Study on Crop Meteorological Index and Change Threshold in Yellow River Sanyizhai Irrigated Area

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Abstract: Based on 756 sets of ten-day meteorological data from 1999 to 2019 in Sanyizhai Irrigation Area, the dynamic threshold of irrigation water demand was studied in order to determine the irrigation water demand in the Yellow River Irrigation Area under the condition of meteorological change. According to the path analysis of crop water requirement of winter wheat, cotton and summer corn, the most significant meteorological factors were selected to construct the meteorological indexes of winter wheat, cotton and summer corn, respectively, and four variation rates of slight, weak, strong and extremely strong were determined. Analysis the growth period of winter wheat all 486 groups of observed meteorological data, strong changes occur most frequently, middle and late time is January, strong change is 2 months early and in late December, in late march to late may meteorological index change is given priority to with slight change and the weak, the weak change based on the analysis of time frequency of the highest (40.79%), strong change frequency of the lowest 13.87%.The maximum frequency of extreme changes in summer corn was in the middle of July, late July and early August, with the highest frequency of extreme changes accounting for 28.57% and the lowest frequency of strong changes accounting for 14.70%.The maximum frequency of strong changes in cotton was in the middle of July, late July and early August, with the highest frequency of small changes accounting for 34.01% and the lowest frequency of strong changes accounting for 15.65%.

1 INTRODUCTION

In the major national strategy of Ecological protection and High-quality Development of the Yellow River Basin, it is clearly pointed out that the economical and intensive utilization of water resources should be promoted (Xinhua, 2019). Henan province is a major agricultural and grain production province in China. In 2020, the sown area of grain in Henan province is 10 738 794 hm2, of which winter wheat and summer corn account for more than 85% (Central Committee of the Communist Party of China and State Council, 2018). However, Henan Province is also one of the regions with severe water shortage in China. The Yellow River Irrigation area mainly uses agricultural water, and in the face of complex and changeable meteorological conditions, an important premise for water conservation and intensive utilization is to predict the water demand of the irrigated area according to meteorological changes, so as to carry out accurate water scheduling and optimal allocation (CUI 1994).

At present, a lot of research achievements have been made in terms of water requirement for crop irrigation (CAI 2008, WEI 2014, WU 2008). However, for the main crops in the irrigated areas of The Yellow River in Henan Province, the research

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on the threshold of irrigation water demand from the perspective of meteorological factors is still scarce. This will bring adverse effects on the promotion and implementation of the strictest water resources management system and the scientific planning of the development of the irrigation area. Based on the meteorological data of Huibei Water Conservancy Experimental Station from 1999 to 2019, the dynamic threshold of crop water demand and irrigation water demand of winter wheat, summer corn and cotton in the whole growth period of Sanyizhai Irrigated Area was predicted from the perspective of the change range of meteorological index. Thus the data foundation and technical support are provided for the conservation and intensive utilization of water resources and high-quality development in Yellow River irrigation area.

2 REGIONAL OVERVIEW AND DATA SOURCES

The water intake of Yellow River Sanyizhai Irrigation Area in Henan Province is located in Lankao County, Kaifeng City. The total land area of the irrigation area is 4 344.2 km2, and the total arable land area is 270,000 hm2, as shown in Fig.1 (FENG 2019). At present, the water diversion capacity of the irrigation area is about 150 m3/s, and the effective irrigation areas are Kaifeng County, Lankao County and Qi County in Kaifeng City, and Minquan County, Ningling County, Suiyang District, Liangyuan District, Sui County and Yucheng County in Shangqiu City, involving a total of 9 counties (districts) in the two regions (FENG 2017). Meteorological data adopted in this study were all from Huibei science Experimental Station of Eastern Henan Water Conservancy Engineering Administration in Henan Province. The geographical location of this station was 114º31 'E and 34º46' N, representing the Yellow River Sanyizhai Irrigation Area in Kaifeng City, Henan Province. The daily and daily surface meteorological observation data of this station from 1999 to 2019 were selected. Including precipitation (X1), water surface evaporation (X2), average temperature (X3), maximum temperature (X4), minimum temperature (X5), air relative humidity (X6), sunshine duration (X7), maximum sunshine duration (X8), average wind speed (X9) and nearly 100,000 data.

