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Statistical Analysis of the Implementation of Resource-saving Technologies for Rapeseed Production in Southeastern Kazakhstan

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Abstract. Rapeseed production has grown in Republic of Kazakhstan nowadays because of the variety of existing possibilities for the rapeseed using. New resource-saving technologies for rapeseed growing are implemented in Kazakhstan. For these new technologies it is necessary to know which are the factors that influence the production of rapeseed and how each factor influence the yield and the quality of this culture. The careful study of these factors is necessary for better understudying the process of the growing aimed increasing the yields and quality of the rapeseed in Southeastern Kazakhstan. The principles of rational use of the natural resources of the rapeseed agro-ecosystem at the southeastern part of Kazakhstan are described. Resource-saving technologies for rapeseed growing save significant part of energy costs per unit of rapeseed production and give good opportunities to strengthen the stability of its agro-environmental systems. They also provide important conditions for the natural recovery of agro-ecological factors and soil fertility. It is needed to combine the three basic scientific principles for sustainable development of agro-economics: creating an optimal soil structure, preserving and improving soil fertility; stabilizing ecophysital health status as a whole; optimizing the environmental conditions for rapeseed growing and increasing yields [1, 3]. This paper is one continuation of our previous work [2], where we have started an analysis of the rapeseed production in Republic of Kazakhstan. Here a statistical analysis of data connected with atmospheric characteristics and technological parameters of rapeseed production in Southeastern Kazakhstan is provided and commented in the paper.

Key words: Rapeseed, resource-saving technology, statistical analysis

INTRODUCTION

Rapeseed (*Brassica napus*) is also known as canola, coleseed, colza and rape. In this article we will use the term rapeseed.

Interest in rapeseed production has grown worldwide in recent years.Most of it is grown in China, Canada, Germany, France and others [2]. Rapeseed is grown in Asia since ancient times.

In the Republic of Kazakhstan, rapeseed is grown mainly in the northern regions. For the southeastern part of the country, this is a new crop whose cultivation technology is not yet fully developed and it still doesn't use properly soil and climatic conditions.

This culture contributes to solving the problem of providing the population with vegetable oil and animal fodder. Also rapeseed is an important raw material for the industry. Thus rapeseed has an immense importance as food, feed, and also as a technical and ecological culture. The expansion of sown areas has broad prospects, above all, to increase theproduction of vegetable oil, whose annual consumption should rise from 8.8 to 13.2kg per capita. Rapeseed oil is becoming increasingly important as an alternative to diesel [5,10]. Rapeseed oil is widely used also as feed. The green mass of rapeseed has a high nutritional value - 100kg contains 3.0-3.5kg digestible protein. Factors that prevent the increase of rapeseed production are the high costs of cultivation and low yields which do not provide quick economic return of investments in rapeseed growing [1,3,11].

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Agrarian production of agricultural crops includes energy, labor, materials and raw materials and information resources. Sustainable development of agricultural economy of the Republic of Kazakhstan in the present and future requires the solution of the problems, both to optimize the consumption of resources and to save them [1,3].

It is known that energy resources are classified as fuels and lubricants of different origins [1,3]. In the current conditions of production, consumers most often strive to obtain maximum yields for a short period of time. The imposition of predominantly consumer views on the exploitation of natural resources leads to anthropogenic impact and destruction of ecological equilibrium. [4]. Applied technical tools and technologies for growing crops in agro-ecosystems are aimed at the use of natural resources with maximum intensity [5]. At this stage of agricultural production, the environmental problems of ecosystems are related to local or regional environmental degradation as well as pollution of all environmental components.

The agroecosystem itself has biological productivity or biological capacity. The size of the populations of individual species included in them varies due to the constant changes in abiotic and biotic factors. The size of the population of a species is limited by the amount of resources of an ecosystem that are necessary for its life. Agroecosystem ecological problems are related to the correct choice of science-based technology for growing crops in certain agricultural areas [6].

In our previous study [2], the main objective was to analyze the factors influencing rapeseed production and to find effective methods in developing and introducing new resource-saving technologies for growing oil crops in the foothills of southeastern Kazakhstan. Such resource saving methods include minimal soil treatment technology using elements of intensive technology - herbicides [7]. The use of these elements in the cultivation of agricultural crops enables a significant reduction in the cost of energy per unit of production. It should be borne in mind that the new technologies applied should fit into the biogeochemical cycle of resources and create sustainable agrophytocenoses [8, 9].

