Drought and Waterlogging Characteristics during the Growth Period of Summer Maize in Luxi Plain Areas

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Abstract In summer maize growth period, the water supply and demand ratio is regarded as the evaluation index of drought and waterlogging for the summer maize in Liaocheng City. Using GIS, statistics, agrometeorology and other methods, we analyze the precipitation during the summer maize growth period in Luxi Plains from 1961 to 2011. Through the calculation of drought and waterlogging index, it indicates that the disasters of drought and waterlogging frequently occur during the summer maize growth period, mainly affected by the drought; the frequency of occurrence of drought accounts for 80.4%, that is, it is very prone to serious drought phenomenon, seriously affecting the normal growth and development of summer maize during the seedling period. With global warming, the industrial and domestic water demand is increasing year by year, so it is extremely difficult to increase the water diversion to solve the problem of water shortage for the growth of summer maize. Finally we put forth the following recommendations: (i) Selecting drought-resistant varieties, and improving the water resource use efficiency; (ii) Promoting the water and fertilizer coupling, sprinkler irrigation, drip irrigation, micro-irrigation and other water-saving irrigation technologies, and improving the water use efficiency; (iii) Promoting the ditch, ridge and laminating cultivation technology, reducing the field evapotranspiration, keeping warming and conserving moisture, and saving water resources; (iv) Strengthening the construction of water conservancy facilities, so that it can be irrigated during drought and drained during waterlogging; (v) During dry season, timely organizing artificial rainfall operation, and increasing precipitation in arid areas to ease drought; (vi) Rationally exploiting the groundwater, and improving the underground water use efficiency.

Key words Summer maize, Drought and waterlogged, Characteristics, Liaocheng City

Liaocheng, also known as the Water City, is a prefecture-level city in western Shandong province, People's Republic of China. It borders the provincial capital of Jinan to the southeast, Dezhou to the northeast, Tai'an to the south, and the provinces of Hebei and Henan to the west. The prefecture-level city of Liaocheng administers eight county-level divisions, including one district, one county-level city, and six counties. Liaocheng is located in the west of Shandong with Mount Tai as its close neighbor. The area of arable land is 577.5 hm^2, and the main planting pattern is winter wheat-summer maize cropping. In recent years, with the rise of the market demand for corn, the planting area of summer maize has showed an increasing trend, and the perennial planting area of summer maize has reached 367.5 hm^2, with the yield per unit of about 7 000 kg/hm^2. Liaocheng City features a semi - arid continental climate, with the annual precipitation of only 566.7 mm, and the precipitation during June to August accounting for 62.9% of total annual precipitation[1-2]. Under high yield conditions, the soil moisture remains at about 80% of field moisture capacity during the growth period of summer maize, and the amount of water needed during the growth period is 417.30 - 507.45 mm[3]. Conspicuously, the precipitation does not meet the high yield requirements. The precipitation is highly concentrated, and the formation of waterlogging disaster is inevitable, so drought or waterlogging has become one of the main meteorological disasters limiting the high yield and quality of summer maize in Liaocheng City. According to statistics, the average annual summer maize drought-hit area accounts for 50% of the total area, and the waterlogging disaster area accounts for 18% of the total area[4].

Therefore, based on the observed data of Liaocheng agro-meteorological observatory, we analyze the drought and waterlogging characteristics during the growth period of summer maize over 50 years in Liaocheng City, in order to provide a reference for scientific disaster prevention and mitigation, reducing the impact of drought and waterlogging on summer maize production, and ensure high yield and quality.

1 Materials and methods

1.1 Data sources and processing (i) The growth period data of summer maize are from the agricultural meteorological observation reports of Shandong Liaocheng national agricultural meteorological observation station. (ii) The meteorological data are from the atmospheric observation report of Liaocheng national standard meteorological observation field. (iii) In accordance with the provisions of Agro-meteorological Observing Practices of China Meteorological Administration, the growth period of maize is divided into ten stages: sowing, seedling emergence, three-leaf stage, seven-leaf stage, elongation, tasseling, flowering, silking, milky ripe stage and maturity. According to the characteristics of needs for water during the different growth stages of summer maize, the growth and development period of summer maize is divided into four main phases: seedling stage (sowing-seedling emergence), elongation stage (three-leaf stage-elongation), flowering stage

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(tasseling – flowering), maturity stage (silking-maturity). The statistical period of precipitation takes the average annual growth period of summer maize in Liaocheng City as the statistical date limit (Table 1).