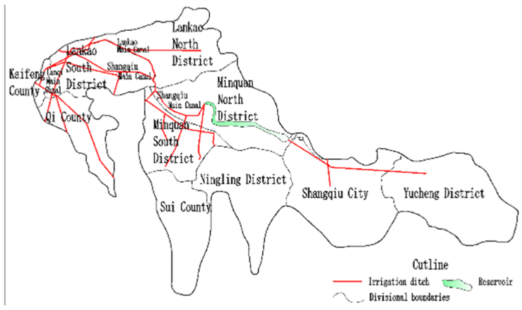

Figure 1: Map of Yellow River Sanyizhai Irrigation Area.

3 METEOROLOGICAL INDEX AND CHANGE THRESHOLD

3.1 Winter Wheat Meteorological Index and Its Change Threshold

According to the previous research results, the regression equation of winter wheat with 9 meteorological factors can predict crop water demand more accurately. Based on 756 sets of 10-day meteorological data from 1999 to 2019, through path analysis of winter wheat crop water demand in Yellow River Sanyizhai Irrigation Area, it can be seen that the four meteorological factors with the greatest influence are: Ten-day average temperature (X3), ten-day maximum temperature (X4), ten-day sunshine hours (X7), ten-day average wind speed (X9). Therefore, the above four factors are selected as representative factors, and the winter wheat meteorological index is calculated as follows:

$$F_{m-w} = [0.25 * (\frac{x_3-\bar{x}_3}{\bar{x}_3}) + 0.25 * (\frac{x_4-\bar{x}_4}{\bar{x}_4}) + 0.25 * (\frac{x_7-\bar{x}_7}{\bar{x}_7}) + 0.25 * (\frac{x_9-\bar{x}_9}{\bar{x}_9})] * 100\% \quad (1)$$

In the formula: F_{m-w} , winter wheat meteorological index in Sanyizhai; X3 ,$\bar{x}_3$ are ten-day average measured temperature, annual average, °C; X4, $\bar{x}_4$ are ten-day maximum temperature measured, annual average, °C; X7,$\bar{x}_7$ are measured value of ten-day sunshine hours, annual average value, h; X9, $\bar{x}_9$ are ten-day average wind speed measured annual average m/s.

According to the change multiples of maximum, minimum and mean values of four meteorological factors during 1999-2019, four ranges of slight change, weak change, strong change and strong change were determined. The threshold range of slight change was -10% to 10%, weak change was -30% to 30%, and strong change was -50% to 50%. The threshold value of the change amplitude developed by the time process is shown in Fig.2, and the threshold range of different change amplitude is shown in Table 1.

Table 1: Threshold range of change amplitude of winter wheat meteorological index in Sanyizhai Irrigation Area.

Factor	Multiple of minimum change	Multiple of maximum change	Threshold range of the change amplitude			
			Small change	Weak change	Strong change	Extreme strong change
X3	-0.63	2.28	-10%~10%	-30%~30%	-50%~50%	<-50%，>50%
X4	-0.58	1.27	-10%~10%	-30%~30%	-50%~50%	<-50%，>50%
X7	-0.83	1.84	-10%~10%	-30%~30%	-50%~50%	<-50%，>50%
X9	-0.77	4.94	-10%~10%	-30%~30%	-50%~50%	<-50%，>50%

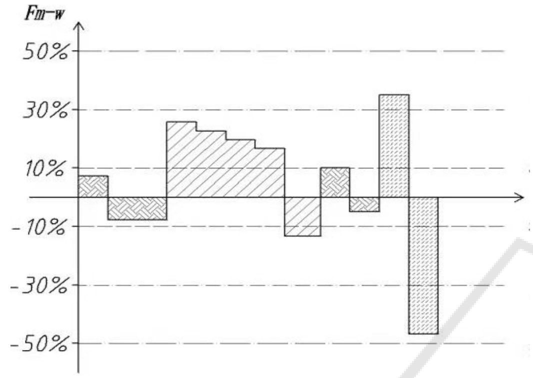

Figure 2: Schematic diagram of the threshold value of change amplitude of winter wheat meteorological index in Sanyizhai Irrigation Area.

The whole growth period of winter wheat is 23 days from mid-October to late May of the next year. Based on 756 sets of ten-day meteorological data in 21 years from 1999 to 2019, the winter wheat meteorological index is calculated by using formula (1), and the variation range of meteorological index in each ten-day in 21 years is determined according to the threshold range in Table 1. Count the occurrence times of the four variation ranges, as shown in Fig.3. It can be seen that the most frequent strong changes of meteorological index occurred in the first, middle and late January, the most frequent strong changes occurred in the first ten days of February and the last half of December, and the change range of meteorological index from late March to late May was dominated by slight changes and weak changes. The frequency of the four variation ranges of the meteorological index in 483 sets of data is shown in Fig. 4. It can be seen that the highest frequency of weak variation is 40.79%, and the lowest frequency of strong variation is 13.87%.