STATISTICAL ANALYSIS

Table 1 represents atmospheric characteristics precipitation, temperature and relative humidity for Kazakhstan for the period 2012-2015. Table 2 shows Data for precipitation and rapeseed yield for different cultivation technology for Kazakhstan for the period 2012-2017. For statistical analysis further we use SPSS software and MATLAB software.

First we calculate Pearson's linear correlation coefficients between all pairs of variables. It is well known [12] that the Pearson correlation r is the most widely used correlation statistic to measure the degree of the relationship between linearly related variables. The point-biserial correlation is conducted with the Pearson correlation formula except that one of the variables is dichotomous. The following formula is used to calculate the Pearson r correlation:

$$r = \frac{N\sum xy - \sum(x)(y)}{\sqrt{[N\sum x^2 - \sum(x^2)][N\sum y^2 - \sum(y^2)]}} \quad (1)$$

Here we denote X_1 – Precipitation in mm, X_2 - Air temperature, °C and X_3 - Relative humidity, % (See Table 1). The result is received using SPSS software and it is given on Figure 1. The coefficient r for X_2 and X_1 (-0.28) and for X_2 and X_3 (-0.58) is negative, while for X_2 and X_3 is positive (0.61).

Second for the same variables X_1, X_2, X_3 we plot Kendall's rank correlations between multiple time series. A hypothesis test was conducted to determine which correlations are significantly different from zero. Kendall rank correlation is a non-parametric test that measures the strength of dependence between two variables. If we consider two samples, a and b, where each sample size is n, we know that the total number of pairings with a b is $n(n-1)/2$. The following formula is used to calculate the value of Kendall rank correlation:

$$\tau = \frac{n_c - n_d}{\frac{1}{2}n(n-1)} \quad (2)$$

The results are given on Figure 2. The correlation coefficients highlighted in red indicate which pairs of variables have correlations significantly different from zero. For these time series, all pairs of variables have correlations significantly different from zero.

Table 2 represent data for precipitation (X_1) and rapeseed yield (Y) for different cultivation technology (D_1, 1 – traditional technology, 2 – mini-till technology in a depth 16-18cm, 3 -– mini-till technology in a depth 11-14cm) for Kazakhstan for the period 2012-2017. From the Table 2 and from the chart below (Figure 3), we can see from the variables for 2015 no high precipitation values are actually observed. These increased yields are the result of the high rainfall reported in the autumn of the previous year i.e. the yield is obviously influenced not only by the measured rainfall in this year, but also the meteorological characteristics over the past periods (so-called lag in forecasts). Also from Figure 3 it follows that the most perspective are Technologies 2 and 3.

Further we create statistical models for yield of rapeseed production in Southeastern Kazakhstan.

TABLE 1. Data for precipitation, temperature and relative humidity for Kazakhstan for the period 2012-2015.

Month	Precipitation, mm	Air temperature, ºC	Relative humidity, %	**Year**	Month	Precipitation, mm	Air temperature, ºC	Relative humidity, %	**Year**
t	X_1	X_2	X_3	Y_i	t	X_1	X_2	X_3	Y_i
January	22.2	-10.2	48	**2012**	January	53.7	-4.3	68	**2014**
February	18.2	-6.0	40		February	38.8	-13.6	57	
March	50.5	2.0	55.6		March	48.6	3.6	58	
April	26.3	15.6	56.3		April	106.7	10.1	66	
May	42.2	18.6	58.5		May	58.8	18.6	49	
June	24.7	23.5	51.8		June	35.3	23	39	
July	34.1	23.7	53.7		July	4.2	24.5	32	
August	6.5	23.4	50.7		August	4.2	24.1	30	
September	0.5	23.3	49.9		September	10.8	18.0	38	
October	8.9	11.6	55		October	175.1	9.4	79	
November	58.3	0.1	59		November	156.4	0.9	60	
December	110.3	-13.6	70		December	31.5	3.3	65	
January	63.3	-9.6	57	**2013**	January	29	-2.5	68	**2015**
February	15.2	-8.8	59		February	25.6	-1.1	60	
March	56.1	3.8	56		March	92.7	4.5	67	
April	13.4	12.3	65		April	112.7	13.5	69	
May	80.7	16.9	60		May	41.2	18.8	47	
June	52.0	21.3	45		June	23.6	22.6	27	
July	32.4	24.9	36		July	6.1	27.3	33	
August	10.5	23.0	30		August	43.2	25.5	37	
September	7.2	19.9	58		September	39.9	19.8	50	
October	21.7	13.4	52		October	31.5	10.5	55	
November	25.0	3.7	61		November	58	1.2	60	
December	58.8	-3.5	68		December	50.3	4.8	68	

