Plant Knowledge Journal
ISSN: 2200-5390
EISSN: 2200-5404
1(2): 33-36 (2012)

Southern Cross Publishing Group
AUSTRALIA

Hydrothermal change in winter wheat-producing area in Northern Anhui of China and its impact on winter wheat production

Yang Shuyun*, Wang Jun, Dong Zhaorong, Chen Qin, Jiang Bo

Anhui Agricultural University, Hefei, 230036, China

***Corresponding author: yangshy@ahau.edu.cn**

Abstract

Generally speaking, in the context of global climate change, the water shortage in northern Anhui winter wheat-producing area will become increasingly serious. The current winter wheat high-yield heavily depended on groundwater irrigation which is not sustainable. Therefore, water interception and storage of the flood season precipitation should be considered from strategic perspectives to solve the water supply problem for winter wheat irrigation. In this article we evaluated the temperature, evaporation, precipitation and other data in various historical periods from major weather stations of main winter wheat –producing area in northern Anhui to study the variation trends of precipitation, evaporation and dryness in winter wheat growing season. We also analyzed their impact on winter wheat production. Our results showed that the northern Anhui area is sensitive to the global weather change and the temperature variation in synchronization with the general trend of global warming. The temperature has raised about 1.8 ℃ since the 1950s of last century, which is higher than the global average increase. In accordance to the temperature rise, evaporation was increased 3 to 5%, with a maximum in February and May. There was no significant change in precipitation in the area, but the non-uniformity of precipitation was enhanced and the proportion of short-term heavy rains tended to increase in the annual precipitation. 24 h maximum rainfall usually accounted for 10 to 30% and the process (storm) precipitation for more than 50% of annual precipitation, with hourly rainfall reaching up to 80 mm or over. The rainfalls per unit time during heavy precipitation are far more than most soil absorption rates. Most precipitations are lost in the form of runoffs and can not effectively replenish soil water and large runoff formations result in a large number of local floods. In total, the uneven rainfall and increased evaporation led to water shortage in this agricultural area which was detrimental to winter wheat production.

Keywords: Winter wheat, rainfall, evaporation, climatic change.

Introduction

The areas along the Huaihe River and to the north of the river in Anhui Province (hereinafter referred as northern Anhui, (Fig. 1) are situated at the south of Huanghuaihai plain and include over 20 municipalities and counties (districts). The northern Anhui has advantageous natural conditions with annual average temperature at 14.3-15.2 ℃, annual sunshine hours of 2088-2315 and a frostless period over 200 days. The lands are flat and fully cultivated by crops and agricultural plants. The cultivated area is 2 × 106 h m^2, about a half of Anhui Province. It is one of the major grain, cotton and oil bearing crops production bases in China. But the precipitation here is uneven and drought happens from time to time, which affect a serious negative influence on grain production (Tang and Cao, 2010). Therefore, study of variation trends of flood and drought in northern Anhui plain is important to ensure a stable and high agricultural yield (Li and Wu, 2009; Hong, 1999). This article aimed to study the variation trends of flood and drought in winter wheat-producing area of northern Anhui at winter wheat-producing season and their influences on the winter wheat production.

Results and discussion

Drought and flood trend analysis related to precipitation change in wheat season

A diagram of annual precipitation change in wheat seasons in northern Anhui was created with the data of wheat seasons (October to May) of Bozhou and Bengbu from 1951 to 2010 (Fig. 2). The diagram shows the average precipitation in wheat season in Northern Anhui is 276.3 mm, about 30.7% of the year. It fluctuated greatly, with the maximum and minimum of 437.8 mm (in 1964) and 174.1 mm (in 1986), respectively. The range of precipitation is 263.7 mm with the standard deviation of 62.9. The total precipitation in the wheat season has a weak declining trend in recent 60 years, but the changing rate is only 0.007 mm/10a, which shows the total precipitation in wheat season, is relatively stable.

Changes of precipitation uniformity

The precipitation in wheat seasons is highly concentrated (Fig. 3), with maximum single day precipitation of each month reaching over 40% of the total monthly precipitation, resulting in short time land logging. The drainage causes water, soil and fertilizer loss and low usage of rain water. The rainwater loss results in drought due to insufficient water supply. The maximum single day precipitation of each month fluctuates greatly, especially in April and May. Thus it can be seen that the unstable precipitation in late wheat season may cause adverse effect on wheat yield.

