

Application of Modified Fisher Integral Model on the Influence of Meteorological Factors on Peanut Yield in Hebei of China

Wang Yu¹, Xu Shiwei^{2*}, Yu Wen², Ahmed Abdul-Gafar¹, and Xiao Guogang³

¹Key Laboratory of Intelligent Agricultural Early Warning Technology and System of Chinese Academy of Agricultural Sciences, Beijing 100081, China

²Agricultural Information Institute of Chinese Academy of Agricultural Sciences, Beijing 100081, China

³Key Laboratory of Agricultural Information Service Technology of Ministry of Agriculture, Beijing 100081, China

Abstract

The Fisher integral model and Chebyshev orthogonal polynomials were used to analyze the Model coefficient between meteorological factors (temperature, precipitation, and sunshine hours) and the peanut yield in Hebei province. The data used in the model was collected from 20 meteorological stations and the National Bureau of Statistics of China from 1980 to 2012 in Hebei. We found the following results: 1) the relationship between precipitation and peanut meteorological yield was positive in June and was negative in May and July. The peanut meteorological yield is expected to increase by 3.65kg/ha with 1mm increase of precipitation in June; 2) the relationship between temperature and peanut meteorological yield was positive in June and was negative in May and July. In June, the peanut meteorological yield is expected to increase by 1.52kg with 1°C increase in temperature; 3) sunshine hours and peanut meteorological yield shows a positive relationship in May, July, and September. The peanut meteorological yield is expected to increase by 2.51kg, 2.44kg and 5.11kg with an hour increase in sunshine in these months. Based on these relationships, the model in this study stands as a guide to improve peanut production and forecast peanut yield for the near future.

Keywords: *peanut yield; meteorological factors; integral regression; orthogonal polynomials; forecast*

1. Introduction

China is the world's largest peanut producer and consumer and also the largest exporter (Wu and Zhou, 2005). The peanut area sowed ranks second for oil crops. However, total production of peanut ranks first, and it is one of the most important oil crops in China. The oil content in peanut is more than 50%, which makes it one of the major oil-bearing crops in the country. Taking Hebei province for example, which is one of the largest

peanut-producing provinces in China, the total output of peanut and the area sown both rank third. However, the yield is relatively low when compared with some productive countries such as Israel, Egypt, and the United States. This indicates that there is still high potential for yield increase. Enhancing the peanut yield level is an important measure to increase self-sufficiency of oil crops in the country. Edible oil and oilseed is the largest

* Corresponding author: xushiwei@caas.cn

agricultural product imported into the country (Wan, 2008). It is critical to study how to improve peanut yield, as this not only increases self-sufficiency but also reduces cost of importation and oil supply tension in China.

Peanut production in the country faces several challenges, including increasing demand as a result of increase in population and decreasing cultivated area due to the effects of environmental change and urbanization (Zhou and Dong, 2012; Yu, 2014). Increasing cultivated area to increase output is impossible because of land scarcity. Thus, increase in output should center more on scientific methods of increasing peanut yield. National and international researchers have been exploring methods to enhance peanut yield but have mainly concentrated on breeding, cultivation pattern, water management, insects and pests, and other comprehensive control, drought resistance and so on (Suprpto et al., 2013; Atayde et al., 2012; Zorzete et al., 2011; Grichar et al., 2010; Nakai et al., 2008; Haro et al., 2013; Phakamas et al., 2008; Putto et al., 2009; Anothai et al., 2009; Chang and Sung 2004; Rosas-Anderson et al., 2014; Woli et al., 2013; Zhang et al., 2012; Abou, 2009; Basu et al., 2008; Bogino et al., 2011; Haro et al., 2008; Haro et al., 2007). All these methods discuss the different factors influencing peanut yield but ignore the influence of meteorological factors on the growth process. This research is based on multiple effect analysis of influential factors on peanut yield, using sunshine, rainfall, and temperature conditions to identify suitable conditions for higher peanut yield during the whole growth period. The changes in meteorological factors are one of the crucial factors affecting the growth of peanut plant, and thus its yield, as shown by many production practices and scientific research. The whole growth period of peanut from sowing to harvest can be divided into five important stages including seedling, flowering, and pod and ripening stage. All these stages have specific requirements of each meteorological condition. Few scholars have done basic research on the relationship between meteorological conditions and peanut yield at different stages (Jon-grungklang et al., 2013). However, most is qualitative or simple statistical comparison research, revealing the relationship between peanut yield and meteorological condition without a mathematic model (Jyostna et al., 2009). This neither

accurately addresses the influences of meteorological factors on different growth periods of peanut nor provides accurate projections for peanut yield. Peanut has the characteristics of thermophilic, drought enduring, and non-waterlogged plants. Thus, appropriate meteorological factors are needed to support its growth and development (Naab et al., 2005; Branch and Culbreath, 2013; Chahal et al., 2012; Culbreath et al., 2013; Dey et al., 2004). It is important to build a scientific mathematical model that would forecast peanut yield systematically and provide a guide to peanut yield improvement.