We first look at the model including the following three factors:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3,$$

where the dependent variable Y represents rapeseed yield (Yield kg /ha), X_1 - Year - accepts values from the 2012-2017 period, X_2 - the amount of precipitation - independent of rapeseed growing technology, taking 6 different values for the respective years and apparently correlated with the year, X_3 - Technology of cultivation of rape - a categorical variable, taking three different values according to the three types of technology: ***Traditional technology***, ***Mini-tillage at a depth of 16-18cm, Mini-tillage at a depth of 12-14cm***.

TABLE 2. Data for precipitation and rapeseed yield for different cultivation technology for Kazakhstan for the period 2012-2017, 1 – traditional technology, 2 – mini tillage technology in a depth 16-18cm, 3 -– minitillage technology in a depth 11-14cm

Year	**Amount of precipitation, mm/year** (X_1)	**Yeld t/ha** (Y)	**Technology of cultivation of rapeseed D_1**
2012	396.7	13.0	**1**
2013	556.9	13.7	1
2014	559.9	14.3	1
2015	553.0	18.4	1
2016	643.5	18.0	1
2017	666.0	18.3	1
2012	396.7	13.5	2
2013	556.9	14.7	2
2014	559.9	15.5	2
2015	553.0	20.9	2
2016	643.5	19.7	2
2017	666.0	19.6	2
2012	396.7	13.5	3
2013	556.9	14.3	3
2014	559.9	16.1	3
2015	553.0	16.7	3
2016	643.5	19.7	3
2017	666.0	20.9	3

The results obtained using SPSS are as follows:

Significance of factors

We observe negligence (this factor does not contribute to the description of the values of the studied Y variable) of the rainfall factor (Sig. = 0.246> α = 0.05), which can be due to two reasons - the correlation of the rainfall factor with the factor "Year" (from the Collinearity Statistics table -> Tolerance = 0.186, all must be greater than 0.5), making it possible to express one of the variables through the other. The second probable reason lies in the mismatch of the precipitation surge that happened in 2014, and the surge in yields was reflected in the next 2015, which contributed to the lower linear dependence between these two magnitudes.

TABLE 3. Model Summary[b)]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	0.919[a)]	0.845	**0.825**	1.16374	2.241

[a)] Predictors: (Constant), Tech, Year2
[b)] Dependent Variable: *Y*

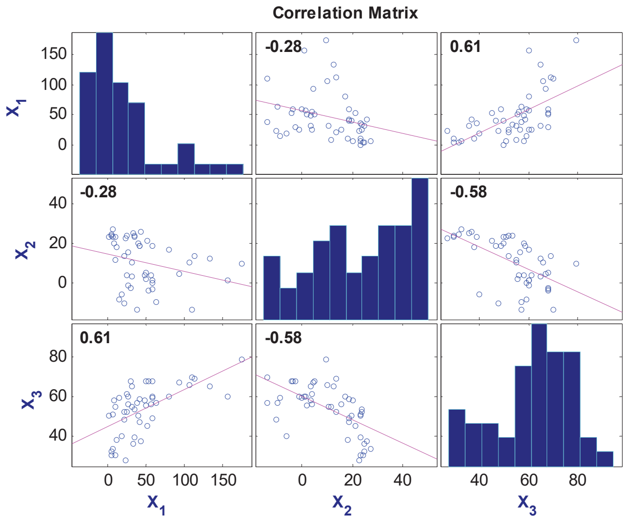

FIGURE 1. Correlation matrix for Pearson correlation coefficient r for the variables X_1 – Precipitation in mm, X_2 - Air temperature, °C and X_3 - Relative humidity, % (See Table 1)

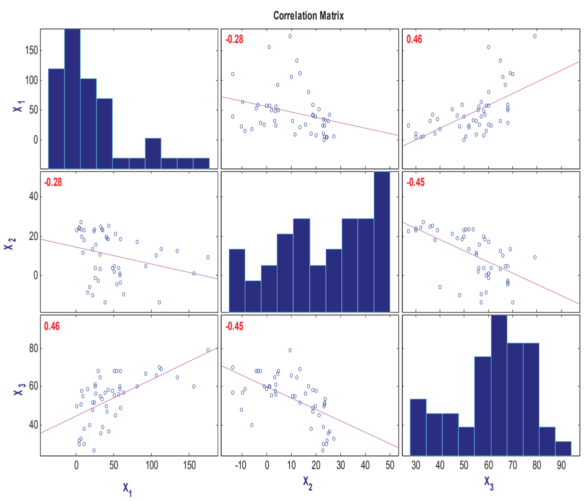

FIGURE 2. Kendall rank correlation for the variables X_1 – Precipitation in mm, X_2 - Air temperature, °C and X_3 - Relative humidity, % (See Table 1)