Temperature change

The temperature of the wheat seasons in northern Anhui is rising significantly (Fig. 4), especially in recent 30 years. The average temperature increase of the wheat seasons is about 0.31 ℃ /10a in the past 60 years. From 1950s to 1980s, the average temperature in wheat seasons was fluctuated around 9 ℃, while it was above 10 ℃ in past 10 years. The temperature has been increased about 1.8 ℃ in 60 years. But the temperature increase is different in each month of the season (Fig. 5), with the lowest rate of 0.214 ℃ /10a in November and the highest of 0.496 ℃ /10a in February. The average temperature of coldest month (January) is well above 0 ℃ and the 0 ℃ line has moved to the north of Anhui Province. According to the relation of evaporation and temperature (Dawson et al., 2000), the rise of temperature will directly result in evaporation and strengthen the transpiration of the plants, increasing the probability and intensity of drought (Kazeli et al., 2003; Itoh et al., 2007; Hou and Li, 1997; Devi et al., 2007; Ferraro et al., 2005;)(Al-Dossari, 2012). On the other hand, the temperature rise in wheat season makes the winter wheat unable to meet the vernalization requirement. As a result, the winter wheat area is reduced greatly and semi-winter wheat and spring wheat become gradually dominant in northern Anhui.

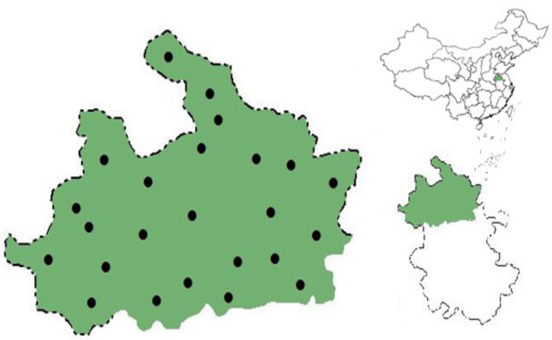

Fig 1. The map of Northern Anhui of China area under study.

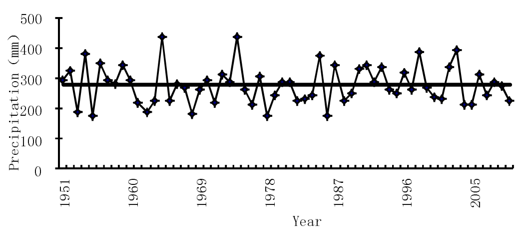

Fig 2. Yearly changes of total precipitation in wheat season in northern Anhui.

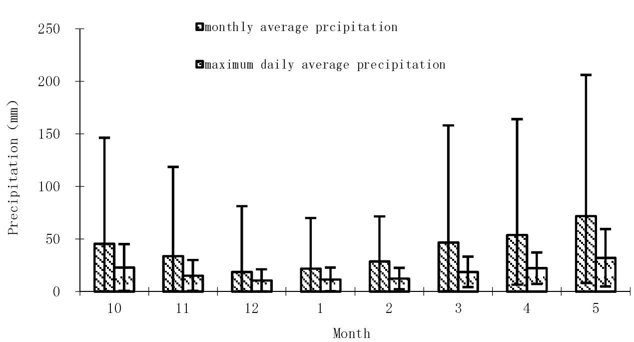

Fig 3. Monthly precipitation differences of wheat season in Northern Anhui.

Actual evaporation changes of land surface

We used Koichiro Takahashi's actual land surface evaporation empirical formula to estimate average monthly actual land surface evaporation with monthly average precipitation and temperature (Takahashi, 1979):

$$E = \frac{3100P}{3100 + 1.8P^2 \exp\left(-\frac{34.4t}{235 + t}\right)}$$

Where, E is monthly actual land surface evaporation, P: monthly precipitation (mm), t (ºC).

According to the estimation (Fig. 6), actual land surface evaporation in wheat season increased about 1.1% and 3.5% if October is not considered. There is a large difference among actual land surface evaporation of each month. The actual land surface evaporations of October, January, March and April tend to decrease, with large drop in October. The actual land surface evaporations of December, February and May tend to increase, with large increases in February and May of 30.8% and 9.3%, respectively. This explains why frequent droughts have happened in northern Anhui during the spring of recent years. As October is sowing season of winter wheat in northern Anhui, evaporation reduction can raise the moisture content of the land, which is favourable to the sowing. In fact, the winter wheat sowing has been successful in recent years and it is in conformity with the actual land surface evaporation reduction in October. As February is the critical period for winter wheat revival in northern Anhui and May is the critical stage for the production output, evaporation increase has a great adverse impact on the wheat growth (Zhang et al., 2008).

