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Impacts of Accumulated Temperature Changes on the Maize Belt in Heilongjiang Province

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Abstract: Global warming has altered the distribution of the maize (Zea mays) belts in China. Climate change has important impacts on regional agricultural planning, especially in Heilongjiang Province. Heilongjiang is the northernmost province in China and is the main production area of maize but is also the most sensitive to temperature changes. In the 1980s, the planted area of maize was divided into five belts in Heilongjiang Province, however, since the 1980s the mean air temperature has increased by 0.77°C and the active accumulated temperature above 10°C has increased by about 200°C in the 2000 sec. These temperature increases have resulted in changes in the area planted with maize. Regional planning of maize planting in the 1980s could not be adapted to meet the demand. The active accumulated temperature above 10°C has typically been a main index used in regional planning. In this study, we have redefined the period of accumulated temperature above 10°C based on the maize growing season. The temperature required for maize germination and cessation differs from other crops, with the maize growing season being designated as the first day in a five consecutive day period with temperature = 10°C until the first frost. In the past, little attention was paid to the onset and length of the maize growing season. A different definition of the growing period would result in different heat distribution maps. An index of ecological divisions based on growing season would be more helpful for regional planning of maize production.

Key words: Maize ,climate change, impact, Heilongjiang

INTRODUCTION

Climate change may have important impacts on agricultural practices (Guo *et al.*, 2010) and regional agricultural planning. Based on general circulation models (GCMs), global average temperatures are expected to increase by 0.74°C in the next century (IPCC, 2007), with some regions predicted to be even warmer than the global average (Giorgi and Bi, 2005). Climate is the dominant factor affecting species distribution over large spatial scales (Pearson and Dawson, 2003). Results from paleontological research and analysis of past meteorological data show that over time, the trend for most species has been to migrate northward or upward (Pitelka, 1997; Kullman, 1998) in response to climate warming.

The climate is warming at an unprecedented rate in Heilongjiang, northeastern China, where the annual mean temperature has risen by approximately 1.5°C over the past 44 years (Sun *et al.*, 2005), thus exceeding the magnitude of change at the global scale. The distribution of growing zones based on accumulated temperature has therefore changed substantially in the past 30 years.

The accumulated temperature above 10°C is an important temperature accumulation during the effective growing season of the maize in the northeastern China It is the basis for determining the layout of maize and their varieties Heilongjiang, in northeastern China.

Among previous studies of regional planning of maize, there has been no definite index proposed to determine the onset and length of the growing period (LGP). Few studies have been performed with insufficient

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data collected to adequately explain its onset and length. In the present study, we analyzed the LGP in detail and identified the real heat demand of maize. It is of significance for agricultural planning to study the heat demand of maize and prepare accurate heat distribution maps of the crop.

MATERIALS AND METHODS

Study area: The study area encompasses Heilongjiang Province, China, which is located between 121°13'-135°05'E longitude and 43°22'-53°24'N latitude (Fig. 1). This northernmost province of China has an area of 454,000 km^2, a population of 38.17 million. Heilongjiang has become one of the most important areas for the production of agricultural products including grain and timber now. In the 1980s, the region was divided into six varieties accumulated temperature belts to guide agriculture production from north to south based on accumulated temperature (1900°C, 1900-2100°C, 2100-2300°C, 2300-2500°C, 2500-2700°C and 2700°C) (AAHFD, 1992 in Heilongjiang province).

Methods: Daily meteorological data were obtained from the Data Center of the National Meteorological Bureau of China, for 31 meteorological stations from January 1, 1951, to December 31, 2010. An administrative map of northeast China was obtained from the National Fundamental Geographic Information System updated in 1995 at a scale of 1:4 million. The accumulated temperature is the cumulative value of the daily mean air temperature during the crop growing season. The accumulated temperature above 10°C is the most important index for identification of the crop growing season and forms the basis for regional maize planning.

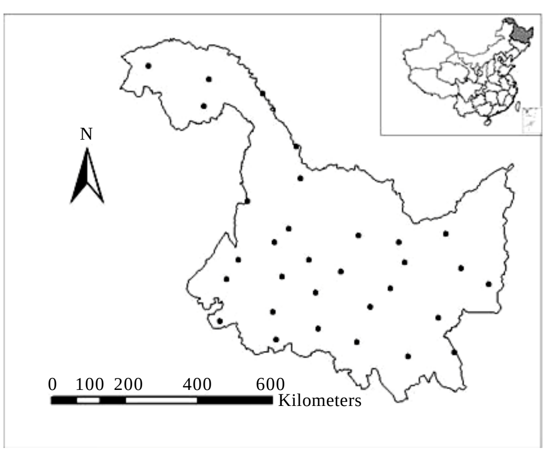

Fig. 1: Location of the study area in China. Dots indicate the location of weather stations

There are two ways to calculate the accumulated temperature. The first method, which come from the calculation of GDD (Gordon and Bootsma, 1993) is the cumulative value of all the mean air temperatures above 10°C every day for a single year, giving the total accumulated temperature. The second method, which was used in this study, is the cumulative value of the accumulated temperature above 10°C based on the maize growing season. This is the period between the first day in a consecutive 5-day period with temperatures = 10°C (Yan *et al*., 2011) through to the first frost.