1.2 Drought and waterlogging index calculation method The ratio of the natural rainfall within the growth period of summer maize to the physiological water demand threshold during the growth and development period, is used to calculate the drought and waterlogging index, which can better reflect the impact of drought and waterlogging on the growth and development of summer maize. The specific formula is as follows[4-12]:

$$K = S.D - 1 \quad (1)$$

where K is the drought and waterlogging index; S is the available water during the growth period (in this article, it refers to the natural precipitation within the growth period of summer maize (mm); D is the physiological water demand of summer maize (Table 2). The ratio of the average water demand within the growth period of summer maize to the minimum water demand and the ratio of the average water demand within the growth period of summer maize to the maximum water demand, is used as the basis for the grade classification of drought and waterlogging grade index.

According to the value of K, the drought and waterlogging index is divided into five grades: severe drought $0.7 \leqslant K$; drought $0.7 < K \leqslant 0.9$; normal $0.9 < K \leqslant 1.1$; waterlogging $1.1 < K \leqslant 1.3$; severe waterlogging $1.3 < K$.

1.3 Calculation method of climate trend rate Climate trend rate uses the simple regression equation method. Assuming the data sequence is Y, and the time sequence is x. x is the year sequence number (1, 2, ... n), then:

$$Y = a + bx \quad (2)$$

$b \times 10$ is the climate trend rate, namely the climate change trend every 10 a. The positive value means that Y increases over the time and the negative value means that Y decreases over the time.

Table 1 The average growth period of summer maize during the period 1961 – 2011

Growth period	Time of occurrence // month-day
Seeding stage	06 – 13 – 06 – 20
Elongation stage	06 – 21 – 07 – 25
Flowering stage	07 – 26 – 08 – 09
Maturity stage	08 – 10 – 09 – 26

1.4 Regional distribution technology GIS technology is used to carry out the analysis of regional distribution characteristics.

2 Results and analysis

2.1 Drought and waterlogging analysis (i) According to the calculated drought and waterlogging index during the growth period of summer maize in Liaocheng City from 1961 to 2011, the frequency of drought and waterlogging disasters is as high as 81.5%. In the natural rainfall conditions, the probability of occurrence of drought and waterlogging during the growth period of summer maize in Liaocheng City is eight in ten years, with frequent drought and waterlogging. The drought is significantly more than waterlogging, and the drought frequency is 61.8%. The frequency of occurrence of severe drought is 34.3%. The frequency of occurrence of waterlogging is 19.8%, and the frequency of severe waterlogging is 7.3% (Fig. 1).

Table 2 The physiological water demand during various growth stages of summer maize

Growth period	Water demand // mm		
	Normal	Least	Most
Seeding stage	25.3	16.8	33.8
Elongation stage	112.6	94.4	130.8
Flowering stage	100.5	92.9	108.2
Maturity stage	224.0	181.1	267.0
Whole growth stages	462.4	417.3	507.5

(ii) The regional characteristics of drought and waterlogging are very obvious. The frequency of drought in the western region is significantly higher than that in the eastern region, and it is the highest in the southwestern region. The waterlogging is the other way around, and the frequency of waterlogging in the eastern region is significantly higher than that in the western region, the highest in the southeast (Fig. 2).

