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Drought Disaster Risk Threshold Value Determination of Maize Different Growth Period in Meitan

LI YANBIN[1], YOU FENG[1] AND LI JIA[2]
[1]North China University of Water Conservancy and Hydroelectric Power, 450011, Zhengzhou, China
[2]Neijiang Vocational Technical College, 641100, Neijiang, China
Email: liyb101@sina.com

Abstract: The evaluation model of agricultural drought disaster risk is built on the base of natural disaster risk theory selecting maize as research subject and Meitan as research area; it includes agricultural drought disaster hazard, exposure, vulnerability and drought resistant ability. Trend yield is simulated by three time's polynomial simulation; relative meteorological yield can be calculated by excluding trend yield from real yield. The relation analysis is done between risk value and relative meteorological yield, the relative equation is established; the risk threshold and risk level of maize different growth stage are defined according to relative equation, crop disaster forming condition and drought level standard. The result show that critical risk value is minimal in seeding-emergence stage, reducing yield occurs easily due to drought when disaster forming condition is met, that is relative meteorological yield value is less than -5%; the possibility of reducing yield due to drought is more in earing –filling and jointing –earing period; drought influence is less in emergence – jointing and filling –mature period. It is coordinate with the fact that summer drought occurs frequently, spring drought occurs on occasion and maize grow characteristics.

Keywords: *drought disaster risk, threshold value, maize, Guizhou Meitan*

1. Introduction

Meitan County is located in the north of Guizhou province, which belongs to subtropical humid monsoon climate with abundant precipitation, annual average rainfall of 1100 mm. but rainfall distributed unevenly, annual variation rate is large[1]. The rainfall in summer is up to 40% total year, it in winter is least and occupy only 6% total year. Storage and diversion is difficult because of special topography and geomorphology and imperfect water conservancy project, agricultural production mainly depends on natural condition, seasonal drought often occurs [2-3]. According to statistic material, drought primarily occurred from April to September during 1990-2012 in Meitan, continuous disaster drought in summer and autumn occurred in 7-9, 2011 because of inadequate precipitation. Cultivated land area of the drought in Meitan were 8339 hectares due to continuous less rainfall, direct economic loss was up to 42.12 million Yuan [4].

Maize is one of the important crops, which plant area occupy 25% of total croups, and plays an important role in production. Maize growth period is from 8th April to 9th August which often occur drought, water supply that maze need in different growth period can't meet if precipitation is short or distribute unevenly, it influence maize production, agricultural product development, people's lives, and economic, city development, and industry layout [5-6]

The article take maize in Meitan as research object, build drought disaster risk evaluate index system and model of maize different growth stage based on natural disaster risk theory [7] from four factors of hazard, exposure, vulnerability and drought resistant ability. Correlation analysis between drought risk index resulted and relative meteorological yield is done, the relation is built between two. According to this drought disaster risk threshold of different growth stage is divided, which provide theory basis for drought risk management and sustainable development of maize plant in southwest area.

2. Material and method:

2.1. Material resources

The article selects meteorological observation data, maize agricultural product material in Meitan during 1990-2012 as research material, which are from Guizhou province weather bureau, statistic reference, and agricultural statistic yearbook, and are provided by Guizhou province Research Institute of Water Conservancy.

2.2. Study method

2.2.1. Division of maize growth stage in Meitan

The starting and ending time of maize each growth stage is determined according to statistical analysis on the starting and ending time of maize each growth stage and total growth period days for years. The five stages are divided, shown as table 1.

Table: *maize growth period in Meitan*

Growth stage	seeding-emergence	emergence - jointing	jointing - earing	earing - filling	filling - mature
date	4.8-4.14	4.15-5.20	5.21-6.22	6.23-7.9	7.10-8.9

2.2.2. Index selection

According to the mechanism and concept of agricultural drought disaster risk, comprehensive considering systemic, simplicity, representative, evaluation of determination index system principle and influences factors of weather, hydrology, agricultural, social economic, combining real situation in Guizhou and difficult degree of obtaining material, evaluation index are selected. Grey relational analysis is done between index and maize loss, shown as table 2. The result show that selected index is closely related to drought disaster loss, it is reasonable that using the index to analyze drought risk.