In this research, we used three meteorological factors and the peanut yield of Hebei from 1980 to 2011. Smoothing average method was employed to calculate the trend output. The research used detached meteorological output as a dependent variable and the same period meteorological factors as independent variables. The relationships between these variables were analyzed using the Improved Fisher Integral algorithm to determine the effect of sunshine duration, precipitation, and temperature on meteorological yield during the whole peanut growth stage. This method is the first of its kind used on Hebei peanut yield. In order to precisely assess the influence of the meteorological factors on peanut yield, we calculated the coefficient of the influencing meteorological yield and built the peanut yield model that can predict peanut production in Hebei Province of China.

2. Materials and Methods

2.1 Source of Data

The 32 years' worth of peanut yield data from 1980-2011 was extracted from the National Bureau of Statistics (NBS) of the People's Republic of China (NBS, 2014). The meteorological data of the same period was extracted from 20 weather stations of the China Meteorological Data Sharing Service System (CMDSSS) (CMDSSS, 2014), and the original meteorological data include sunshine hours daily (0.1 hour), precipitation observation time starts from 8:00 pm to 8:00 pm the next day daily, average temperature (0.1°C). These data were later transformed into monthly data that is the monthly cumulative sunshine hours, precipitation, and temperature which would henceforth be used

as sunshine hours (h), precipitation (mm) and temperature ($^{\circ}\text{C}$).

2.2 Research Methods

In the research of the statistic relationship between meteorological factors and crop production, researchers often decompose the yield into tendency yield, meteorological yield and random error (NBS, 2014). Tendency yield is used to measure the progress in management. Technology contributes to output, which is also called technological yield, and reflects all the unnatural factors of crop yield components. The meteorological yield is only caused by the meteorological conditions. Many factors affect peanut yield, including soil variety, plant density, pruning, fertilization, meteorological factors, and more. In order to effectively analyze the influence of the meteorological factors on peanut yield, other factors should be excluded by separating the trend yield, which is often adopted by researchers. The meteorological yield (variable to be analyzed) was calculated using actual yield and trend yield, which is affected by the changes in meteorological factors (CMDSSS, 2014). The meteorology output will be different when using different measures to separate trend yield (Fang 2011). Trend yield was separated from the peanut yield by smoothing average method based on the practical considerations of social technology, management, and other aspects during the different stages (Xu et al., 2013a; 2013b).

The meteorological factors in the growth stages on peanut yield were analyzed in this paper, and the data on sunshine hours, precipitation, and temperature from April to September (life cycle period) was chosen; and the separated meteorological variable was used as the independent variable. In this way, we used the modified Fisher integral regression method and orthogonal polynomial transform method to analyze the effects on peanut yield. According to Baier theory, we can define meteorological yield as the multiplication of the different meteorological factor' The Baier crop weather model is as follows:

$$\widehat{y}_w = \sum_{i=1}^n a_i \cdot y_{i1} \cdot y_{i2} \cdot y_{i3}$$

The $\widehat{y}_w$ represents the meteorological yield of a crop; a_i stand for the different weight function of meteorological factor; $i = 1, 2, \dots, n$ represents different time phases;

In this paper, peanut growth stage from April to September was chosen as an integral growth period. The Baier like Meteorological Model becomes:

$$\widehat{y}_w = a \cdot y_1 \cdot y_2 \cdot y_3 \quad [1]$$

The average weight coefficient was chosen as weight coefficient and equation [1] could be changed to:

$$\widehat{y}_w = \sqrt[3]{y_1 \cdot y_2 \cdot y_3} \quad [2]$$

In the equation above, y_1, y_2, y_3 stand for the relationships between meteorological factors (i.e., sunshine hours, precipitation, and temperature) and the meteorological yield. The linear equation of one unknown was employed to express the relationship between them, and the equation is as follows:

$$y_i = c_i + a_i(t) \cdot x_i(t) \quad [3]$$

The $i=1, 2, 3$ represents meteorological factors; “ t ” stand for different periods of peanut growth, namely the stages from April to September; $x_i(t)$ represents the values of meteorological factors in one growth stage; c_i is the constant term of the regression equation; $a_i(t)$ is the regression coefficient of the independent variables, which is a function of the peanut growth stage as well as the function of time, so we can choose the method of orthogonal polynomial approximation.

