Analysis of precipitation during maize growth period in Huaibei Plain, China

Weiwei Sun[1], Zhiwei Wang[1], Brian Collins[3] and Youhomg Song[1,2]

[1]Anhui Agricultural University, School of Agronomy, 130 Changjiang West Road, Hefei, 230036, Anhui, China, Email: y.song@ahau.edu.cn.

[2]The University of Queensland, Queensland Alliance for Agriculture and Food Innovation, Centre for Crop Science, St Lucia, Brisbane, 4072, QLD, Australia.

[3]James Cook University, College of Science and Engineering, Townsville, QLD 4811, Australia, Email: brian.collins@jcu.edu.au.

Abstract

The uneven spatiotemporal distribution of precipitation may pose a great threat to summer maize production in Huaibei Plain, China. Based on the daily dataset from June 1st to October 15th from 1955 to 2017 collected from 6 representative stations, we analyzed the spatiotemporal variation of precipitation during growth period of summer maize. The average precipitation at seedling stage was the greatest, and the probability of heavy rain reached the maximum in the 2nd two weeks of seedling stage (Phase iii), accounting for 9.35%. The average precipitation in two weeks after anthesis (Phase v) was less than that in two weeks before anthesis (Phase iv). The fitting analyses showed that there was a negative correlation between grain yield and precipitation from 1998 to 2017. This study can provide useful quantitative information for disaster management in summer maize production in Huaibei Plain.

Keywords

Zea mays, precipitation, waterlogging, drought, grain yield, Huaibei Plain

Introduction

Precipitation is a key hydrological variable that can directly affect floods, droughts, water resources, etc. (Costa et al. 2012). Therefore, information on temporal and spatial changes in precipitation characteristics is critical for predicting possible changes in recent hydrological systems (Chen et al. 2014). Knowing in advance the possible start and end times of rainfall can effectively reduce maize production risk due to sowing and harvesting too early or too late (Hachigonta et al. 2008). Since the 1990s, there has been a significant interdecadal variation of precipitation in China. Global warming and the re-enhanced of East Asian monsoon will inevitably influnce the distribution and variation tendency of precipitation (Wang et al., 2015), hence the characteristics of precipitation during the crop growth period shows complexity and diversity, with different trends in different regions and years (Lobell and Burke, 2010).

Due to the lack of irrigation water resources, maize production still relies on conventional rainfed system in the Huaibei Plain, China. Crop performance under the rainfed systems generally depends on rainfall and distribution (Yamoah et al. 2000), thus studying the rainfall distribution characteristics in the Huaibei Plain will be beneficial for optimal crop water management and ensuringhigh productivity. However, most of the researches at home and abroad focus on the temporal and spatial distribution of rainfall in potentially risky areas or representative areas (Pavan et al. 2019; Tong et al., 2019). There are few studies on the short-term precipitation changes in the growth cycle of crops, especially maize. Thus, in this study, the spatial and temporal distribution of precipitation in maize growth period was discussed in detail.

Methods

The precipitation data during the summer maize growing season (June 1st -Oct 15th) between 1955 and 2017 were collected from six meteorological stations in northern Anhui. The maize yield data at each station is obtained through the public database query of Anhui Provincial Bureau of Statistics. In this study, the precipitation is divided into five categories (Figure 2): light rain (less than 10mm), moderate rain (10-25mm), heavy rain (25-50mm), rainstorm (50-100mm), and large rainstorm (more than 100mm). In addition, the whole growth period of maize is divided into six stages, Phase i: one week before and after sowing (6.3-6.16), Phase ii: the 1st two weeks of seedling stage (6.17-6.30), Phase iii: the 2nd two weeks of seedling stage (7.1-7.14), Phase iv: two weeks before anthesis (7.26-8.8), Phase v: two weeks after anthesis (8.9-8.22), and Phase vi: one week before and after harvest (9.23-10.6).

Results

Average annual precipitation during the summer maize growth period

As can be seen from Fig.1, the mean precipitation distribution of the six stations during the summer maize growth period in 63 years was around 500-600 mm, among which Bengbu Station was the highest, reaching 603.75mm. (Figure 1). The range value of precipitation between different years is more than 790mm, even up to 960mm, the degree of deviation from the mean value in different years was great. There is a great difference in precipitation between different years, and the probability of the occurrence of rainy years and drought years in 63 years is more than 25% (Table 1). Therefore, it is necessary to consider the occurrence of extreme precipitation and its influence on the growth and development of maize.