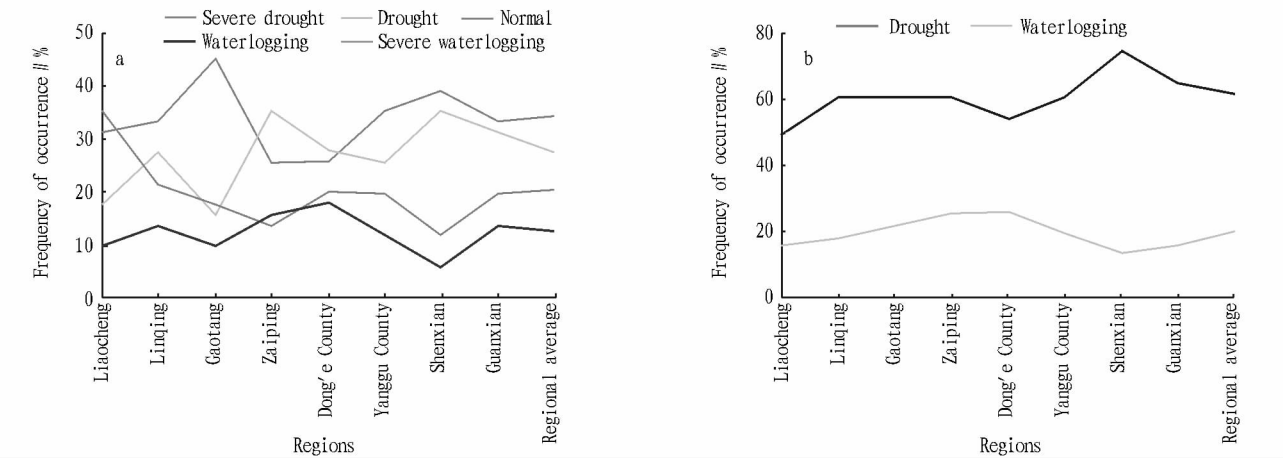
(iii) Along with the global warming climate change, during the growth period of summer maize, the entire Liaocheng region shows the climate trends of conversion to drought (The climatic trend rate of drought and waterlogging index in Liaocheng, Linqing, Gaotang, Chiping, Dong'e, Yanggu, Shenxian and Guanxian is –0.012, –0.028, –0.019, –0.029, –0.038, –0.029, –0.033, –0.012, respectively, with the regional average of –0.025), which poses grimmer situation for the Liaocheng region whose natural precipitation can not meet the requirements of high yield and quality cultivation of summer maize. Since the 1980s, the frequency of drought and waterlogging during the growth period of summer maize has been significantly increased, and the disasters of droughts and waterlogging have had an increasingly serious impact on summer maize production. Especially in the tasseling and silking period of summer maize, the drought will seriously affect the yield and quality.

In the late growth period of summer maize in 2002, the scarce rainfall resulted in serious reduction of output of summer maize, and in Liaocheng City, 2.1×10^4 hm^2 of summer maize was affected by the disaster and 7.7×10^3 hm^2 of summer maize underwent crop failure. During the filling period of summer maize in 2011, the rainy weather resulted in the reduction of output of summer maize more than 10%, and delayed the maturity period of summer maize compared to normal years, affecting the timely sowing of winter wheat and making some winter wheat fail to produce tillers before winter.

2.2 Analysis of drought and waterlogging situation at different stages of growth Through the analysis of drought and waterlogging index at various developmental stages, it can be found that the frequency of occurrence of drought and waterlogging during the seedling period is up to 100%, and the frequency of occurrence of

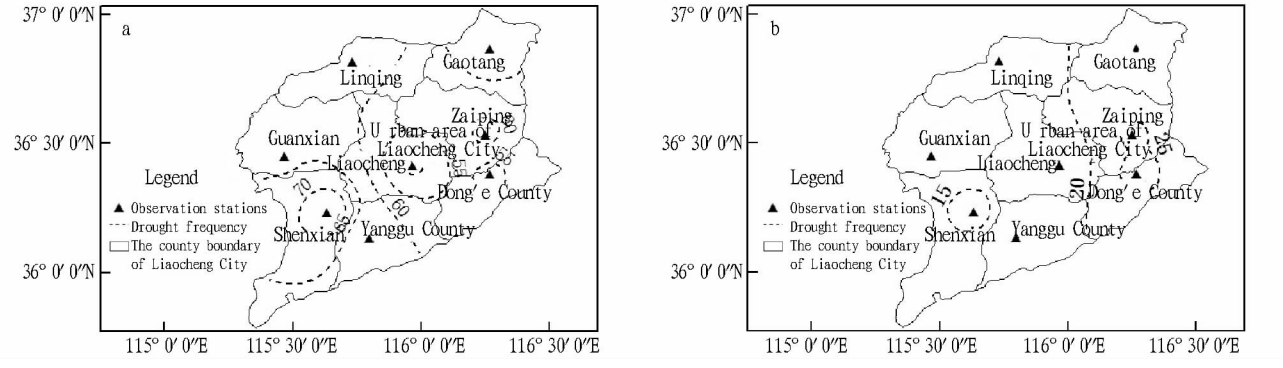
drought accounts for 80.4%, that is, it is very prone to serious drought phenomenon, seriously affecting the normal growth and development of summer maize during the seedling period.

