 2–3 °C and increasing precipitation of about 70–250mm in each part of China were simulated by the OSU model. The soil moisture might decrease in the northern China and increase in the most parts of South China.

Fig. 1 Shows 2 $\times CO_2$ accumulated temperature ($\Sigma T10$ in China. It is noticed in Fig. 1 that $\Sigma T10$ is about 3000 °C with increasing by about 10% in the northeastern part, 4000–5500°C with increasing by about 10–15% in the Huabei Plain, 5500–7000°C with increasing by about 10% in the Yangtze River Valley ad 5000-7000°C with increasing by about 20–30% in the Southwestern China. A mean increasing value of about 15% in China has been found.

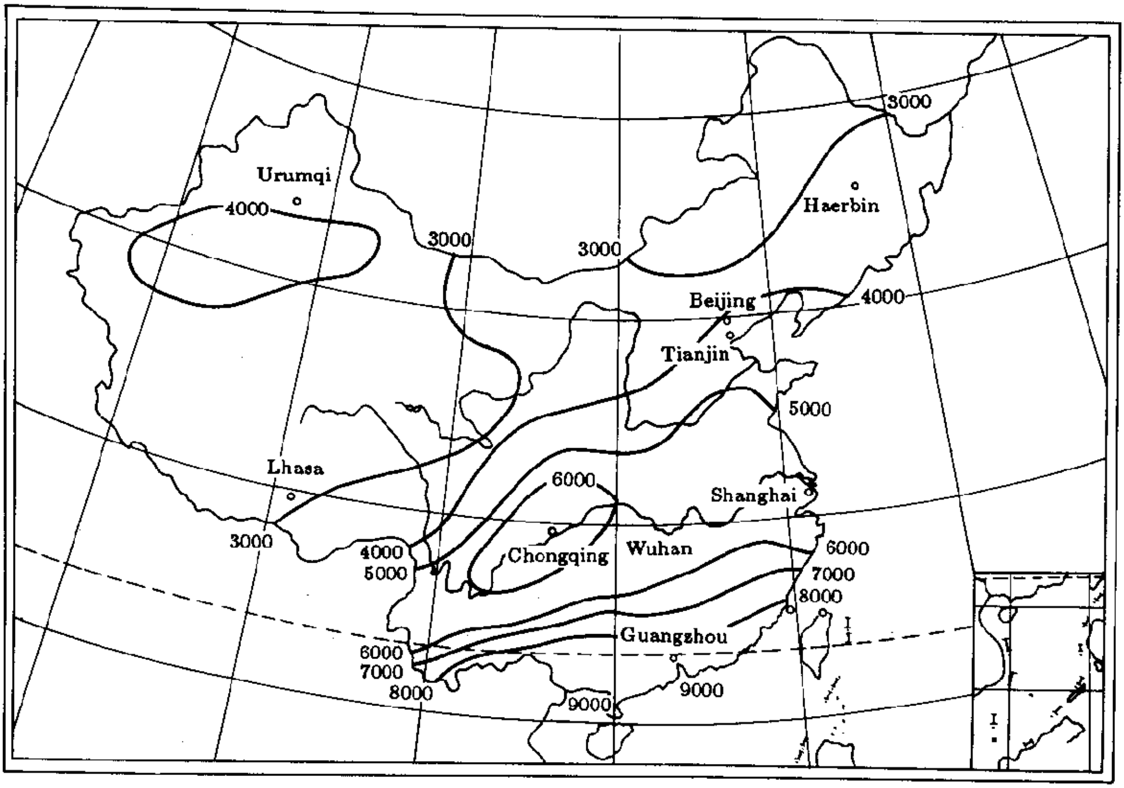

Fig. 1 Distribution of accumulated temperature $\Sigma T10$ induced by doubled CO_2

The relation between the continuous numbers of days of accumulated temperature higher than 10°C ($D10$) and $\Sigma T10$ can be expressed as

$$D10 = \Sigma T10/(14.89 + 0.0013\Sigma T10) \quad (1)$$

(Gao, 1982). The $D10$ increases due to the increase in the accumulated temperature. The change of $D10$ in North China is greater than that in South China. The $D10$ in China increases by about one month when doubled CO_2 appears.

The correlation coefficient between the annual mean temperature and frost-free period in China is 0.93 (significant level is 0.01). A significant linear relationship can express as

$$Y = 11.69X + 68.32. \tag{2}$$

When doubled CO_2, temperature increases and frost-free period extends for about one month in China. The frost-free period in North China is longer than that in South China.