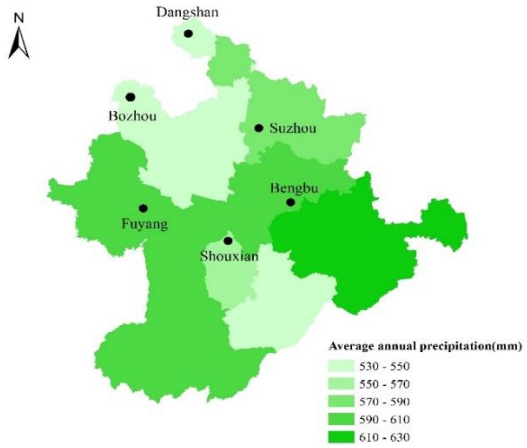

Figure 1. Average annual precipitation during the growth period of summer maize at 6 stations from 1955-2017.

Table 1. Comparison of the characteristics about rainy years and drought years at different stations from 1955-2017. Rainy years mean A minus B>+C, drought years mean A minus B<-C (A means precipitation in any given year, B means the average precipitation over 63 years, C means standard deviation of precipitation in 63 years).

Stations	Bengbu	Bozhou	Dangshan	Fuyang	Shouxian	Suzhou
Rainy Years	9	7	11	10	10	10
Drought Years	12	11	9	8	10	9
Range value/mm	909.4	796.3	797.5	960.1	844.7	851.6

Analysis of average daily precipitation in different periods during summer maize growth season

Although there are some differences in the average precipitation in different growth stages of maize at different stations, there is a consistent trend in general. In other words, it first increased and then decreased, and reached the maximum value of more than 87mm in Phase iii. In addition, the precipitation is mainly distributed in the seedling (Phase ii, Phase iii) and flowering (Phase iv, Phase v) stage, the average precipitation in Phase v was less than that in Phase iv, and that was the least in Phase vi. The difference between the maximum and minimum

precipitation at different growth periods of the six stations were all greater than 60mm (Figure 2).

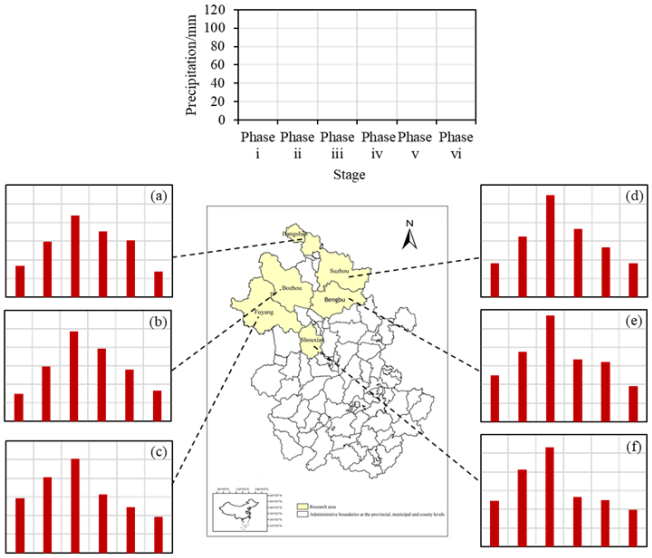

Figure 2. Average precipitation in different summer maize growth periods at 6 stations i.e. Dangshan (a), Bozhou (b), Fuyang (c), Suzhou (d), Bengbu (e) and Shouxian (f) in Huaibei Plain from 1955-2017.

The occurrence probability of different precipitation levels during maize season

The probability trend of different precipitation levels in the growth stage of maize at the six stations is basically the same, and the probability of no precipitation accounts for the largest proportion in each stage. However, the probability of no precipitation in Phase iii is the smallest, and the probability of precipitation increases dramatically. The probability of no precipitation in different periods followed the law of decreasing first and then increasing, and the average minimum was 56.67 %. On the contrary, the occurrence probability of heavy rain or more increased first and then decreased in the growth stage, and also reached the highest in Phase iii, accounting for 9.35%. (Figure 3).