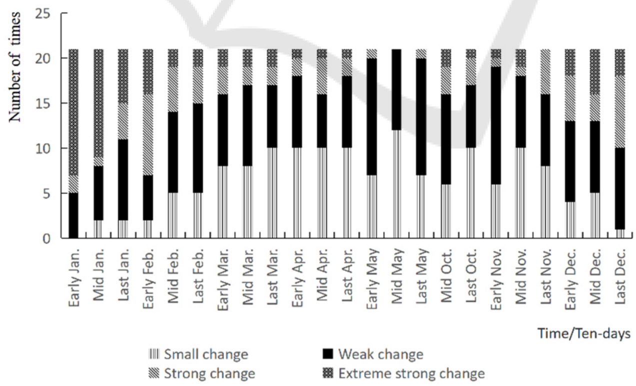

Figure 3: The frequency of different variation ranges of meteorological index during the whole growth period of winter wheat in Sanyizhai Irrigation Area from 1999 to 2019.

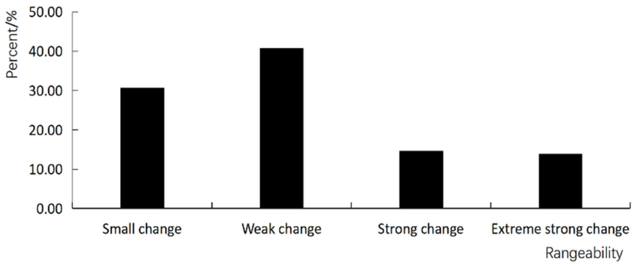

Figure 4: Percentage of different variation ranges of meteorological index in the whole growth period of winter wheat in Sanyizhai Irrigation Area from 1999 to 2019

3.2 Meteorological Index and Variation Range of Cotton and Summer Corn

According to the previous research results, through path analysis of the water demand of cotton and summer maize crops in Sanyizhai Irrigation Area, it can be seen that the three most influential meteorological factors are: ten-day water evaporation (X2), ten-day air relative humidity (X6), and the actual maximum sunshine hours per day (X8). Therefore, the above factors are selected as representative factors, and the calculation of the meteorological index of cotton and summer corn is as follows:

$$F_{m-cc} = [0.33 * (\frac{x_2-\bar{x}_2}{\bar{x}_2}) + 0.33 * (\frac{x_6-\bar{x}_6}{\bar{x}_6}) + 0.34 * (\frac{x_8-\bar{x}_8}{\bar{x}_8})] * 100\% \quad (2)$$

In the formula: F_{m-cc},The meteorological change index of cotton and summer corn; X2, $\bar{x}_2$ are measured value of water surface evaporation in ten days, average value over many years, mm; X4,$\bar{x}_4$ are ten-day air relative humidity measured value, annual average,%; X7, $\bar{x}_7$ are actual measured maximum hours of sunshine per day, multi-year average, h.

According to the change multiples of the maximum, minimum and average of the three meteorological factors during 1999-2019, the change ranges of four meteorological factors were determined as slight change, weak change, strong change and strong change. The threshold range of the slight change of meteorological index was -10% to 10%, the weak change was -20% to 20%, and the strong change was -30% to 30%. The threshold value of the change amplitude developed by the time process is shown in Fig.5, and the threshold range of different change amplitude is shown in Table 2.

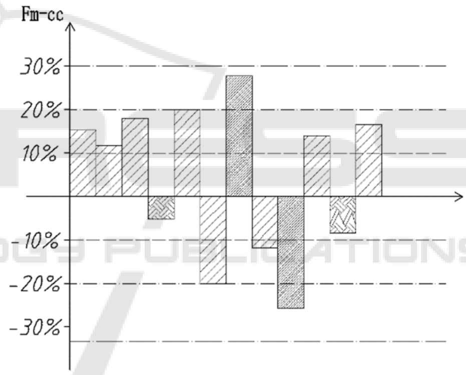

Figure 5: Schematic diagram of thresholds of cotton and summer corn meteorological change index in Sanyizhai Irrigation Area.

Table 2: Threshold range of change amplitude of meteorological index of cotton and summer maize in Sanyizhai Irrigation Area.