Influence of hydrothermal changes of wheat season on winter wheat production in northern Anhui

Winter wheat yield analysis

9-year linear sliding mean simulation method is used to divide the average per unit yield of winter wheat in northern Anhui into trend yield and climate yield, in which $y = y_t + y_w + \Delta y$, Where, y: average per unit yield; y_t: trend yield; y_w: climate yield; Δy: random component (not considered normally). The unit is t/hm^2. The result is shown in (Fig. 7). Generally speaking, the unit yield before 1970s was increasing slowly and it has been increased rapidly after 1980s, thanks to the combined influence of management and agricultural technology progress.

Climate yield changes

The proportion of climate yield was about ±10% per unit yield in the 38 years out of the 61 years, from 1949 to 2009. Other 21 years was within ±5%. The climate yield was positive (climate conditions increased production) in 32 year. It shows that the natural conditions for winter wheat production in northern Anhui are stable. The average climate yield was about 8.48% per unit yield between 1949 and 2009. The climate environment has a significant role in the winter wheat yield and a major factor in bumper harvest or crop failure. Improvement of ability to cope with climate disasters is a basic condition for stable and high winter wheat yield (Valdez-Cepeda et al., 2003; 2007; Gale et al., *2005*). From Fig. 8, it is clear that, although the output of years were more than decrease due to climate factors since 1949, the proportion of climate yield to the yield per unit in the yield

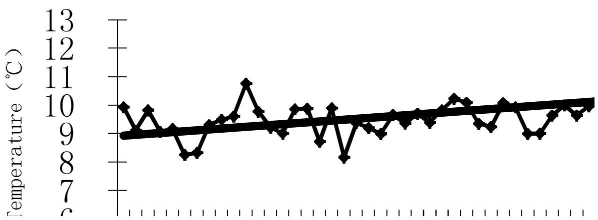

Fig 4. Yearly changes of average temperatures of wheat seasons in northern Anhui.

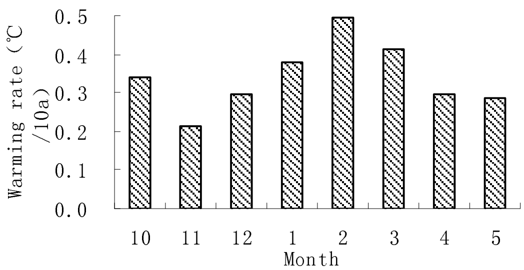

Fig 5. Monthly temperature increase rate (℃/10a) in wheat season.

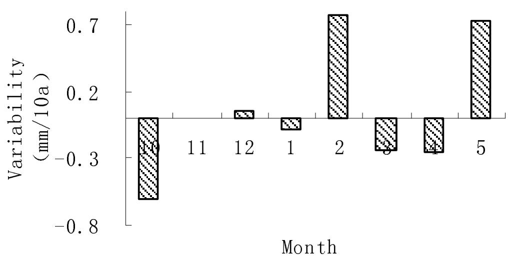

Fig 6. Monthly actual land surface evaporation change rates in wheat season.

decrease years is generally higher. It means that the yield increasing efficiency of good climate is far less than the yield decreasing efficiency at disastrous climate. No matter whether the yield has reduced or increased, the proportion of climate yield to the yield per unit shows a falling trend. Comparing with yield change trend, we know that is the result of human intervention (Carroll et al., 2010; Boxian and Lye, 1994). It means human intervention capability and roles are being enhanced (Fig. 8) in case of disasters and that is also proved by weak correlation of the climate factors and climate yield of each month in wheat season (Riyaz and Park, 2010; Porporato and Ridolfir, 1996; Pruszakp, 2002). The climate yields are mainly negative values when there is plenty of rainfall in the wheat season, whereas the high rainfall volume in May have the most adverse effect. The climate yields are mostly positive when the rainfall is normal or less. It indicates the adverse effect of water-logging on the climate yield exceeds far more than drought. The influenece of human intervention to flood and logging is not as effective as human intervention to drought (Boxian and Lye, 1994). The analysis of climate yield, monthly precipitation, land surface evaporation and monthly average temperature in each month of wheat season with SPSS showed that the climate yield is negatively correlated ($p \leq 0.05$) with the monthly precipitation and land surface evaporation especially in May. It also has shown a positive correlation with the average temperature in May and has no significant correlation

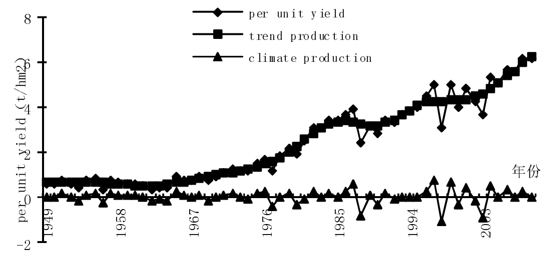

Fig 7. Per unit yield changes of winter wheat in northern Anhui.

