Weather Risk Management and Production Forecast of Tea in Xinyang City

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Abstract. Meteorological conditions are one of the most important factors affecting tea yield, and the increase of meteorological disaster events due to climate change in recent years makes it particularly important to carry out tea disaster risk management and yield analysis and prediction based on the changes of meteorological factors. In this paper, using the meteorological data of Xinyang City, Henan Province, from 1990 to January-April 2010, the correlation analysis between meteorological factors and tea yield was carried out by using SPSS statistical software, and a multiple regression model for tea yield prediction of Xinyang City was established on the basis of the screened major meteorological factors. By further analysing the disaster-causing risk situation of each meteorological factor, corresponding meteorological risk management approaches for tea were proposed to mitigate the impact of meteorological risk on tea yield.

Keywords: tea; meteorological factors; risk management; prediction model

1 INTRODUCTION

Due to its own special characteristics, agriculture is a typical risk industry, facing numerous meteorological risks throughout the production cycle[1]. Agricultural meteorological risk management is a series of economic management activities that use appropriate means to identify and control the risk sources of various meteorological elements, trying to maximise the safety and security of farmers at the smallest cost[2]. Yamoaha assessed the threat of drought risk to local maize by analysing the relationship between maize yields and precipitation coefficients in the Braska region[3]. Agnew and Keating constructed a more general drought risk evaluation methodology by examining the effects of indicators such as precipitation and evapotranspiration on crop yields[4-5]; Lidon analysed the mechanisms of low temperature cold damage to crops and risk management tools[6], while Richter chose a crop simulation model to study the relationship between climate on wheat yield and wheat climate risk[7]. These studies have achieved some results, but the traditional weather risk management mainly focuses on the treatment of disasters when they occur, and pays little attention to pre-disaster precautions,

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and most of the research objects are large crops, and there is a lack of effective weather risk management measures for the production of cash crops such as tea.

Xinyang City, Henan Province, has a history of growing tea for more than 2,300 years, and its main product, Xinyang Mao Jian, won a gold medal at the Panama Universal Exposition in 1915 and was hailed as one of China's top ten famous teas in 1959. As the most important leading industry in Xinyang, the fluctuation of green tea production is directly related to the local economic development and the livelihood of many people[8]. Xinyang is located on the north bank of the middle and lower reaches of the Yangtze River, with abundant sunshine and rainfall, but the tea area is mostly a high mountain tea plantation at an altitude of about 800 m. The temperature is lower than that of the plains, with the extreme minimum temperature reaching -12 ℃ to -18 ℃, and the annual precipitation is less than that of the southern tea area, which makes the tea trees suffer from the risk of meteorological disasters, such as low temperature, frost, and drought, and so on[9]. Therefore, it is of great significance to study the relationship between meteorological factors and tea yield during the growing period of Xinyang tea, and to carry out targeted meteorological risk management of tea.

2 MATERIALS AND METHODS

2.1 Source of Information

Tea production data are the total tea production and the area of exploited tea plantations in Xinyang City from 1986 to 2023. Meteorological data are the ten-days and monthly meteorological data from January to April from 1990 to 2023 in Xinyang City, including average air temperature, average ground temperature, average wind speed, average relative humidity and precipitation, sunshine hours, ≥0 °C cumulative temperature, etc. The data are obtained from the Statistics Bureau and the Meteorological Bureau of Xinyang City.

2.2 Research Methods

The methods of analysis mainly include correlation and regression analyses, as well as yield segregation methods for cash crops. Factors affecting tea yield are variable and complex, and under the same variety and maintenance level in the same area, the yield and quality of tea are mainly affected by meteorological factors. Combining the actual situation of tea crops, the actual tea yield (Y) is decomposed into trend yield (Yt), meteorological yield (Yw) and stochastic yield (ε), viz:

$$Y = Y_t + Y_w + \varepsilon \tag{1}$$

Among them, Y is the actual yield per unit area of tea (kg/ha, the same below); Y_t is the trend yield per unit area of tea, which is formed by the production level and economic conditions and other factors; Y_w is the meteorological yield per unit area of tea, which reflects the fluctuations caused by the differences in meteorological conditions between years; ε is the yield affected by statistical errors or random factors, which can be ignored due to the large uncertainty and small impact on the fluctuation of yield. Equation (1) is simplified as follows:

$$Y = Y_t + Y_w \tag{2}$$

3 ANALYSIS OF THE RESULTS OF THE FORECAST OF METEOROLOGICAL PRODUCTION OF TEA

3.1 Trend yield and Meteorological Yield

In the prediction equation, the trend yield value is increasing with productivity progress, and the linear sliding average method is a more concise and accurate method to separate the yield. The unit yield of tea in Xinyang City from 1986 to 2010 was processed as a sliding average with a 5-year cycle, and the sample range became 1990 to 2010 after sliding.