With reference to Fisher integral regression model,

$$\widehat{y}_1 = c_i + \sum_i \int_0^{\tau} a_i(t) \cdot x_i(t) dt \quad [4]$$

In the function above, c_i stands for constant term; “ τ ” as the growth period from April to September, the effects of the meteorological factors were analyzed in this paper.; “ t ” stands for the time variable in a growth period, and according to this research, $t = 30$ days was chosen as the period of time, $x_i(t)$ represents a growth period of certain value of each meteorological element; $a_i(t)$ is the function of time denoting the coefficient of the meteorological yield.

In the actual process of calculation, the discrete form of integral model is usually adopted. In other words, Chebyshev Orthogonal polynomial will be used to change the above equation [4] into the following function;

$$\hat{y}_i = c_i + \sum_j a_{ij} \cdot \rho_{ij} \quad [5]$$

And then,

$$\rho_{ij} = \sum_t \varphi_{ij} \cdot x_i(t) \quad [6]$$

In the above equation [6], $j = 1, 2, \dots, 6$, “ φ_{ij} ” could get 6 times orthogonal polynomial at most, and the Chebyshev Orthogonal transformation matrix is as follows,

$$\varphi_{ij} = \begin{bmatrix} 1 & -5 & 5 & -5 & 1 & -1 \\ 1 & -3 & -1 & 7 & -3 & 5 \\ 1 & -1 & -4 & 4 & 2 & -10 \\ 1 & 1 & -4 & -4 & 2 & 10 \\ 1 & 3 & -1 & -7 & -3 & -5 \\ 1 & 5 & 5 & 5 & 1 & 1 \end{bmatrix}$$

Considering the one time equation [3], substituting the equation [6] in [5], the equation below is expected:

$$\left. \begin{aligned} \hat{y}_1 &= c_1 + a_{11} \cdot \rho_{11} + a_{12} \cdot \rho_{12} + \dots + a_{1K} \cdot \rho_{1K} \\ \hat{y}_2 &= c_2 + a_{21} \cdot \rho_{21} + a_{22} \cdot \rho_{22} + \dots + a_{2K} \cdot \rho_{2K} \\ \hat{y}_3 &= c_3 + a_{31} \cdot \rho_{31} + a_{32} \cdot \rho_{32} + \dots + a_{3K} \cdot \rho_{3K} \end{aligned} \right\} \quad [7]$$

“K” is the chosen period of time, which is 6 in this paper. Ordinary Least Square (OLS) was used to calculate the coefficient of the Integral regression model in equation [7]. The coefficients in the model represent the influential factors on meteorological yield during the different growth stages.

3. Results

3.1 Calculation of Trend Production

This paper applies a 3-year smoothing average to separate tendency yield, using the following function:

$$\dot{y}_k = \frac{y_{k-1} + y_k + y_{k+1}}{3} \quad [8]$$

$\dot{y}_k$ denotes the k^{th} year's tendency yield, y_k denotes the k^{th} year's peanut yield. By subtracting the tendency yield from actual yield ($y_k - \dot{y}_k$) we derived the meteorological yield, which is used as

the dependent variable $\hat{y}_W$. The actual yield, tendency yield, and meteorological yield from 1980 to 2011 in Hebei province are shown in the table below.

3.2 Calculation of Integral Regression

The meteorological yield calculated in the Table 1 is the dependent variable, considering the whole growing period of peanut in Hebei within the period April to September.

3.3 Calculation of Coefficient

By applying equation [3], the partial derivative of peanut meteorological yield on various meteorological factors is calculated as $\frac{\partial y_i}{\partial x_i}$, which stands for the elasticity of meteorological factors on meteorological yield using the equation below:

$$\begin{cases} \frac{\partial y_1}{\partial x_1} = a_1(t) \\ \frac{\partial y_2}{\partial x_2} = a_2(t) \\ \frac{\partial y_3}{\partial x_3} = a_3(t) \end{cases} \quad [9]$$

Based on this calculation, we conclude that the coefficient $a_i(t)$ in different stages of peanut of the whole growth periods is the elasticity, which is used to measure the impact of different meteorological factors on meteorological yield in different periods.