Factor	Multiple of minimum change	Multiple of maximum change	Threshold range of the change amplitude			
			Small change	Weak change	Strong change	Extreme strong change
X3	-0.79	1.66	-10%~10%	-20%~20%	-30%~30%	<-30%, >30%
X4	-0.30	1.30	-10%~10%	-20%~20%	-30%~30%	<-30%, >30%
X7	-0.84	1.84	-10%~10%	-20%~20%	-30%~30%	<-30%, >30%
X9	-0.79	1.66	-10%~10%	-20%~20%	-30%~30%	<-30%, >30%

3.2.1 Calculation of Summer Maize Eteorological Index

The whole growth period of summer corn is 10 days from mid-June to mid-September every year. Based on 756 sets of ten-day meteorological data in 21 years from 1999 to 2019, the meteorological factors of summer corn are calculated using formula (2), and the change range of meteorological index of each ten-day in 21 years is determined according to the threshold range in Table 2. The occurrence times of the four variation ranges are statistically shown in Fig.6. It can be seen that the most frequent strong changes of meteorological index occurred in the middle and late July and the first ten days of August, the most frequent strong changes occurred in the first ten days of July and the last ten days of August, and the change range of meteorological index in the middle and late June and the first and middle of September was dominated by slight changes and weak changes. The frequency of the four variation ranges of the meteorological index in 210 sets of data is shown in Fig.7. It can be seen that the highest frequency of strong variation takes up 28.57%, and the lowest frequency of strong variation takes up 14.70%.

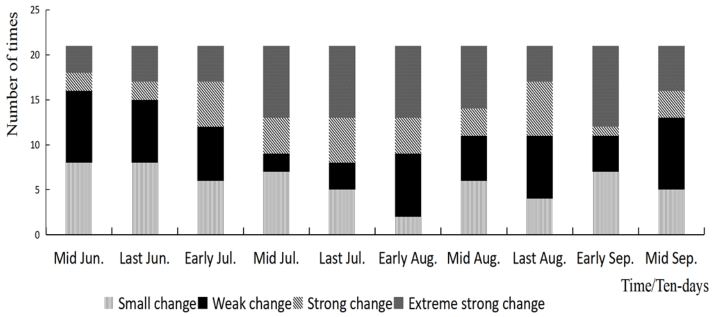

Figure 6: The frequency of change of ten-day meteorological index in the whole growth period of summer maize in Sanyizhai Irrigation Area from 1999 to 2019.

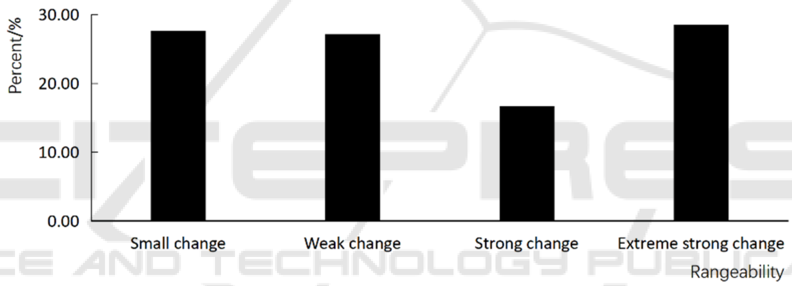

Figure 7: Percentage of change of meteorological index during the whole growth period of summer corn in Sanyizhai Irrigation Area from 1999 to 2019.

3.2.2 Calculation of Cotton Meteorological Index

The whole growth period of cotton is 21 days from early April to late October every year. Based on 756 sets of ten-day meteorological data in 21 years from 1999 to 2019, the cotton meteorological factor is calculated by Using formula (2), and the change range of meteorological index in each ten-day in 21 years is determined according to the threshold range in Table 2. The occurrence times of the four variation ranges are statistically shown in Fig.8. It can be seen that the most frequent occurrence of strong changes of meteorological index is in the middle and late July, early August and early September, and the most frequent occurrence of strong changes is in the early July, late August and late October. In other periods, the change range of meteorological index is dominated by slight changes and weak changes. The frequency of the four change ranges of the meteorological index in 441 sets of data is shown in Fig.9. It can be seen that the highest frequency of the slight change is 34.01%, the second frequency of the weak change is 28.34, and the lowest frequency of the strong change is 15.65%.