After separating the trend yield, SPSS was used to conduct a linear regression analysis of year and trend yield, in which the trend yield Y_t was used as the dependent variable and year T as the independent variable. The results of the analysis showed that the R^2 was 0.935, and the adjusted R^2 was 0.931, and F was much larger than $F_{0.05}$, and the regression equation had high significance, which led to the trend yield regression equation:

$$Y_t = 18.022T - 35703.534 \tag{3}$$

3.2 Significant Meteorological Factors Affecting Meteorological Yield of Tea

The meteorological yield of tea is affected by several meteorological factors. Through the correlation analysis of each meteorological data and meteorological yield from 1990 to 2010, it was found that the meteorological yield and the precipitation in early January, the average relative humidity in mid-February, the number of sunshine hours in early March, and the number of sunshine hours in mid-April were significantly negatively correlated; and with the average relative humidity in early March, the average air temperature in mid-March, and the precipitation in late March, The average relative humidity in mid-April was significantly positively correlated. All the above eight meteorological factors fluctuate, and the intensity of their fluctuation will have a greater impact on tea yield and quality (Table 1).

Table 1. Meteorological factors significantly associated with meteorological yield of tea in Xinyang City from 1990 to 2010

Main targets	Meteorological factor	r	P
Temperatures	Average temperature in mid-March	0.506^{*}	0.019
Precipitation	Precipitation in early January	-0.639^{**}	0.002
	Precipitation in late March	0.559^{**}	0.008

Main targets	Meteorological factor	r	P
Humidity level	Average relative humidity in mid-February	-0.537*	0.012
	Average relative humidity in early March	0.536*	0.012
	Average relative humidity in mid-April	0.471*	0.031
Sunshine	Hours of sunshine in early March	-0.467*	0.033
	Hours of sunshine in mid-April	-0.518*	0.016

Note: * indicates a correlation at the 0.05 level of significance, ** indicates a correlation at the 0.01 level of significance.

3.3 Tea Yield Prediction Model

After screening the meteorological factors that have a high impact on the meteorological yield of tea, regression analyses were carried out using SPSS (Table 2), with the dependent variable being the annual meteorological yield Yw, and the independent variables being the eight factors with high significance.

Table 2. Regression Coefficients of Meteorological Factors with High Impact on Meteorological Yield of Tea in Xinyang City from 1990 to 2010

Meteorological factor	Unstandardised coefficient		Standardised coefficient	t
	b	Standard error		
A constant	303.671	10.372		1.952
Precipitation in early January	-1.044	0.570	-0.302	-1.834
Average relative humidity in mid-February	-1.571	0.554	-0.385	-2.836
Hours of sunshine in early March	-0.605	0.420	-0.221	-1.439
Average relative humidity in early March	0.145	0.651	0.040	0.222
Average temperature in mid-March	2.046	2.679	0.119	0.764
Late March precipitation	1.191	0.437	0.424	2.729
Average relative humidity in mid-April	-1.909	1.568	-0.399	-1.217
Hours of sunshine in mid-April	-0.812	0.731	-0.366	-1.112

Based on the above results, assuming that the meteorological yield Y_w is linearly correlated with n influencing factors, the underlying relational equation can be derived as $Y_w = a_0+a_1x_1+a_2x_2+a_3x_3+......+a_nx_n$, and the correlation coefficients in Table 3 are brought into the relational equation to obtain the meteorological yield prediction equation:

$$Y_w=303.671-1.044x_1-1.571x_2-0.605x_3+0.145x_4+2.046x_5+1.191x_6-1.909x_7-0.812x_8 \quad (4)$$

Checking the ANOVA table shows that F = 6.964, significance P = 0.002, and checking the F distribution table shows that $F > F_{0.05}$, which indicates that the regression effect of the prediction equation is significant.

Substituting Eqs. (3) (4) into Eq. (2) at the same time, the Xinyang tea yield prediction model was obtained:

$$Y=-35399.863+18.022T-1.044x_1-1.571x_2-0.605x_3+0.145x_4+2.046x_5+1.191x_6-1.909x_7-0.812x_8 \quad (5)$$

3.4 Predictive Model Accuracy Test

Each relevant index from 2011 to 2023 was substituted into the model for yield prediction, and the predicted yield was derived and compared with the actual yield, with an average accuracy of 93.53 % and a good fitting rate.