3.4 Peanut Yield Model

By substituting equation [7] in equation [2], we have the peanut meteorological yield model as follows:

$$\hat{y}_W = \sqrt[3]{\hat{y}_1 \cdot \hat{y}_2 \cdot \hat{y}_3} \quad [10]$$

By substituting equation [10] in $\hat{y}_W = y_k - \dot{y}_k$, then we have Hebei peanut yield model as follows:

$$\begin{aligned} y_k &= \hat{y}_W + \dot{y}_k \\ y_k &= \sqrt[3]{\hat{y}_1 \cdot \hat{y}_2 \cdot \hat{y}_3} + \frac{y_{k-1} + y_k + y_{k+1}}{3} \end{aligned} \quad [11]$$

where,

$$\begin{aligned}\hat{y}_1 &= -175.49 - 0.2269 \cdot \sum_t \varphi_{11} \cdot x_1(t) - 3.0541 \cdot \sum_t \varphi_{12} \cdot x_1(t) + 3.6468 \cdot \sum_t \varphi_{13} \cdot x_1(t) - 3.2899 \cdot \sum_t \varphi_{14} \cdot x_1(t) + 1.9021 \\ &\quad \cdot \sum_t \varphi_{15} \cdot x_1(t) - 1.2836 \cdot \sum_t \varphi_{16} \cdot x_1(t) \\ \hat{y}_2 &= -1408.86 + 0.1387 \cdot \sum_t \varphi_{21} \cdot x_2(t) - 1.3853 \cdot \sum_t \varphi_{22} \cdot x_2(t) + 1.5159 \cdot \sum_t \varphi_{23} \cdot x_2(t) - 2.4215 \cdot \sum_t \varphi_{24} \cdot x_2(t) - 0.7187 \\ &\quad \cdot \sum_t \varphi_{25} \cdot x_2(t) + 0.6697 \cdot \sum_t \varphi_{26} \cdot x_2(t) \\ \hat{y}_3 &= 563.17 - 0.1088 \cdot \sum_t \varphi_{31} \cdot x_3(t) + 2.5088 \cdot \sum_t \varphi_{32} \cdot x_3(t) - 1.3555 \cdot \sum_t \varphi_{33} \cdot x_3(t) + 2.4362 \cdot \sum_t \varphi_{34} \cdot x_3(t) - 0.7494 \\ &\quad \cdot \sum_t \varphi_{35} \cdot x_3(t) + 5.1135 \cdot \sum_t \varphi_{36} \cdot x_3(t)\end{aligned}$$

Table 1

Various yield of peanut from 1980 to 2011 [Unites: kg/ha]

	1980	1981	1982	1983	1984	1985	1986	1987
Yield	1508	1343	1440	1448	1658	1755	1395	1725
Trend Yield		1289.44	1367.66	1445.87	1524.09	1602.31	1680.53	1758.75
Meteoro-logical Yield		53.561	72.343	2.126	133.908	152.69	-285.528	-33.746
	1988	1989	1990	1991	1992	1993	1994	1995
Yield	1530	1605	1950	2010	1645	2110	2484	2548
Trend Yield	1836.96	1915.18	1993.40	2071.62	2149.84	2228.05	2306.27	2384.49
Meteoro-logical Yield	-306.963	-310.181	-43.399	-61.617	-504.835	-118.052	177.73	163.512
	1996	1997	1998	1999	2000	2001	2002	2003
Yield	2686	2672	2787	2741	2862	2918	2927	3026
Trend Yield	2462.71	2540.92	2619.14	2697.36	2775.58	2853.80	2932.01	3010.23
Meteoro-logical Yield	223.29	131.08	167.86	43.64	86.12	63.81	-5.01	16.17
	2004	2005	2006	2007	2008	2009	2010	2011
Yield	3071	3198	3224	3338	3417	3438	3517	3579
Trend Yield	3088.45	3166.67	3244.88	3323.10	3401.32	3479.54	3557.76	3635.97
Meteoro-logical Yield	-17.25	31.43	-21.08	14.50	16.08	-41.54	-40.36	-57.07

Table 2Integral regression coefficient $a_i(t)$ of all kinds of meteorological factors in different periods and constant term c_i