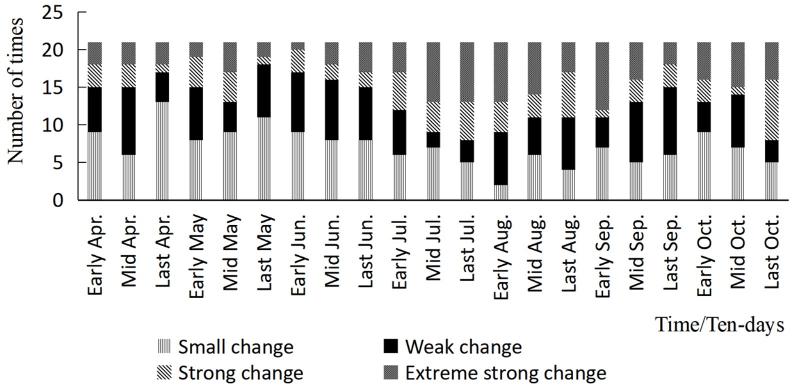

Figure 8: The frequency of change of ten-day meteorological index during the whole growth period of cotton in Sanyizhai Irrigation Area from 1999 to 2019.

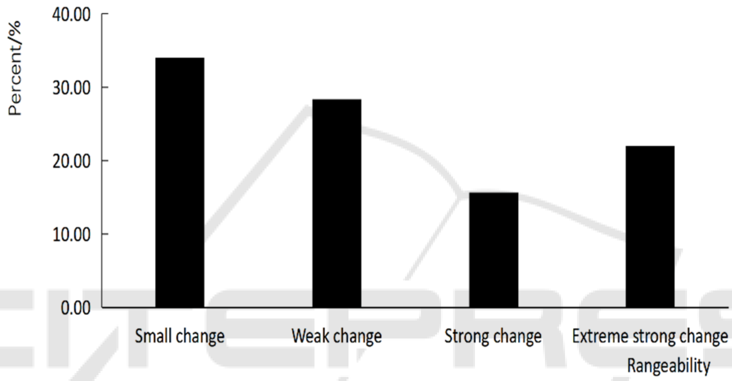

Figure 9: Percentage of different variation ranges of meteorological index in the whole growth period of cotton in Sanyizhai Irrigation Area from 1999 to 2019.

4 CONCLUSIONS

(1) Based on 756 sets of ten-day meteorological data from 1999 to 2019, the most significant four meteorological factors were selected to construct the winter wheat meteorological index according to the path analysis of the water demand of winter wheat crops in Yellow River Sanyishai Irrigation area, and the four ranges of slight, weak, strong and extremely strong were determined. The slight change refers to the meteorological index between -10% and 10%. The weak variation is between -30% and 30%, and the strong variation is between -50% and 50%. According to the path analysis of the water demand of cotton and summer maize crops, the most significant three meteorological factors were selected to construct the meteorological index, and four ranges were determined. The slight change means that the meteorological index is between -10% and 10%, the weak change is between -20% and 20%, and the strong change is between -30% and 30%.

(2) According to the frequency and time of occurrence of meteorological indexes of different variation ranges of winter wheat, it can be seen that the most frequent occurrences of strong changes occurred in the first, middle and late January, and the most frequent occurrences of strong changes occurred in the first ten days of February and the last ten days of December. In the whole growth period of winter wheat, the frequency of weak change was the highest (40.79%), and the frequency of strong change was the lowest (13.87%). The period when the strong change occurred was the non-critical water demand of winter wheat, so the change range of irrigation water demand of winter wheat in the whole growth period was not large. The most frequent occurrence of strong changes in summer maize was in mid-July, late July and early August, and the most frequent occurrence of strong changes was in early July and late August. The highest

frequency of strong variation was 28.57%, and the lowest frequency of strong variation was 14.70%. The 10 days of the whole growth period of summer maize belong to the period when the summer weather is susceptible to strong or strong changes. In these periods, special attention should be paid to the change of irrigation water demand caused by meteorological changes, and the water diversion and allocation plan of the irrigated area should be dynamically adjusted in advance according to the meteorological forecast. The strongest changes of cotton meteorological index occurred most frequently in the middle and late July, early August and early September, and the strongest changes occurred most frequently in the early July, late August and late October. In other periods, the change ranges of meteorological index were slight and weak changes. The highest frequency of micro change was 34.01%, and the lowest frequency of strong change was 15.65%. The probability of small and weak changes in the whole growth period of cotton is high, but the fluctuation of irrigation water requirement in summer when the weather is prone to strong changes should also be concerned.

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