Table 3. Forecast Production and Actual Production of Tea in Xinyang City from 2011 to 2023 and Forecast Accuracy

vintages	Projected production (kg/ha)	Actual production (kg/ha)	Predictive accuracy
2011	626.93	690.00	90.86%
2012	680.08	678.90	99.83%
2013	624.61	676.20	92.37%
2014	613.70	663.45	92.50%
2015	653.28	650.25	99.53%
2016	663.13	614.25	92.04%
2017	666.22	600.00	88.96%
2018	643.98	638.70	99.17%
2019	680.15	648.60	95.14%
2020	693.24	642.90	92.17%
2021	728.31	674.10	91.96%
2022	760.63	683.40	88.70%
2023	722.95	673.35	92.63%

4 CHARACTERISTICS OF METEOROLOGICAL FACTORS AFFECTING TEA YIELD AND RISK MANAGEMENT COUNTERMEASURES

In order to further verify the scientific validity of the meteorological factors affecting tea production, and to provide a scientific basis for meteorological risk management to further analyse the meteorological characteristics of the relevant factors, and to a certain extent, to guide the tea farmers to effectively reduce or avoid the reduction of tea production brought about by weather changes.

4.1 Negative Correlation Meteorological Factors

Negative correlation factors mainly include precipitation in early January, average relative humidity in mid-February, sunshine hours in early March and sunshine hours in mid-April. Xinyang is a tea area in the north of the Yangtze River, tea overwintering period is very susceptible to the effects of frost, Xinyang City, January to mid-February the average temperature is only 3.34 °C, this stage of precipitation or continuous high humidity, it is easy to produce freezing rain and lead to tea tree branches iced and broken.

In spring, tea shoots need to be in a relatively moist environment to maintain good quality. If the sunshine is too long, the precipitation is low and the humidity is low, the tea shoots are exposed to too much sunlight, which will result in smaller and thicker buds, affecting the quality of the tea leaves.April to May is the peak picking season for Xinyang Mao Jian, and the quality of the tea leaves is the best before Ching Ming (around 5 April) and Grain Rain (around 20 April). Xinyang City, in mid-April in the last 30 years, the average maximum temperature between 22 °C to 23.5 °C, in the last 30 years, the average number of hours of sunshine in mid-April 53.95 hours, the daily average of 5.39 hours, if the average ten-day temperature is too high, too long hours of sunshine, the spring tea shoots and leaves are not picked in a timely manner will soon be aging, the quality of tea and production will be significantly reduced.

4.2 Positively Correlated Meteorological Factors

The positive correlation factors mainly include the average relative humidity in early March, the average air temperature in mid-March, the precipitation in late March, and the average relative humidity in mid-April. In the full growth period of Xinyang Mao Jian, March is the most critical period, from the budding period to the three true leaf phenology are completed in this month. At this time in the dryness of 0.5 or so mild humid rainy environment, the tea new shoots tender, large and thin leaves, yield high quality; mid-April is also in the "rainy tea" picking the key period, abundant water vapour content and less sunshine brought about by the cloud conditions are conducive to the tea in the aromatic hydrocarbons, flavonoids and other aroma substances to further accumulation of At the same time, the growth is slowed down to maintain the nitrogen compounds in the new tissues of the tea leaves, thus maintaining the unique aroma and taste of green tea and improving the quality of the tea leaves.

4.3 Weather Risk Management Countermeasures for Tea

According to the theory of general meteorological risk management proposed by ADRC in 2005, disaster risk reduction is achieved through a combination of prevention/preparedness and prevention/mitigation. Based on the aforementioned characterisation of positive and negative correlated meteorological factors, tea farmers and relevant government departments should take appropriate countermeasures at different stages. For the low winter temperature in January-February, meteorological and agricultural departments should set up an early warning system for meteorological risks of tea, and pass unfavourable meteorological information to farmers in a timely manner through multiple communication channels. For the March tea critical growth period drought, on the one hand, can be mixed in the soil water retention agent, inhibit water evaporation, on the other hand, can determine the tea water demand critical period timely irrigation. For April tea picking period of high temperature sunshine, the government and tea farmers should be prepared early, and actively organise manpower on mature tea harvesting, to avoid excessive sunshine makes the quality of tea reduced.

5 CONCLUSION

This paper is based on the analysis of meteorological factors affecting tea production, screening the key meteorological factors with large impacts to establish a yield prediction model, and put forward targeted countermeasure suggestions for the meteorological risks of tea reflected by the impact factors. In the event of adverse changes in meteorological conditions, in advance of the tea farmers to carry out targeted meteorological services to minimise the impact of meteorological disasters on tea production, which is also a meteorological risk management "to minimise the economic cost of obtaining the maximum safety and security" of the basic principles of the practical demonstration.

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