Meteorological Factors	Coefficient	Period (t)						Constant term c_i
		1	2	3	4	5	6	
Precipitation	$a_1(t)$	-0.2269	-3.0541	3.6468	-3.2899	1.9021	-1.2836	-175.49
Temperature	$a_2(t)$	0.1387	-1.3853	1.5159	-2.4215	-0.7187	0.6697	-1408.86
Sunshine	$a_3(t)$	-0.1088	2.5088	-1.3555	2.4362	-0.7494	5.1135	563.17

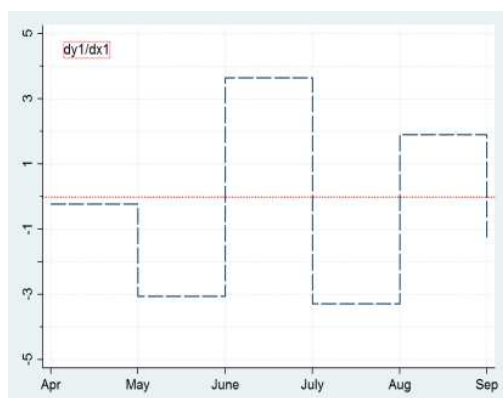
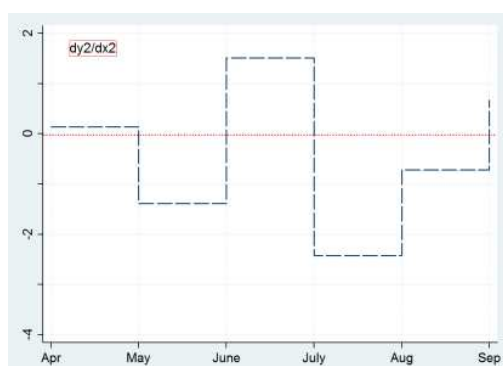
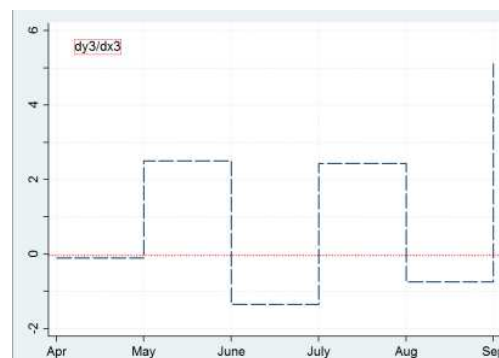
Table 3

Average value of Meteorological factors from 1980 to 2011 and yield change rate in different period

Meteorological Factors		Period (t)					
		1	2	3	4	5	6
Precipitation x_1	$\bar{X}_1(t)$	21	39	75	141	114	51
	$\partial y_1 / \partial x_1$	-0.2269	-3.0541	3.6468	-3.2899	1.9021	-1.2836
Temperature x_2	$\bar{X}_2(t)$	12.5	18.9	23.3	25.1	23.7	18.6
	$\partial y_2 / \partial x_2$	0.1387	-1.3853	1.5159	-2.4215	-0.7187	0.6697
Sunshine x_3	$\bar{X}_3(t)$	8.2	8.6	8.1	7.1	7.2	7.5
	$\partial y_3 / \partial x_3$	-0.1088	2.5088	-1.3555	2.4362	-0.7494	5.1135

4. Discussions

According to Table 3, we can draw the meteorological yield change rate in each growth period of peanut, i.e., the influencing coefficients of different meteorological factors as depicted in Figure1-1, Figure1-2 and Figure1-3.

**Figure1-1:** Influence coefficient of precipitation on Peanut yield**Figure1- 2:** Influencing coefficient of temperature on peanut yield**Figure1- 3:** Influencing coefficient of sunshine on peanut yield

4.1 Effect of Precipitation on Peanut Yield

Based on the coefficient between temperature and peanut yield shown in Figure 1-1, peanut meteorological yield is greatly influenced by precipitation in May, June, and July. The coefficient of precipitation on the peanut yield shows negative signs in May in Hebei ($-3.05 \text{ kg} \cdot \text{hm}^{-2} \cdot \text{mm}^{-1}$), which shows that with more rainfall during these periods, peanut yield would be negatively affected. With more rainfall above the required amount, the boot of peanut plant becomes weak, and the seedling becomes yellow. Thus, lesser water in the soil would benefit the booting and seedling. In June, the peanut yield shows a promising positive sign in the region. The estimate shows that peanut yield will increase by 3.65 kg when there is 1 mm increase in precipitation. During this period, the peanut plant requires more water to flower and peg. In July, the coefficient of precipitation on the peanut yield reveals a negative relationship ($-3.29 \text{ kg} \cdot \text{hm}^{-2} \cdot \text{mm}^{-1}$), demonstrating that with increase in precipitation, yield is expected to reduce as a result of hypoxia. During the pod development stage, the peanut plant needs more air in the soil not more water. Moreso, with increased presence of water,

the boot of the peanut becomes weak, and the seedling of the peanut would be yellow.