2.2.3. Index building

Index weights are determined according to grey relational analyses between risk evaluation index and maize loss rate due to drought, combined with the analytic hierarchy process [8], shown as table 3. Each index is processed by dimensionless method in order to calculate simply because the index dimension is different [9].

***Table 2**: Grey relational analyses between risk evaluation index and maize loss rate due to drought*

Index System		Grey relational degree
Hazard index	Precipitation (mm)	0.661
	Evaporation (mm)	0.663
	Soil type	0.679
Exposure index	Maize sown area(10^3ha)	0.715
	Population density(person/km^2)	0.613
Vulnerability index	The drought area ratio (%)	0.723
	Crop yields (kg/ha)	0.810
Drought resistant ability index	Irrigation area (%)	0.712
	Per capital net income (Yuan/person)	0.592
	Drought relief funds (Yuan/ha)	0.622
	Water-saving percentage (%)	0.611

***Table 3** drought disaster risk evaluation index system of maize different growth stages in Meitan County*

	Factor	Vice factor	Index system	weight
drought disaster risk evaluation index system of maize	Hazard (H) 0． 387	Weather	Precipitation (mm)	0.443
			Evaporation (mm)	0.387
		Soil	Soil type	0.170
	Exposure(E) 0.155	Maize sown area	Maize sown area (10^3ha)	0.750
		Population	Population density (person/km^2)	0.250
	Vulnerability(V) 0.265	Drought degree	The drought area ratio (%)	0.400
		Drought resist ability	Crop yields (kg/ha)	0.600
	Drought resistant ability(RE) 0.193	Water conservancy project	Irrigation area (%)	0.471
		Economic	Per capital net income (Yuan/person)	0.169
			Drought relief funds (Yuan/ha)	0.224
		Agricultural using water level	Water-saving percentage(%)	0.136

2.2.4. Evaluation model building

According to the mechanism of drought disaster risk, comprehensive considering drought disaster four factors and corresponding index, drought disaster risk index model is established, shown as:

$$Risk = (W_H H) + (W_E E) + (W_V V) + (W_{RE} RE) \quad (1)$$

$$H = \sum_{i=1}^{n=3} X_{hi} W_{hi} \quad (2)$$

$$E = \sum_{i=1}^{n=2} X_{ei} W_{ei} \quad (3)$$

$$V = \sum_{i=1}^{n=2} X_{vi} W_{vi} \quad (4)$$

$$RE = \sum_{i=1}^{n=4} X_{ri} W_{ri} \quad (5)$$

In equations, Risk is an agricultural drought disaster value, which is used to represent the drought disaster risk degree, the large the value is, the more the drought disaster risk degree is; H, E, V and RE represent values of hazard, exposure vulnerability and drought resistant ability respectively; Wh, We, Wv, Wr represent values of index weight coefficient of hazard, exposure, vulnerability and drought resistant ability respectively; Xi is the quantitative value of each index; Wi is weight coefficient of each evaluation index, it represent each index relative importance for the drought disaster risk primary factors.

2.2.5. Determination of relative meteorological yield

Maize yield is influenced by many factors which relation are complex and restricted each other as others crops yield. Agricultural produce measures are improved further with productivity and society development. People emphasis aspects such as planting, fertilization, pests and diseases control, variety characteristic, agricultural product new technology, yield increasing measure etc, economic input is increased, all these benefit for maize yield increased. Maize yield express certain trend in certain degree, it is called maize time technology trend yield, simply called trend yield, which reflect social productivity development level in certain period.

Simulation methods of trend yield are various, including three times polynomial simulation, sliding-line average simulation, linear simulation, sectional simulation etc. the article adopt three times polynomial simulation method to process maize yield per ha during 1949-2012 in Meitan, establish trend yield equation and relative coefficient, shown as table 4. The real yield and trend yield are shown as figure 1, it can represent the factors of agricultural technology level improvement and social economic development contribute to maize yield, it is gradualness and stability, maize yield per ha in typical area increase with time going (wave line represents).