POSSIBLE INFLUENCE ON AGRICULTURAL PRODUCTIVITY INDUCED BY DOUBLED CO_2

Possible influence on agricultural productivity induced by doubled CO_2 could be assessed in two ways. One is the direct effect by means of photosynthesis and metabolism; another is called the indirect effect. The doubled CO_2 first impact on climatic change. Then the change of agricultural productivity are impacted due to the changed climatic situation. We shall focus on the latter effect in this paper.

Influence on the climatic productivity force

Climatic productivity force may be estimated using Thornthwaite Memoral expression (Gao, 1986). It is written as

$$TSP(v) = 3000[1 - e^{-0.0009685(v-20)}], \tag{3}$$

where TSP (v) is the estimated plant production according to the real evapotranspiration; v is the annual mean real evapotranspiration. It is estimated using Ture formula as

$$v = 1.05N/\sqrt{(1 + (1.05N/L)^2)}, \tag{4}$$

where L=3000 + 25t + 0.05 t^2, N is the precipitation and t is the mean temperature.

The change of TSP (v) in China in case of doubled CO_2 is shown in Fig. 2. It is noticed in Fig. 2 that the mean increase of about 17.23% is found in the whole China. The biggest increase of about 21.1% is noted in the Southwestern China and the smallest one of about 5.84% is in the Northeastern China.

Possible impact on the planting system in China induced by doubled CO_2

The planting system in China is greatly dependent on the heating condition. Fig. 3 shows the painting system in China. Single cropping per year expressed as I in Fig. 3 occupies the half areas of China. The frost-free period in area I is 100–150 days. The line 4000°C indicates

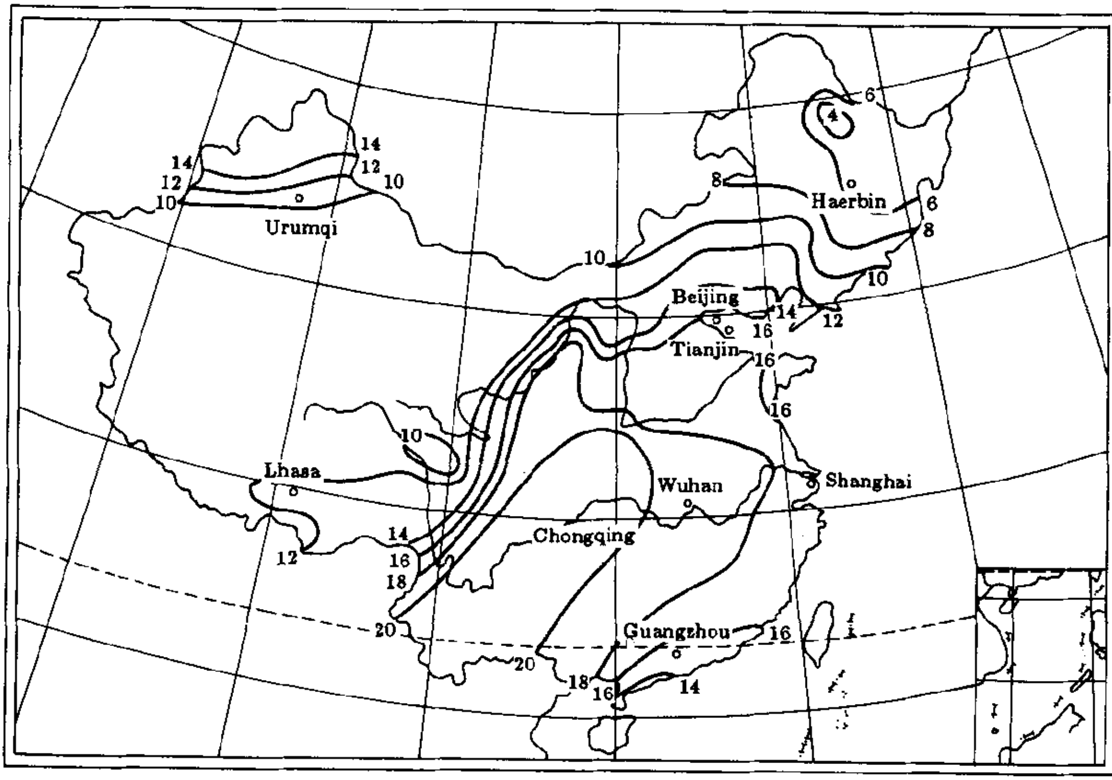

Fig. 2 Change of TSP (v) induced by doubled CO_2

the southern edge of the $\Sigma T0$ (AMS, 1981). Double croppings per year expressed as II in Fig. 3 occupy in the central part of China. The $\Sigma T0$ is 4000-4800°C for wheat and corn planting areas, 4800–5500°C for wheat and rice planting areas, and more than 5500°C for doubling seasonal rice. The triple croppings per year expressed as III in Fig.3 occupy in the most parts of South China. The norther edge of the $\Sigma T0$ is line 5800°C.