4.2 Effect of Temperature on Peanut Yield

Based on the coefficient between temperature and peanut yield shown in Figure 1-2, we found that peanut meteorological yield is greatly influenced by temperature in May, June, and July and that the growing of peanut requires a certain amount of accumulated temperature during the whole growth period. On one hand, higher temperature above the normal range shortens the length of the growth period, preventing the plant from getting enough time to accumulate nutrients. As a result of this, yield decreases. On the other hand, an appropriate lower temperature below the normal range lengthens the growth period. Therefore, the plant gets enough time to accumulate nutrients and yield increases as a result.

The coefficient of average temperature on the peanut yield shows negative sign in May ($-1.39 \text{ kg} \cdot \text{hm}^{-2} \cdot \text{mm}^{-1}$), implying that higher temperatures accelerate the growth of the seedling, but a lack of nutrients results in a weak plant. Appropriate lower temperatures in the month relate inversely. The effect of higher temperatures on the peanut yield was negative in May but was positive in June. Peanut yield is expected to increase by 1.52 kg when the precipitation increased by 1°C in June. The average temperature (23.3°C) proves to be suitable for the peanut plant in June ($23\text{--}28^{\circ}\text{C}$) during the flowering and pegging stages. In the July period, the coefficient of average temperature on the peanut yield reveals a negative relationship with peanut yield ($-2.42 \text{ kg} \cdot \text{hm}^{-2} \cdot \text{mm}^{-1}$). With higher temperatures, the number of peanut flower would reduce, thus affecting its yield.

4.3 Effect of Sunshine on Peanut Yield

The influencing coefficient of the sunshine hours on peanut yield during the growth periods is depicted in Figure 1-3, and it explains the following results: the sunshine also greatly influenced peanut yield the same way temperature affects peanut meteorological yield but in May, July, and September. The coefficient of sunshine on the peanut yield shows a positive relationship in May. Peanut yield is expected to increase by 2.51 kg with an hour increase in sunshine.

The effect of longer sunshine on the peanut plant introduces multi branches, early flowering, and

blossoms, which in turn increase yield. The coefficient of sunshine reveals positive relationship in May as confirmed by the above-mentioned agronomy. The coefficient of sunshine on the peanut yield was positive in July; peanut yield is expected to increase by 2.44 kg when the sunshine increased by an hour. In July, the average sunshine hours were low in Hebei, the plant demand for sunshine would increase for photosynthesis. Thus, the greater the sunshine hours, the healthier the peanut plant. The coefficient of sunshine on the peanut yield was also positive in September; peanut yield will increase by 5.11 kg , as the sunshine increased by an hour. The ample sunshine is conducive to the full weight of the pods and kernels.

4.4 Discussion of Peanut Yield Model in Hebei

Hebei peanut production (2002 - 2012) accounted for 7.6% of the nation's total peanut output (Dey et al., 2004). As mentioned earlier, Hebei has been one of the most important peanut producing provinces. Meteorological data (sunshine hours, precipitation, and temperature) of Hebei was collected from CMDSSS in 2012 and was used in model. The calculated value of meteorological yield was 47.36 kg/ha , Trend yield 3714.19 kg/ha was derived by the use of the trend extrapolation method. Using the Hebei peanut yield model equation [11], we got an actual yield (3761.55 kg/ha) in 2012, and practical peanut yield data collected from NBS of the People's Republic of China in 2013 shows (3581 kg/ha) with only 4.8% error indicating the high accuracy of Hebei peanut yield model.

5. Conclusion and Prospect

A Modified Fisher Integral Regression model was used to analyze the impact and relationship between the meteorological factors and the meteorological yield, which can be used for guiding the production of peanut in Hebei. The findings reveal that the meteorological factors have a great influence on peanut yield. For instance, during the early stages (in May), the precipitation and temperature relates negatively to yield but sunshine hours was positive. During the vegetation period (June and July) in June, precipitation relates positively and temperature relates negatively to yield. In July, both precipitation and temperature have a negative relationship to yield. The strongest impact of

precipitation and temperature was observed more in June and July while the impact of sunshine hours was stronger towards the maturing and harvesting stage.