Maize relative meteorological yield can be calculated by formula (6) annually in Meitan. Meteorological yield that except trend yield can reflect the degree that real yield affected by drought. The year is yield increasing year that relative meteorological yield is positive, the value is increasing rate; the year is yield decreasing year that relative meteorological yield is negative, the value is decreasing rate.

$$Y = \frac{y - y_t}{y_t} \tag{6}$$

***Table 4**: maize trend yield equation in Meitan*

Typical area	maize trend yield equation	Relative coefficient
Meitan	$y = -0.0063x^3 + 0.7324x^2 - 15.454x + 125.53$	0.961

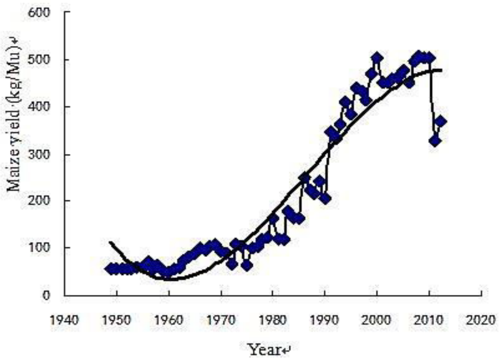


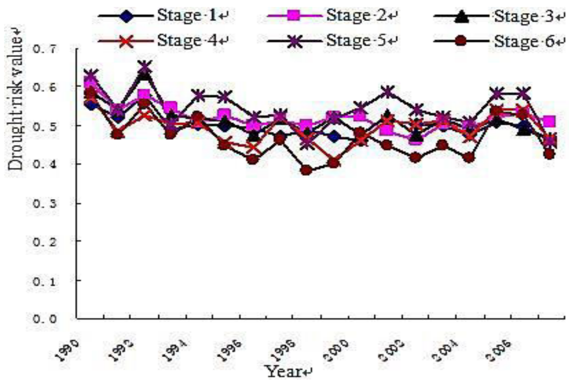
***Fig 1**: real yield and trend yield in Meitan*

3. Determination of maize different growth stage risk threshold

Drought disaster comprehensive risk value for each growth stage in 1990-2012 can be obtained according to drought disaster risk evaluation model, comprehensive considering hazard of disaster-causing factors, exposure and vulnerability of hazard bearing body, and drought-resistant ability; it is shown as figure 2. The number values of the risk assessments reflect the risk degree directly. From the figure, we can know that drought disaster risk trend is descending year by year in typical area. The reason is drought resistant ability enhancement gradually and drought risk decreasing, which is resulted by resistant materials and funding increasing, conservancy infrastructure enhancement further, resistant organizations and institutions perfected further with society development and economic enhancement.

The relativity analysis of maize each growth stages drought disaster risk value and maize relative meteorological yield calculated by formula (6) is processed, the results are shown as figure 3-7.

From figure 3 to 7, it can be known that maize every growth stage risk value is negative correlation with yield variation rate obviously. The critical risk value in seeding- emergence period is 0.490 when reducing rate is up to 5%, it is minimal in each periods. When drought disaster risk occurs in each growth stage, reducing yield possibility is maximal in this period, the risk value is 0.498 in earing –filling period, the value is 0.510 in total growth period, the value is 0.518 in jointing-earing period, the value is 0.548 in emergence – jointing period. The critical risk value in filling –mature is 0.588; it is maximal in each period, shown that reducing yield possibility is minimal in this period when drought disaster risk occurs in each growth stage.



Stage 1: seeding- emergence Stage 2: emergence – jointing Stage 3: jointing –earing, Stage 4: earing – filling Stage 5: filling –mature Stage 6: whole growth stages

***Fig 2**: maize each growth stages drought disaster risk value in Meitan*

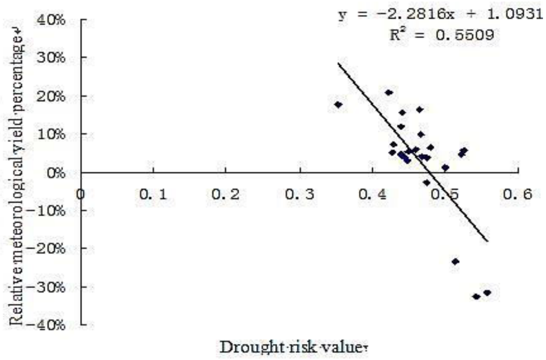


***Fig 3**: the percentage relation of drought disaster risk value and relative meteorological yield in seeding-emergence*