As mentioned above, the increasing accumulated temperature in China induced by doubled CO_2 has been noticed. Fig. 4 presents the distributions of the major planting system in China due to $2 \times CO_2$. It is interesting to find in Fig. 4 that the areas of the planting system in China might be moved northward by about 5 degree latitudes. That is to say, area I and II might be replaced by area II and III, respectively.

The increasing temperature of about 2–3°C and increasing precipitation of about 75 mm in area I by doubled CO_2 are helpful to get a good harvest. In area II, the temperature may increase by about 2.5°C and precipitation might increase by about 190 mm due to $2 \times CO_2$. It is beneficial to plant double-harvest rice in this area. In area III, increasing precipitation of

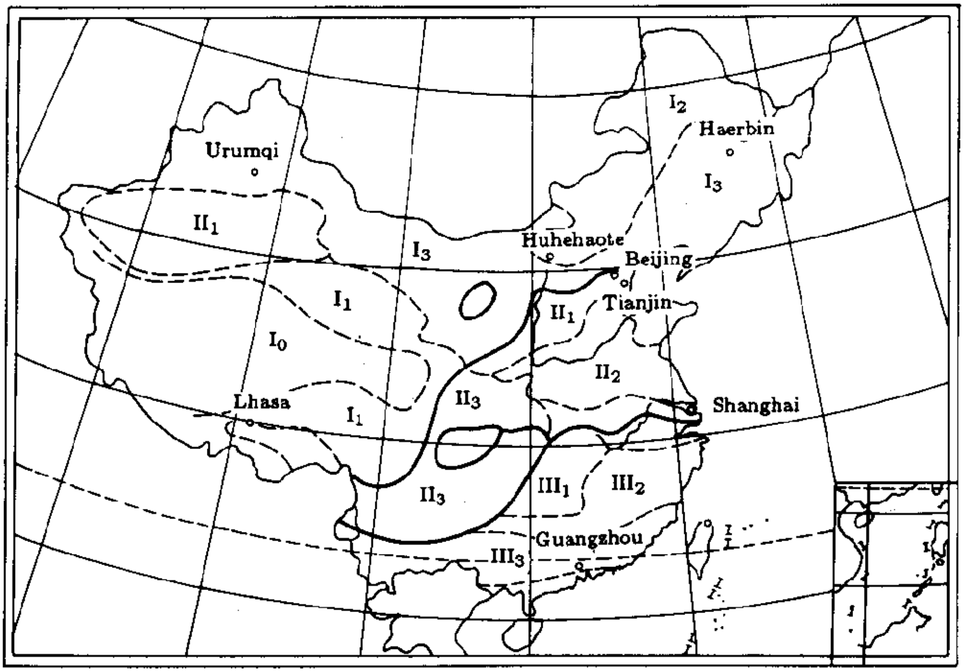

Fig. 3 Planting system in China

about 140–250 mm due to $2\times CO_2$ is not enough to help triple-harvest rice in some parts of this area. Besides, the decreasing soil moisture in the Northern China due to $2 \times CO_2$ is a worse situation for getting a nice harvest.

Possible influence on the crop productivity in China induced by doubled CO_2

The data of crop productivity and meteorological situation in seven areas of China and whole China for 1981–1987 have been used in this paper. Crop productivity in China mainly depends on the temperature and precipitation. Using the successive sieving factors, two equations of regressions are given as:

$$Y1 = -728.7963 + 23.5469X1 + 36.7934X2 - 0.0238X3 - 0.0601X4;$$

$$Y2 = -558.7440 + 18.7619X1 + 5.4757X5 - 0.0258X3 - 0.2695X4.$$

where $Y1$ and $Y2$ are meteorological productions; $X1$ is temperature in summer; $X2$ is the annual mean precipitation; $X3$ is the cubic annual mean temperature; $X4$ is the cubic annual precipitation; $X5$ is the square annual precipitation.

When $2\times CO_2$ appears, the meteorological data for $2 \times CO_2$ were put into both equations. The changes of meteorological production was obtained from averaged value of $Y1$ and $Y2$. The changes of meteorological production for $2\times CO_2$ related to the mean meteorological pro-