Based on the relative effects of temperature, precipitation, and sunshine hours on yield, the model in this study stands as a guide for peanut production and forecasting peanut yield more accurately. This paper focuses on the autumn peanut production in Hebei. Nevertheless, as a future research direction,

spring peanut production can be examined by the same model in this paper but in different meteorological periods. Other provinces could also use this model to study peanut production while considering other meteorological factors such as wind. If daily meteorological data can be fitted in this model and soil temperature considered as another factor, maybe more precise results could be achieved.

Reference

- Abou K. A. (2009), "Macromanagement of deficit-irrigated peanut with sprinkler irrigation", *Agricultural Water Management*, Vol. 96 No.10, pp. 1409-1420
- Anothai J., Patanothai A., Pannangpetch K., Jogloy S., Boote K., and Hoogenboom G. (2009), "Multi-environment evaluation of peanut lines by model simulation with the cultivar coefficients derived from a reduced set of observed field data". *Field Crops Research*, Vol. 110 No. 2, pp. 111-122
- Atayde D, Reis T, Godoy I, Zorzete P, Reis G. and, Corrêa B. (2012), "Mycobiota and aflatoxins in a peanut variety grown in different regions in the state of são paulo, brazil". *Crop Protection*, Vol. 33, pp. 7-12
- Basu M., Bhadoria P., and Mahapatra S..((2008), "Growth, nitrogen fixation, yield and kernel quality of peanut in response to lime, organic and inorganic fertilizer levels", *Bioresource Technology*, Vol., 99 No. 11, pp. 4675-4683
- Bogino P., Nieves F., Banchio E., and Giordano W. (2011), "Increased competitiveness and efficiency of biological nitrogen fixation in peanut via in-furrow inoculation of rhizobia", *European Journal of Soil Biology*, Vol. 47 No. 3, pp. 188-193
- Branch W., and Culbreath A. (2013), "Yield performance and pest resistance among peanut genotypes when grown without fungicides or insecticides", *Crop Protection*, Vol., 52, pp. 22-25
- Chahal G., Jordan D., Brandenburg R., Shew B., Burton J., Danehower D, and et al, (2012), "Interactions of agrochemicals applied to peanut; part 3: effects on insecticides and prohexadione calcium", *Crop Protection*, Vol. 41 No.41, pp. 50-57
- Chang C., and Sung J. (2004), "Nutrient uptake and yield responses of peanuts and rice to lime and fused magnesium phosphate in an acid soil". *Field Crops Research*, Vol. 89, No.2-3, pp. 319-25
- CMDSSS: China Meteorological Data Sharing Service System (2014), <http://cdc.cma.gov.cn>.
- Culbreath A., Tubbs R., Tillman B., Beasley J., Branch W., Holbrook C. and et al. (2013), "Effects of seedling rate and cultivar on tomato spotted wilt of peanut", *Crop Protection*, Vol. 53, pp.118-124
- Dey R., Pal K., Bhatt D., Chauhan S., (2004), "Growth promotion and yield enhancement of peanut (*arachis hypogaea* l.) by application of plant growth-promoting rhizobacteria", *Microbiological Research*, Vol. 159 No. 4, pp. 371-394
- Fang S,(2011), "Exploration of method for discrimination between trend crop yield and climatic fluctuant yield", *Journal of Natural Disasters*, Vol. No.6, pp.13-18
- Grichar W., Dotray P., and Baughman T. (2010), "Peanut variety response to postemergence applications of carfentrazone-ethyl and pyraflufen-ethyl", *Crop Protection*, Vol. 29 No. 9:pp. 1034-1038
- Haro R., Baldessari J, and Otegui M.(2013), "Genetic improvement of peanut in argentina between 1948 and 2004: seed yield and its components", *Field Crops Research*, Vol. 149 No. 76-83