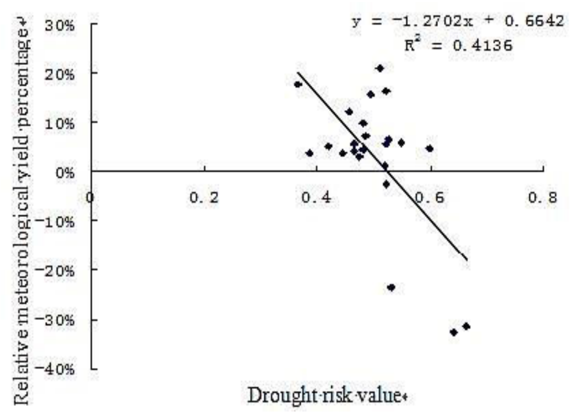


Fig 4: *the percentage relation of drought disaster risk value and relative meteorological yield in emergence – ointing*

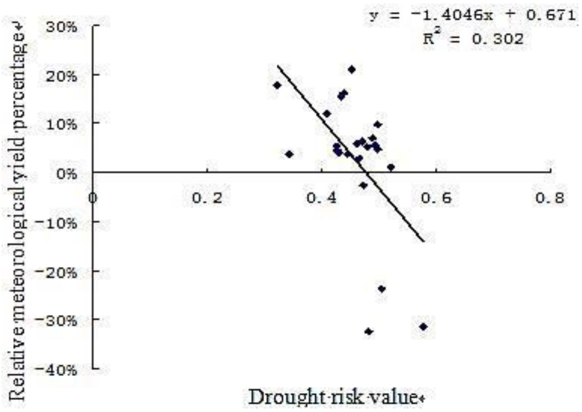


Fig 5: *the percentage relation of drought disaster risk value and relative meteorological yield in jointing – earing*

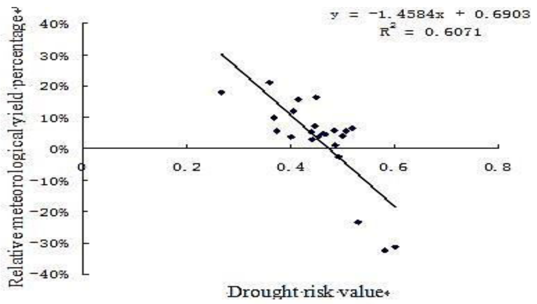


Fig 6*: the percentage relation of drought disaster risk value and relative meteorological yield in earing – filling*

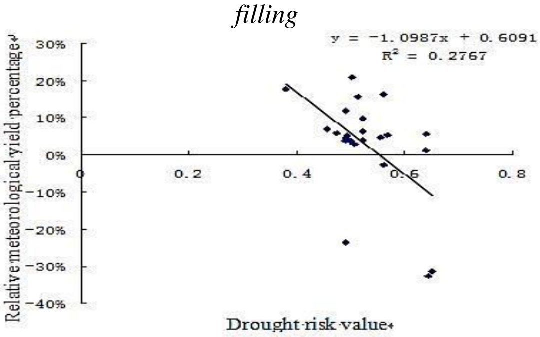


Fig 7*: the percentage relation of drought disaster risk value and relative meteorological yield in filling – mature*

The relation is built between drought risk and yield through correlation analysis, yield wave resulted by drought risk is estimated through drought risk evaluation. Usually disaster condition forms when relative meteorological yield value is less than -5%, it is called disaster forming year [10]; drought level is light when relative meteorological yield value is between -10%~5%; drought level is middle when relative meteorological yield value is between -20%~-10%; drought level is high when relative meteorological yield value is between -30%~-20%; drought level is extreme when relative meteorological yield value is less than -30%. Risk threshold in every growth stage is determined according to these, shown in table 5.