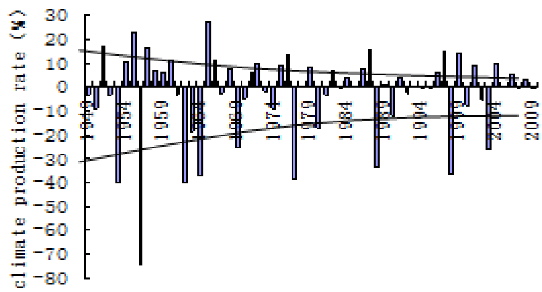

Fig 8. Change of relations of climate yield and per unit yield.

with other months. This also proves that the adverse effect of climate factors on winter wheat production is lowering year by year and the output tends to become stable with the improvement of human intervention (Carroll et al., 2010; Lewis et al., 2011). Using the climate yield model built with stepwise regression method, only the relation of precipitation in May (J_5) and the climate yield passed the t-test and the formula of the model is: y_w=-0.002 J_5+0.153.

Conclusion

In recent 60 years, the average temperature increase rate in the wheat season of northern Anhui was about 0.31 ºC/10a. It exceeds the average temperature increase rate in the year and the average values of Anhui province and whole world. The temperature increase rates in January, February and March are relatively higher and warming in winter is the main reason. The temperatures of wheat season will remain rising in the future and the winter wheat will continuously face inadequate cold temperatures for vernalization, shortened growth period etc. It is necessary to take the initiative to adjust varieties and sowing dates constantly to adapt to the situation. The northern Anhui is in water shortage during the whole growth period of wheat. Water shortage is a major factor in restricting stable yield. Temperature rise increases the land surface evaporation, about 30.8% and 9.3%, respectively in February and May, while precipitation is basically stable. The water shortage is most serious in May, a critical month for the wheat yield formation. With stable rising of temperature, the water shortage will be more serious.

The major disaster for climate yield reduction is water-logging and the short-term heavy rainfall during wheat harvest, especially in May which results in serious climate yield reduction. Good harvests are usually achieved when rainfalls are normal or less than usual, which shows that people have a better capability to intervene drought than water-logging. The average climate yield was about 8.48% of the yield per unit from 1949 to 2009 and the proportion of the yield per unit had a tendency to decrease. But as the per unit yield level is constantly increasing, the absolute value of the climate yield becomes larger and tends to increase, where as the increase rate of yield reduction is about 56kg/hm^2.10a. Therefore, dealing with the climate change and reducing climate yield loss are the important guarantee for high and stable wheat yield.

Materials and methods

Meteorological data

The study is targeted at the variation trends of flood and drought and water supply with monthly temperature, precipitation and evaporation data of over 20 cities and counties including Shuzhou, Bozhou, Fuyang, Bengbu, Huainan and Huaibei etc. in northern Anhui in winter wheat season. The data are from Anhui Provincial Meteorological Bureau. The monthly temperature, precipitation and evaporation data in wheat season of various municipalities and counties of the northern Anhui were analyzed by SPSS to estimate correlations (Wang and Tang, 2011; Xie et al, 2004) (Lixin et a.l, 2006). The results show they have positive correlation at 0.001 levels and prove that the hydro-heat and evaporation are basically same and can be used for analysis as representative unit information (He,2009). The article uses the data from Bozhou and Bengbu as representatives of the north and south.

Production yield data

The information obtained from the statistical data of Anhui agriculture. 9-year linear sliding mean simulation method was used for trend yield and climate yield analysis.

Acknowledgments

The authors acknowledge financial support from National Key Technology R&D Program (2009BADA6B06, 2008BAD96B12).

References

Al-Dosari MS (2010) The effectiveness of ethanolic extract of *Amaranthus tricolor* L. A natural hepatoprotective agent. Am J Chin Med. 38(6):1051-1064.