- Haro R., Dardanelli J., Otegui M, and Collino D. (2008), "Seed yield determination of peanut crops under water deficit: soil strength effects on pod set, the source–sink ratio and radiation use efficiency", *Field Crops Research*, Vol. 109 No. 1-3, pp.24-33
- Haro R., Otegui M., Collino D, and Dardanelli J. (2007), "Environmental effects on seed yield determination of irrigated peanut crops: links with radiation use efficiency and crop growth rate", *Field Crops Research*, Vol. 103, No. 3, pp. 217-228
- Jongrunklang N., Toomsan B., Vorasoot N., Jogloy S., Boote K., Hoogenboom G, and Et Al.(2013), "Drought tolerance mechanisms for yield responses to pre-flowering drought stress of peanut genotypes with different drought tolerant levels", *Field Crops Research*, Vol, 144, pp. 34-42
- Jyostna D. M., Sinclair T., Vadez V. and Krishnamurthy L. (2009), "Peanut genotypic variation in transpiration efficiency and decreased transpiration during progressive soil drying", *Field Crops Research*, Vol. 114 No. 2, pp. 280-285
- Naab J., Tsigbey F., Prasad P., Boote K., Bailey J., and Brandenburg R. (2005), "Effects of sowing date and fungicide application on yield of early and late maturing peanut cultivars grown under rainfed conditions in ghana", *Crop Protection*, Vol. 24 No. 4, pp. 325-332
- Nakai V., De Oliveira R. L, Gonçalves E, Fonseca H, Ortega E. and Corrêa B.(2008), "Distribution of fungi and aflatoxins in a stored peanut variety", *Food Chemistry*, Vol. 106 No. 1: pp. 285-290
- NBS: National Bureau of Statistics of the People's Republic of China(2014), <http://www.stats.gov.cn/tjsj/>
- Phakamas N., Patanothai A., Pannangpetch K., Jogloy S., and Hoogenboom G. (2008), "Dynamic patterns of components of genotype × environment interaction for pod yield of peanut over multiple years: a simulation approach", *Field Crops Research*, Vol. 106 No. 1, pp. 9-21
- Putto C., Patanothai A., Jogloy S., Pannangpetch K., Boote K., and Hoogenboom G. (2009). "Determination of efficient test sites for evaluation of peanut breeding lines using the csm-cropro-peanut model", *Field Crops Research*, Vol. 110, No. 3, pp. 272-281
- Rosas-Anderson P., Shekoofa A., Sinclair T., Balota M., Isleib T. and Tallury S.. (2014), "Genetic variation in peanut leaf maintenance and transpiration recovery from severe soil drying", *Field Crops Research*, Vol. 158, pp. 65-72
- Suprpto, A., Sugito Y., Sitompul S.M., and Sudaryono.(2013), "Study of growth, yield and radiation energy conversion efficiency on varieties and different plant population of peanut", *Procedia Environmental Sciences*, Vol. 17, pp.37-45
- Wan S..(2008), "Attach importance to peanut production and insure the oil security", *Journal of Peanut Science*, Vol. 37 No.3, pp. 1-4
- Woli P., Paz J., Hoogenboom G., Garcia Y., Garcia A, and Fraisse C. (2013), "The enso effect on peanut yield as influenced by planting date and soil type", *Agricultural Systems*, Vol. 121, pp. 1-8
- Wu Q., and Zhou K..(2005), "The peanut production situation and competition ability analysis of anhui province", *Journal of Anhui Agricultural Science*, Vol. 33 No.1, pp. 164-165
- Xu S., Yu W., Liu S., Ahmed A., and Wang Y. (2013a), "Meteorological impact on the winter wheat yield in weishan, china", *Journal of Applied Sciences*, Vol. 13 No. 14, pp. 2740-2743
- Xu S., Yu W., Liu S., Zhang S., and Wang Y., (2013b), "The impact of meteorological factors on the winter wheat yield - the case from weishan county, shandong province", *Journal of Agriculture*, Vol. 3 No.10, pp. 45-51
- Yu L., (2014), "Low carbon eco-city: new approach for chinese urbanisation", *Habitat International*, Vol. 44, pp. 102-110
- Zhang H., Liu Q., Yu X., Lü G. and Wu Y. (2012), "Effects of plastic mulch duration on nitrogen mineralization and leaching in peanut (arachis hypogaea) cultivated land in the yimeng mountainous area, china", *Agriculture, Eco-systems & Environment*, Vol. 158, pp. 164-71

Zhou Z. and Dong X.,(2012) "Analysis about the seasonality of china's crude oil import based on x-12-arima", *Energy*, Vol. 42, pp. 281-288

Zorzete P., Reis T., Felício J, Baquião A, Makimoto P, and Corrêa B. (2011), "Fungi, mycotoxins and phytoalexin in peanut varieties, during plant growth in the field", *Food Chemistry*. Vol., 129 No. 3, pp. 957-964