RESULTS

Trend of temperature and in heilongjiang province: We established the departures from the annual average temperature from 1951 to 2010, which indicated a difference between the annual average temperature and the average temperature from 1951 to 2010 in Heilongjiang Province. There was a slight decrease from 1951 to the late 1980s, followed by a large increase from the late 1980s to the present day, indicating a significant warming in Heilongjiang Province since the 1980s (Fig. 2). The departures were greater than zero in the 1990s and 2000s and reached a maximum in 2009 and 2010.

Based on data from 31 meteorological stations in Heilongjiang, the annual mean air temperature has increased since the 1980s. The annual average temperature in the 2000s was 2.86°C, which is approximately 0.77°C higher than the mean air temperature in the 1980s.

Analysis of meteorological data using the two method Comparison of period with two method: Use of the duration of the active accumulated temperature above 10°C may raise some issues. How to determine the onset and LGP needs to be addressed. For example, the LGP

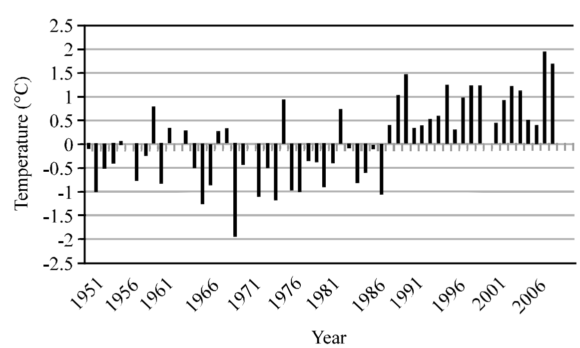

Fig. 2: Temperature departures from the average annual temperature from 1951 to 2010 in Heilongjiang Province, China

Table 1: Comparison of the accumulated temperature calculation and growing season duration in heilongjiang province

		The first method				The second method			
No.	Station	Start date	End date	Accumulated temperature (°C)	Duration (days)	Start date	End date	Accumulated temperature (°C)	Duration (days)
50136	Mohe	6-May	17-Sep	1791.38	134	8-Jun	1-Sep	1437	85
50775	Hegang	14-Apr	12-Oct	2735.66	181	15-May	6-Oct	2729.7	154
50983	Hulin	20-Apr	17-Oct	2778.26	180	6-May	6-Oct	2733.66	153
50788	Fujin	19-Apr	14-Oct	2818.09	178	5-May	8-Oct	2823.33	156
54096	Suifenhe	15-Apr	16-Oct	2397.01	184	18-May	24-Sep	2189.72	129

Average sowing dates, harvest dates, accumulated temperature, and duration of the maize growing season from 1981 to 2010. (The first method which period is from the first day =10°C to end day =10°C for a single year. The second method which period is from the first day in 5 days to the first frost for a single year

determines the heat demand in the maize growing season. The effectiveness of heat during the period with an accumulated temperature above 10°C can be questioned. Crops have variable sowing and harvest dates, which will affect their growth stages. Maize seeds commonly germinate when the air temperature regularly reaches 10°C. Accordingly, this means that when the air temperature = 10°C for five consecutive days, seeds will safely germinate. As a result, the heat acquired during earlier periods cannot be used. An early frost could cause a premature cessation of crop growth and the heat received after the frost cannot be used for maize growth. As a result, the heat accrued from the first day of five continuous days = 10°C to the first frost could be an effective index of the growing season. However, traditionally heat was measured as the cumulative value of the daily mean air temperatures from the first day = 10°C to the last day = 10°C during the year, even though some of that heat was not available for plant growth. Maize distribution maps based on this data will not be accurate. Table 1 compares the start dates, end dates and accumulated temperatures for two approaches of partial region. It shows the average typical sowing and harvest dates for maize from 1981 to 2010. The difference between two methods is substantial (Table 1). The maximum difference in the duration of the growing season was 55 days (in Sufenhe), with an average difference of 36.97 days. The maximum difference between the start dates was 33 days in Sufenhe, in the end date was 22 days in Sufenhe, The average difference was 24.06 days. The maximum difference in the accumulated temperature was 354.38°C in Mohe.