Boxian W, Lye LM (1994) Identification of temporal scaling behaviour of flood: a study of fractals. Fractals, 2(2):283-286.

Carroll B, Balogh R, Morbey H, Araoz G (2010) Health and social impacts of a flood disaster: responding to needs and implications for practice . J Disasters. 34(4):1045-1063.

Dawson CW, Browm MR, Wilby RL (2000) Inductive learning approaches to rainfall runoff modelling. Int J Neural Syst. 10(1):43-57.

Devi KN, Sarma HN, Kumar S (2007) Particle induced X ray emission studies of some Indian medicinal plants. Int J PIXE. 17(3/4):169-176.

David-Valdez R, Delgadillo-Ruiz O, Magallanes-Quintanar R, et al. (2007) Scale invariance of normalized yearly mean grain yield anomaly series. Adv Complex Syst. 10(3)395-412.

Ferraro P, Godin C, Prusnkiewicz P (2005) Toward a quantification of self similarity in palnts. J Fractals. 13(2):91-109.

Gale K, Jiang H, Westcott M (2005) An optimzation method for the identification of minimal sets of discriminating gene markers: application to cultivar identification in wheat. J Bioinform Comput Biol. 3(2):269-279.

He D (2009) Use SSAS 2005 estimate qingyuan stand and evaporation. J Guangdong Meteorology. (06).

Hong WXT (1999) Quantitative research on effects of climatic change on agriculture in Anhui. J Anhui Agric Univ. 26(4):493-498.

Hou TZ, Li MD (1997) Experimental evidence of a plant meridian system: IV. The effects of acupuncture on growth and metabolism of *Phaseolus vulgaris* L. beans. Am J Chin Med. 25(2):135-142.

Itoh J, Saitoh Y, Futatsugawa S, Ishii K, Sera K (2007) Elemental analysis of edible plants in natural environment: Trace Elements in Wild Plants. Int J PIXE. 17(3/4):119-127.

Kazeli H, Keravnou E, Christofides TC (2003) An intelligent hybrid decision support system for the management of water tesources. Intl J Pattern Recogn Artificial Intellige. 17(5):837-862.

Lewis Matt, Horsburgh K, Bates P, Smith R (2011) Quantifying the uncertainty in future coastal flood risk estimates for the U.K. J Coastal Research. 27(5): 870-881.

Li B, Wu H (2009) The characteristics of agricultural drought disaster and its impact on food security in Anhui Province. J Agr Res Arid Areas. 27(5):18-23.

Lixin Y, Xiurong D, Wei H et al. (2006) With SPSS establish zigong rice yield prediction model year. J Sichuan Meteorology, 2006, (01).

Porporato A, Ridolfir L (1996) Cluse to the existence of deterministic chaos in river flow. Int J Modern Physics B. 10(15): 1821 - 1862.

Pruszakp Z, Szmytkiewicz M, Hung NM, Ninh PV (2002) Coastal processes in the red river delta area, Vietnam. Coastal Engineering J. 44(2):97-126.

Riyaz M, Park KH (2010) "Safer island concept" Developed after the 2004 indian ocean tsunami: a case study of maldives. J Earthquake and Tsunami. 4(2):135-143.

Tang G, Cao C (2010) Agricultural drought and its effect food production in Anhui province. J Irrig Drain. 29(6):47-50.

Takahashi K (1979) The estimation of evaporation formula from monthly mean temperature and monthly precipitation. J weather (Japan). 26(12):29-32.

Valdez-Cepeda RD, Mendoza B, Díaz-Sandoval R, Valdés-Galicia J, López-Martínez JD, Martínez-Rubín de Celis E (2003) Power-spectrum behavior of yearly mean grain yields. Fractals. 11(3)295-301.

Wang G, Tang D (2011) Analysis of runoff variation of Zhengyixia section in Heihe river based on SPSS Model. J Water Resources and Power.(09) .

Xie A, Wang S, Wei H et al. (2004) Climatic division with SPSS in Shanxi province. J Shanxi Teachers University (Natural Science Edition). (3).

Yang Zongqu; Yin Jun; Zhou Ran et al. Effects of accumulated temperature before wintering and vernalization treatments on spike differentiation of wheat cultivars with different vernalization development characteristics. J. Nuclear Agricultural Sciences，2008，22(4):503-509.

Zhang Z, Ma Q, Li S (2008) Sensitivity analysis of rainfall in the growth stages on yield of winter wheat. J Anhui Agric Sci. 36(28):2134-2135.