The frequency of occurrence of drought and waterlogging during the elongation period is 82.4%, and the frequency of occurrence of waterlogging accounts for 70.6%, that is, the water is too much, hampering the root growth, and the drought-resistant power of maize in the late period is weak.



Note: a. The frequency of different levels of drought and waterlogging (%); b. Comprehensive frequency of drought and waterlogging (%).

Fig. 1 The frequency of occurrence of drought and waterlogging in Liaocheng City (%)



Note: a. Regional distribution of frequency of occurrence of drought; b. Regional distribution of frequency of occurrence of waterlogging.

Fig. 2 Regional distribution of frequency of occurrence of drought and waterlogging

The frequency of occurrence of drought and waterlogging during the flowering period is 74.5%, and the frequency difference of droughts and waterlogging is the smallest in this period.

The frequency of occurrence of drought and waterlogging during the maturity period is 90.2%, and the frequency difference of drought accounts for 86.3%. The natural rainfall is insufficient, affecting maize's filling rate and grain formation, and also affecting the yield and quality (Table 3).

Table 3 The frequency of occurrence of drought and waterlogging at different stages of growth (%)

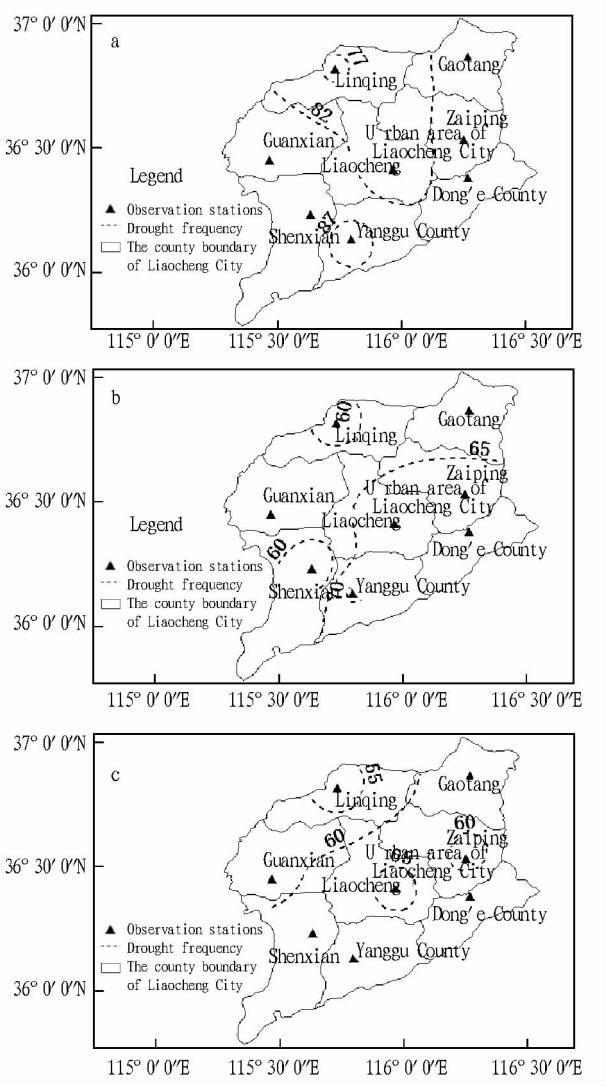
Growth stage	Seeding stage	Elongation stage	Flowering stage	Maturity stage
Severe drought	76.5	5.9	39.2	60.8
Drought	3.9	5.9	3.9	25.5
Normal	0.0	17.6	25.5	9.8
Waterlogging	7.8	5.9	9.8	0.0
Severe waterlogging	11.8	64.7	21.6	3.9

At various stages of the growth period of summer maize, there is the climate trend of transforming to drought (The climate trend rate of drought and waterlogging index at the stages of seedling, elongation, flowering and maturity is −0.001, −0.088, −0.083, −0.007, respectively), which will further destroy the moisture supply and demand balance during the growth period of summer maize, and affect the high yield and quality cultivation.

At various growth stages, the regional characteristics of drought and waterlogging are more obvious. At the seedling stage, the drought is very serious in the central regions and most serious in the south-central regions (Fig. 3-a); at the flowering stage, the regional distribution is relatively even; at the elongation stage, the waterlogging is serious in the southern regions (Fig. 3-b); at the maturity stage, the drought is most obvious in the central areas (Fig. 3-c).