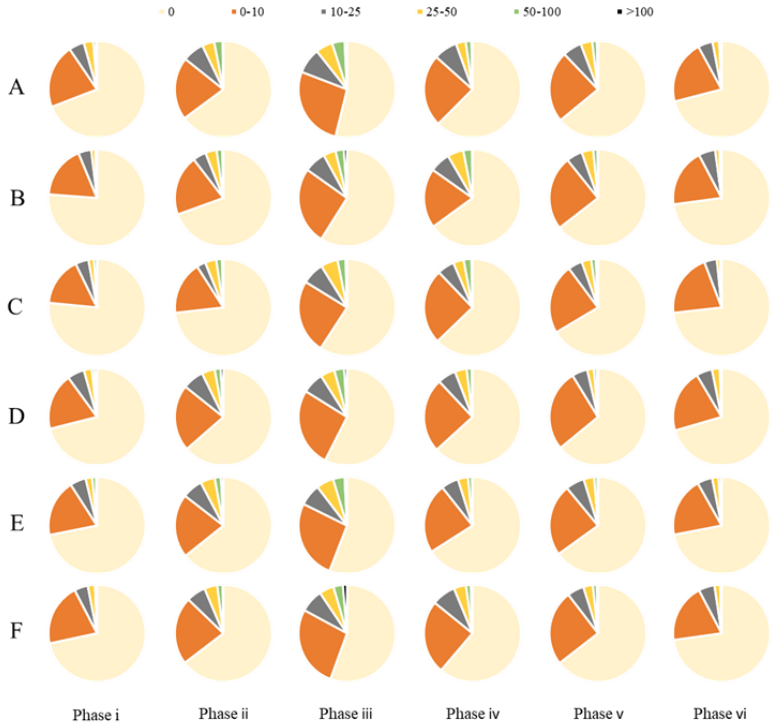

Figure 3. Occurrence probability of different precipitation levels in summer maize growing season at 6 stations i.e. Bengbu (A), Bozhou (B), Dangshan (C), Fuyang (D), Shouxian (E) and Suzhou (F).

Fitting relationship between yield and precipitation from 1998 to 2017

It can be seen by analyzing the fitting relationship between yield and precipitation, Bozhou station has the highest fitting degree, and the decreasing trend is the most obvious. The fitting degree of Suzhou station is the lowest, the decreasing trend is also the most moderate. Besides, in the case of low or moderate rainfall, the yield showed a centralized trend without obvious increase or decrease, and the yield level dropped sharply when the rainfall was excessive, which was also an important reason for the downward trend of the fitting curve (Figure 4).

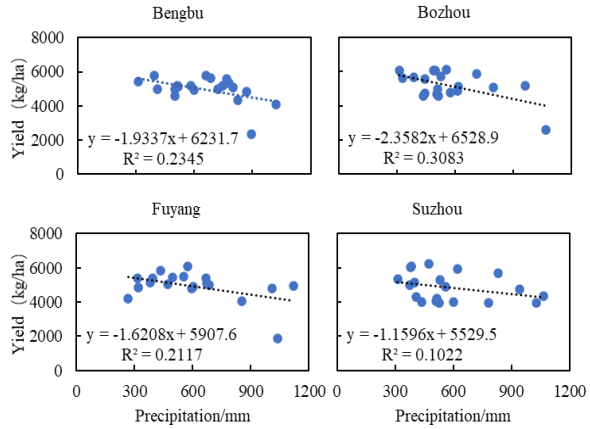

Figure 4. The fitting relationship between precipitation and yield at four stations from 1998 to 2017.

Conclusions

The total amount of precipitation in Huaibei Plain appear to meet the water requirement for maize growth period, but the distribution of precipitation is uneven and may pose risk for maize cropping. The lack of precipitation during the sowing period affected the emergence of seedlings, and the excessive rainfall at seedling stage easily causes waterlogging, while lower precipitation in reproductive phase, compromising the fertilization process. Overall, the analysis will be valuable in advising maize cropping in Huaibei Plain, Anhui Province.

Reference

Costa AC, et al. (2012). Climate change scenarios for precipitation extremes in Portugal. Theoretical and Applied Climatology 108, 217–234. (doi:10.1007/s00704-011-0528-3).

Chen J, et al. (2014). Variability and trend in the hydrology of the Yangtze River, China: annual precipitation and runoff. Journal of Hydrology 513, 403–412. (doi:10.1016/j. jhydrol.2014. 03.044).

Hachigonta S, et al. (2008). An analysis of onset date and rainy season duration over Zambia. Theoretical and Applied Climatology 91, 229–243. (doi:10.1007/s00704-007-0306-4)

Lobell DB and Burke MB. (2010). On the use of statistical models to predict crop yield responses to climate change. Agricultural and Forest Meteorology 150(11), 1443-1452. (doi:10.1016/j.agrformet.2010.07.008)

Pavan V, et al. (2019). High resolution climate precipitation analysis for north-central Italy, 1961–2015. Climate Dynamics 52(5), 3435-3453. (doi:10.1007/s00382-018-4337-6).

Tong S, et al. (2019). Spatial and temporal variability in extreme temperature and precipitation events in Inner Mongolia (China) during 1960–2017. Science of The Total Environment 649, 75–89. (doi:10.1016/j. scitotenv.2018.08.262)

Wang Y, et al. (2015). Spatial and temporal variations of annual precipitation during 1960–2010 in China, Quaternary International 380–381, 5-13. (doi:10.1016/j.quaint.2014.12.047.)

Yamoah CF, et al. (2000). Standardized precipitation index and nitrogen rate effects on crop yields and risk distribution in maize. Agriculture, Ecosystems & Environment 80(1-2), 113-120. (doi:10.1016/S0167-8809(00)00140-7).