Table 5: *drought disaster risk threshold and risk level classification of maize different growth stages in Meitan*

Growth stage	Risk threshold and risk level			
	Light risk	Middle risk	High risk	Extreme risk
Seeding-Emergence	0.501~0.523	0.523~0.567	0.567~0.611	≥0.611
Emergence -jointing	0.562~0.602	0.602~0.680	0.680~0.759	≥0.759
Jointing -earing	0.513~0.549	0.549~0.620	0.620~0.691	≥0.691
Earing -filling	0.508~0.542	0.542~0.610	0.610~0.679	≥0.679
Filling -mature	0.600~0.645	0.645~0.736	0.736~0.827	≥0.827

4. Time distribution of maize drought disaster threshold

Sensitivity for drought is different in maize different growth stages; the critical risk value that drought disaster occurs is different even though the condition is same. Time distribution of maize drought disaster threshold is critical drought risk value in maize each growth period distribute situation when relative meteorological yield value is less than -5%, maize reduce degree reaches disaster forming level. The less the critical drought risk value is, the more the possibility of maize reducing yield due to drought is.

From figure 4, when reducing yield degree due to drought reaches disaster forming level, that is reducing rate is up to 5%, critical risk value is minimal in seeding-emergence stage, this is initial life in total growth period, maize is strict to all kinds of condition, especially temperature and water. Maize can't be seeded and emergence if drought occurs, it will influence further growth and yield, maize reducing yield occurs easily, so critical risk value is minimal; earing –filling is maize water critical period, maize is sensitive to water and require water most, if temperature condition is abnormal and water is inadequacy, it will influence seeds volume enlargement and dry matter transport and accumulation, the final yield is influenced extremely; jointing –earing is maize most vigorous growth period, water need enlarge rapidly, it is water need critical period in total life, if drought occurs, it made plant vegetative mass small, aerial root can't grow successfully, tassels from infertile pollens, tassels can't ear in time, female grow are hindered.

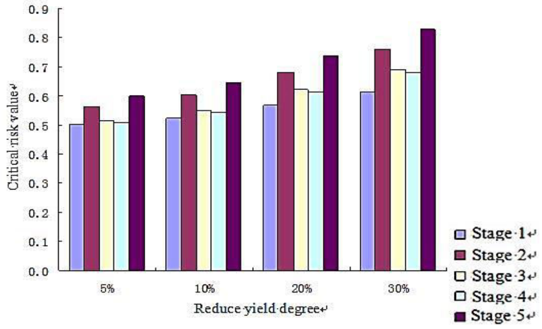


Fig 8: *the critical drought risk value in maize different growth stage*

If the situation occurs, loss resulted can't remedy even though water supply enough; plant is smaller, leaf area is small, evaporation is low, water need is less in emergence – jointing, seed root expand deeply, so drought resist ability is strong, the disaster year due to drought forms when risk value reaches 0.562; dry matter total and seed volume reaches maximum, dry matter accumulate stop, dehydration happens primarily, when maize is filling –mature. So the maize drought critical value is larger, the disaster year due to drought forms when risk value reaches 0.6; the critical risk vale distribution of each growth stage when reducing rate reaches 10%, 20%, 30% is same to it when reducing rate reaches 5%.

5. Conclusions

The evaluate model is built based on natural disaster risk theory from four factors of hazard, exposure, vulnerability and drought resistant ability, and drought disaster risk value of maize each growth stage in Meitan can be obtained. The relative meteorological yield is separated from maize real yield; the relation analysis is done between each growth stage risk value and relative meteorological yield, the relation is established between risk value and yield. The risk threshold and risk level of maize different growth stage are defined according to agricultural disaster forming condition, drought level standards and relation equation of risk value and yield, drought disaster threshold is analyzed in maize different growth stage. Seeding-emergence period is influenced by drought mostly, reducing yield occurs easily; the possibility of reducing yield due to drought is more in earing –filling and jointing –earing period. According to history material statistic and drought disaster real situation in Meitan, drought frequency is higher in summer; drought often occurs in spring, it shows that maize drought disaster risk threshold definition in different growth stage and relative analysis results are convincible in certain degree, which is fit for real situation in Meitan.

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