3 Conclusions and recommendations

3.1 Conclusions Liaocheng City is located in the irrigation area of lower reaches of the Yellow River, and with the accelerated process of the development in the Yellow River Delta, the indus-



Note: a. The drought frequency of maize during the seedling period and regional distribution; b. The waterlogging frequency of maize during the elongation period and regional distribution; c. The drought frequency of maize during the maturity period and regional distribution.

Fig. 3 The drought and waterlogging frequency of maize during various growth stages and regional distribution

trial and domestic water demand is increasing year by year, so it is extremely difficult to increase the water diversion to solve the problem of water shortage for the growth of summer maize. Based on this, the fundamental way to solve water shortage problems for summer maize is to develop high-yielding and water-saving cultivation techniques of summer maize, research the laws of occurrence of drought and waterlogging, store water when there is waterlogging, save water when there is drought, make full use of groundwater, scientifically develop the air resources, and regulate the water supply and demand balance at different growth stages of summer maize[13].

3.2 Recommendations We put forth the following recommendations:

(i) Selecting drought-resistant varieties, and improving the water resource use efficiency.

(ii) Promoting the water and fertilizer coupling, sprinkler irrigation, drip irrigation, micro-irrigation and other water-saving irrigation technologies, and improving the water use efficiency.

(iii) Promoting the ditch, ridge and laminating cultivation technology, reducing the field evapotranspiration, keeping warming and conserving moisture, and saving water resources.

(iv) Strengthening the construction of water conservancy facilities, so that it can be irrigated during drought and drained during waterlogging.

(v) During dry season, timely organizing artificial rainfall operation, and increasing precipitation in arid areas to ease drought.

(vi) Rationally exploiting the groundwater, and improving the underground water use efficiency. Liaocheng, as the Yellow River alluvial plain, has abundant groundwater. The exploitation and utilization of groundwater should gradually shift from the role increasing water to the function of adjusting the seasonal imbalance between supply and demand of water, to improve the efficiency of utilization of groundwater resources.

References

[1] BAI Y, DONG BZ, SUN AQ. Discussion on situation of water resources and its rational utilization in Liaocheng[J]. Science & Technology Information, 2012(7): 649, 641. (in Chinese).

[2] WANG J, YANG SE, HAN FJ, *et al*. Analysis on characteristics of drought and flood of Liaocheng in summer in recent 50 years[J]. Journal of Shandong Meteorology, 2011, 31(128): 6-11. (in Chinese).

[3] LIU ZD, XIAO JF, LIU ZG, *et al*. Study on water requirement and consumption rules of summer maize with high-yield[J]. Water Saving Irrigation, 2011(6): 4-6. (in Chinese).

[4] GAO SH. The charts of agroclimatic resources and main crops output change of China[M]. Beijing: China Meteorological Press, 1995: 36-37. (in Chinese).

[5] DAI RF, HAN JT, DING ZM, *et al*. Flood and drought disaster in Hebei Province[M]. China Water Power Press, 1998: 299-302. (in Chinese).

[6] ZHANG HL. Flood and drought disaster in China[M]. Beijing: China Water Power Press, 1997: 281-285. (in Chinese).

[7] Research Group of "Crops Water Stress and Drought Study of North China Plain". Study on crops water stress and drought[M]. Zhengzhou: Henan Science and Technology Press, 1991: 111-134. (in Chinese).

[8] ZHANG SY, YAO PZ. The determination of index of drought and flood in North China and waterlogging distribution[J]. Journal of Natural Disasters, 1998, 7(2): 22-28. (in Chinese).

[9] SUN RQ. Drought evaluation and disastrous index[J]. Journal of Natural Disasters, 1994, 3(3): 49-55. (in Chinese).

[10] LIU CM, WEI ZY. Agricultural hydrology and water resources of North China Plain[M]. Beijing: Science Press, 1989: 133-136. (in Chinese).

[11] ZHAO JB, LI KH. Drought and agriculture[M]. Beijing: China Agriculture Press, 1995: 32-39. (in Chinese).

[12] JIN ZF, YING YB. Study on agriclimate feature in Jiaxing[J]. Acta Agriculturae Zhejiangensis, 2004, 16(4): 213-217. (in Chinese).

[13] QIAO YQ, CAO CF, ZHAO Z, *et al*. Filling rate and filling quality characteristics of super-high-yielding wheat[J]. Acta Agriculturae Zhejiangensis, 2011, 23(2): 221-225. (in Chinese).