The change in accumulated temperature zones in Heilongjiang Province: The maize-growing areas in Heilongjiang were divided into five belts from north to south in the 1980s based on the accumulated temperature (1900-2100°C, 2100-2300°C, 2300-2500°C, 2500-2700°C, =2700°C) (Fig. 3 (the first method) and Fig. 4(the second method)) except = 1900°C zone which can't meet the maize heat demand. It is clear from Fig. 3 that the area in

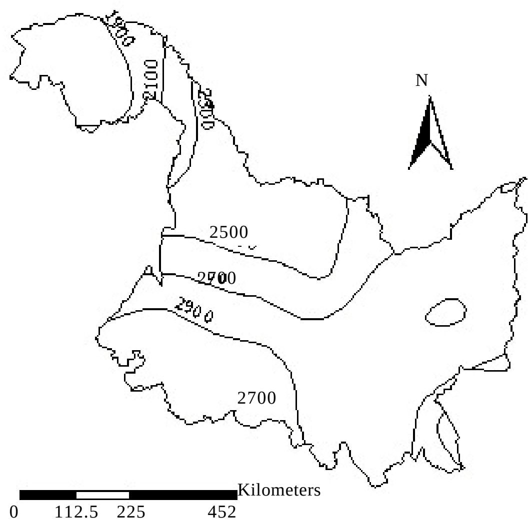

Fig. 3: Distribution of annual accumulated temperature = 10°C in heilongjiang province. (The first method)

the >2900°C zone is greater than the area in Fig. 4 for 1981-2010, there are big difference just because the difference of two criterions. It is apparent that the area of higher accumulated temperature zones moved northward and upward within Heilongjiang Province from 1951-2010 (Fig. 4). The first accumulated temperature zone moved northwards by an average longitudinal distance of about 1 degree, while the fourth accumulated temperature zone expanded eastwards with a latitudinal distance of 2 degrees.

Figure 4a and 4b show the changes in the accumulated temperature distribution over the past 60 years. It is clear that the internal structure of the accumulated temperature changed considerably in most areas. The area with an accumulated temperature = 2700°C expanded substantially, experiencing the largest increase of any zone. In the 1951-1980 period, the area with an accumulated temperature = 2700°C comprised only 30,761 ha, but the area had grown to 202,039.96 ha by the 1981-2010 period, i.e., an increase of 171,279.33 ha. The

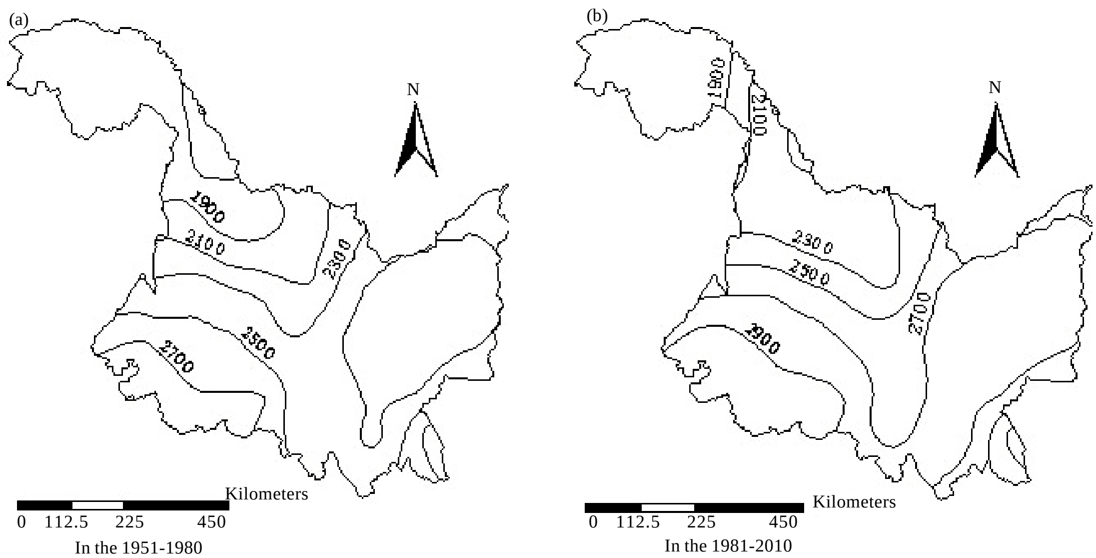

Fig. 4: The Distribution of the annual accumulated temperature during the maize growing season in heilongjiang province. (The second method)