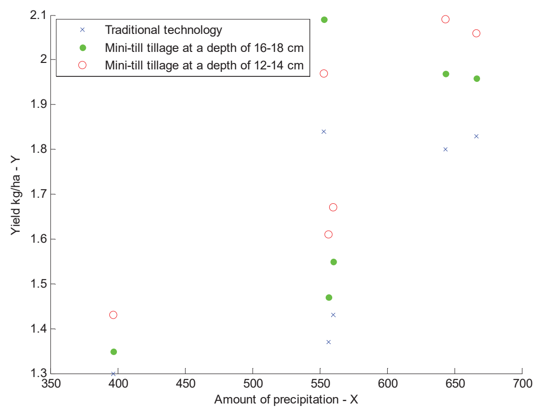

FIGURE 3. Dependence of the rapeseed yield Y on amount of precipitation – X for the different technologies

For this reason, the next stage is to consider the model excluding the factor X_2 from the original. Strength of dependence between dependent and independent variables: Despite the exclusion of one of the factors, there was no change in the determination coefficient $R^2 = 82.5\%$. Which shows that in fact this factor most of the description of the behavior of the dependent variable does not come from an exception factor.

TABLE 4. ANOVA[a)]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	111.015	2	55.508	40.987	0.000[b)]
	Residual	20.314	15	1.354		
	Total	131.329	17			

[a)] Dependent Variable: Y
[b)] Predictors: (Constant), X_3, X_1

Verification of adequacy of the model:

The ANOVA Table 4 shows the results of the regression model residue analysis, which is also a criterion for the adequacy of the model. The F-statistics and significance level of this statistic, Sig = 0.000 <0.05, indicate that the residues correspond to the requirements for normal linear regression analysis, the basics of which are - the residues are independent, normally distributed, describing the influence of random factors on the behavior of the dependent variable Y. The choice of such a model is appropriate, establishing a link between variables (dependent Y and independent X_i):

From the last table follows that both remaining variables are significant. The constant with sigma level = 0.069> 0.05 can be excluded from the model. Thus the model can take the following form:

$$Y = 1.365 * X_1 + 1.05 * X_3$$

The positive value of the coefficient for the year X_1 factor can be interpreted as a positive direction of the yield dependence, *i.e.,* there is a tendency to increase the yield over the years.

TABLE 5. Coefficients[a)] of the model

Model		Unstandardized Coefficients		Std Coefficients	t	Sig.	Correlations			Collinearity Statistics	
		B	Std. Error	Beta			Zero-order	Partial	Part	Tolerance	VIF
1	(Constant)	-4.783	2.439		-1.961	**0.069**					
	X1	1.365	0.161	0.863	8.497	0.000	0.863	0.910	0.863	1.000	1.000
	X3	1.050	0.336	0.317	3.126	0.007	0.317	0.628	0.317	1.000	1.000

[a)] Dependent Variable: *Y*

CONCLUSION

Due to the increasing use of rapeseed in different spheres of human activity, its cultivation starts in Southeastern Kazakhstan. The study of all factors and conditions influencing the high yields of rapeseed in this region is an important task.

Pearson correlation coefficients r for the variables X_1 – Precipitation in mm, X_2 - Air temperature, $^{\circ}$C and X_3 - Relative humidity, % were calculated and commented. A correlation analysis of precipitation (mm) and yields of rapeseed (kg/ha) was made. The correlation between the amount of precipitation and yield for the technology mini-till tillage at a depth of 12-14cm is "very strong." This means that the third technology is most perspective**.**

Statistical modeling of factors affecting rapeseed yields is also applied. Observed high precipitation levels in October and November 2014 have had a significant impact on rape yields in the next 2015, which is a sign of a "postponement effect." It should be monitored and confirmed in the coming years.

This study does not take into account the type of soil on which this crop is grown and since they are essential for the yields and the technology of its cultivation, this factor will be the subject of future analyzes and research.

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