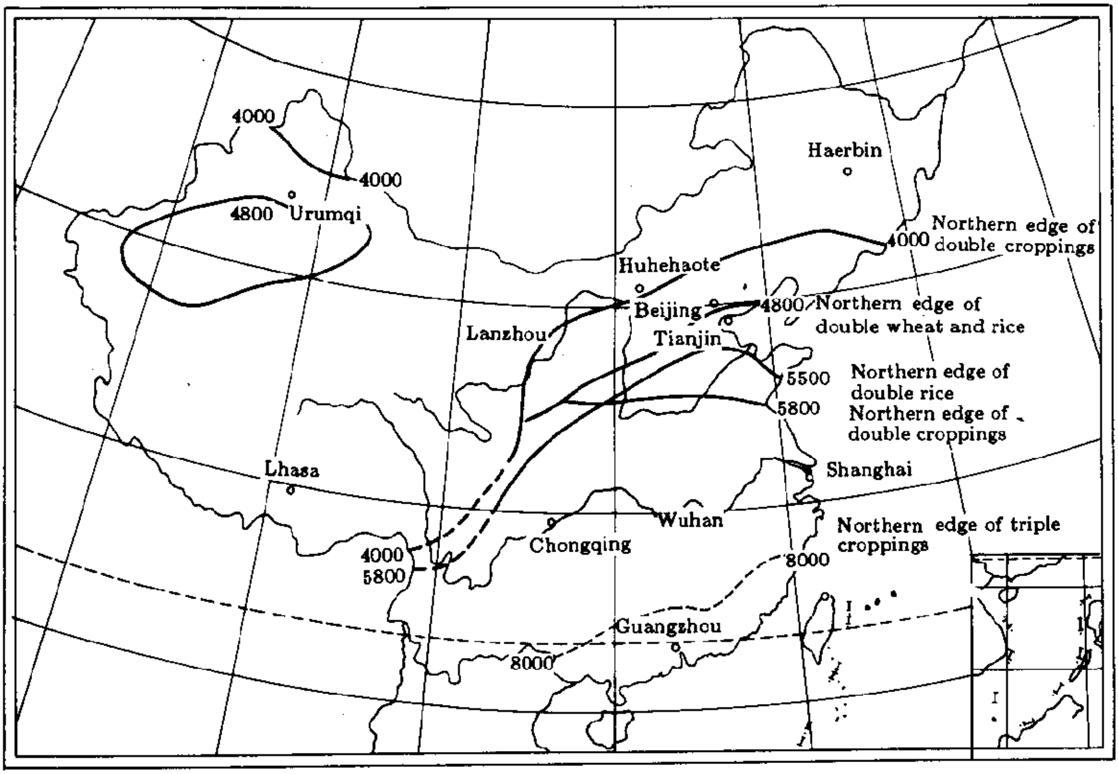

Fig. 4 Change of demarcation of planting system induced by doubled CO_2

duction for 1981–1987 are given in Table 3. It is found in Table 3 that there are the increasing productions in most parts of China, except for the Southern China induced by doubled CO_2. An obvious increasing production of about 25.0% might appear in the Northwestern China. The mean meteorological production in China increases by about 9.5%.

Table 3 Change of crop productivity in China induced by doubled CO_2

Items areas	1	2	3	4	5	6	7
Change of crop productivity, kg/ha	739.5	874.5	1008	922.5	682.5	171	997.5
Change, %	13.0	13.7	11.6	-12.6	13.7	2.4	25.0

Areas: 1. Northeast China 2. Huabei 3. Yangtze River Valley 4. Huanan 5. Xinjiang and Qinghai 6. Southwest China 7. Northwest China

SUMMARY AND DISCUSSION

Greenhouse effect influences on the climatic changes as simulated by the GCMs. According to the above estimation, the obvious warming, increasing accumulated temperature and growth period induced by doubled CO_2 have been found. Therefore, the northern boundary of crop planting system in China move northward and the climatic productivity force increases. It is useful to increase agricultural productivity.

The agricultural productivity depends on many meteorological factors, such as temperature, precipitation, soil moisture, and their changes for the different seasons. The agricultural productivity also depends on the agricultural factors, such as rank grass in farms, insect pest and other disasters. Some changes of those factors induced by doubled CO_2 in some parts of China might be favorable for the agricultural productivity, but some are harmful for the productivity. We only think about a simple impacting mode. It is not fully conclusive to explain greenhouse effect on agriculture in China. Further works remains to be performed in future.

REFERENCES

Academy of Meteorological Science, Agricultural and climatic resource and planting system in China, Agriculture Press, 1981 (in Chinese)

Gao Suhua, J. Meteorology, 1982, 3:20 (in Chinese)

Gao Suhua, Tropical Meteorology, 1986, 4:327 (in Chinese)

Schlesinger, M.E. and Zhao Zongci, J. Climate, 1989, 2:459

Zhang Jiacheng, Climate and human, Henan: Science and Technic Press, 1988 (in Chinese)

Zhang Xiangong, Ding Yihui and Ma Shijun, Climatic change, impact and assessment in China, The Second PAN-Earth Conference, Cornell University, March, 1989