Table 2: The changes in areas by accumulated temperature zone based on the two criteria

Accumulated temperature zone	1981-2000 (ha) (Fig3)	1981-2000 (ha) (Fig4B)	Variable (ha)
≤1900 °C	3,854,500	5,263,345	1,408,845
1900°C -2100°C	1,407,200	896,660	-510,540
2100°C -2300°C	1,153,500	6,451,537	5,298,037
2300°C -2500°C	7,381,300	4,390,323	-2,999,977
2500°C -2700°C	5,871,600	7,764,222	1,892,622
≥2700°C	25,301,900	20,203,996	-5, 097,904

area of the 2100-2300°C zone increased to some degree, while the areas of the 1900-2100°C, 2300-2500°C and 2500-2700°C zones all decreased to varying degrees.

Comparison of the two methods: Figure 3 uses the first method to define the growing season and Fig. 4 uses the second method to define the growing season.The different criteria used resulted in different data. The duration of the growing season affects the distribution and area of the accumulated temperature. Table 2 shows the difference between the two methods in 1981-2000 for two criteria. The largest difference in area of accumulated temperature was 5, 298,037 ha in the 2100-2300°C zone and the smallest difference was 510,540 ha in the 1900-2100°C zone.

Because of the change in accumulated temperatures, the six zones from 1700-2900°C, established in Heilongjiang in the 1980s, no longer meet current demands. It is no longer an accurate distribution of the accumulated temperature. As a result, an accumulated temperature belt (=2900°C) needs to be added.

DISCUSSION AND CONCLUSION

Global average temperatures are expected to increase by 0.74°C in the next century (IPCC, 2007), while the annual average temperature in the 2000s was 0.77°C higher than in the 1980s in Heilongjiang Province. And the annual average accumulated temperature in the 2000s was 189°C higher than in the 1980s.

Global warming has altered the distribution of maize growing belts. The area with a temperature accumulation =2700°C has experienced the largest increase, based on duration of the maize growing season. The other accumulated temperature zones all experienced substantial changes.

The onset and LGP was found to be less relevant to maize suitability zoning because the heat accumulated over the LGP does not match maize production in the first method. Therefore, we selected the period from the first day =10°C in a consecutive 5-day period to the first frost as the onset and length of the maize growing period. Using these criteria, we have been able to produce a more accurate maize regional planning map based on relatively accurate accumulated temperature data.

There were some differences between this study and previous studies of the planting divisions of maize. We focused on the role of accumulated temperature. Only by accurately defining the onset and LGP of maize can we determine the heat requirements associated with maize growing. A map based on this definition of the maize growing season would be more scientific. However, there are many factors influencing regional agricultural planning that may not be captured by these criteria and the method will need to be refined by further study.

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REFERENCES

AAHFD, 1992. Farming system and division in Heilongjiang Province. Agriculture and Animal Husbandry Fishery Department, Heilongjiang Province, China. (In Chinese).

Giorgi, F. and X. Bi, 2005. Updated regional precipitation and temperature changes for the 21st century from ensemples of recent AOGCM simulations. Geophys. Res. Sett., Vol. 32. 10.1029/2005GL024288

Gordon, R. and A. Bootsma, 1993. Analyses of growing degree-days for agriculture in Atlantic Canada. Climate Res., 3: 169-176.

Guo, R., Z. Lin, X. Mo and C. Yang, 2010. Responses of crop yield and water use efficiency to climate change in the North China plain. Agric. Water Manage., 97: 1185-1194.

IPCC, 2007. Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK, New York.

Kullman, L., 1998. Tree-limits and montane forests in the Swedish scandes: Sensitive biomonitors of climate change and variability. Ambio, 27: 312-321.

Pearson, R.G. and T.P. Dawson, 2003. Predicting the impacts of climate change on the distribution of species: Are bioclimate envelope models useful? Global Ecol. Biogeogr., 12: 361-371.

Pitelka, L.F., 1997. Plant migration and climate change: A more realistic portrait of plant migration is essential to predicting biological responses to global warming in a world drastically altered by human activity. Am. Scientist, 85: 464-473.

Sun, F.H., S.Y. Yang and P.S. Chen, 2005. Climatic arming-drying trend in Northeastern China during the last 44 years and its effects. Chinese J. Appl. Ecol., 24: 751-755.

Yan, M., X. Liu, W. Zhang, X. Li and S. Liu, 2011. Spatio-temporal changes of = 10? accumulated temperature in Northeastern China since 1961. Chinese Geogr., 21: 17-26.