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Forecasting Methods of Agrometeorological Conditions in the Northern Zone of the Republic of Kazakhstan

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Abstract

This work presents the forecast of quality indicators of wheat from weather conditions in the Northern zone of the Republic of Kazakhstan, obtained on the basis of the correlation of protein and gluten content of grain with an av-erage monthly air temperature and precipitation. The equation obtained by the authors allows estimating the quality of grain with the monthly advance, which is important in the organization of harvesting of grain crops.

Keywords

Natural and Climatic Conditions, Agricultural Meteorological Changes, Grain Yield, Regression Analysis, Forecasting

1. Introduction

Climatic and weather conditions have a great impact on agricultural production. These conditions largely determine the yield of crops, the quality of products, the costs of its production, the characteristics of agrotechnical activities, and territorial specialization.

At cultivation of grain crops, considerable attention is paid not only to in-crease of quantity of the received grain, but also to improvement of its quality.

The quality of wheat grain, as well as other agricultural products, largely depends on the soil and climatic conditions of its cultivation area. It is known that as the aridity of the climate increases, the flour-baking properties of grain im-prove, and the protein content in it also increase. Wheat grain grown in arid re-gions is always highly valued in the international market.

Any grain has its so-called generally accepted quality indicators. These are essential, as they make it possible to make a preliminary picture of the state of the grain, to decide whether it is possible to store it and store it without loss of quality. It is with this definition that the evaluation of each batch of grain be-gins, and according to these data, the direction for placing grain in storages is given.

The forecast of the quality of the grain of the new crop, compiled with sufficient lead time, is important for the organization of harvesting of grain crops.

There is a lot actual material about variability of chemical composition of grain depending on climatic conditions. However, there are few quantitative dependencies that allow calculating the expected quality of wheat grain, and this issue requires development.

A number of studies allow us to conclude that the quality of the crop, for example, the protein content in the seeds of cereal crops, depends more on climate and weather than on varietal characteristics or agricultural techniques, although agricultural technology affecting the water and thermal regime of the soil and the surface layer of air, including fertilizers, has a significant impact on bio-chemical processes and, as a result, on the quality of the crop.

Methods for forecasting agrometeorological conditions, phenological fore-casts, and forecasts of the yield of the main agricultural crops have found wide application in the daily practice of agricultural meteorological support. Howev-er, it is desirable to supplement the crop yield forecast with a forecast of crop quality with a certain lead time. It is known that the chemical composition of plants is influenced not only by climatic conditions in general, but also agrome-teorological conditions of the current growing season.

Agriculture is actively developing in three main areas: Akmola, Kostanay and North-Kazakhstan regions. In the structure of sown areas, the wedge of winter crops and cereals is especially large. At the same time, most of the territory is in the zone of unsustainable agriculture. Therefore, in order to obtain high and stable yields, it is necessary to introduce advanced technologies for cultivation of cereals and winter crops. However, climatic and weather conditions also largely determine the yield and quality of agricultural products. The study of the cli-matic conditions of the growing regions and their influence on the quality of the wheat grain produced will improve the efficiency of grain production by prop-erly selecting varieties and increasing the country's export potential.

The evaluation of soft wheat grain is carried out mainly on three indicators:
grain glassiness, protein and gluten content.

For research have been used the materials of Akmola, Kostanay and Petropavlovsk Regional Center for Hydrometeorology and Environmental Monitor-ing for the period May-August in 1994-2015.

The quantitative dependence of grain quality indicators of soft wheat on climatic and agrometeorological conditions is established by many researchers. For the first time N. Lyaskovskiy (1936) noted fluctuations from 12.19% to 26.56% in protein content in wheat growing in the European part of Russia. Such a significant difference in protein content he explained by the influence of temperature, precipitation, humidity, soil and, finally, varieties. These conclusions were confirmed by other authors.

Therefore, the technology of wheat food grain production is aimed primarily at the rational use of climatic resources (heat, moisture, etc.) [1].

Studies of a number of scientists [2] found that the formation of the quality of spring wheat grain is most influenced by the amount of air temperature and precipitation during the growing season. The increase in the protein content in wheat grains, as well as the mass fraction of gluten, is largely determined by the air temperature during the formation—grain ripening (July) [3]. Precipitation adversely affects the accumulation of protein substances in wheat grain, as a rule, while reducing the atmospheric temperature and illumination of crops [4]. It is known that in all periods of plant growth and development, the effect of moisturizing (air humidity deficiency) is weaker than air temperatures [5].

In practice of planning of economic development often there is a problem of division of the territory on the most homogeneous on a number of indicators of area. In this case, the objects can serve as different territorial units (districts, regions, republics, etc.). This or another association of territorial units gives the scheme of zoning of the studied territory [6]-[13].

2. Main-Stages of the Study

Formulation of the Problem

Very often the researcher is faced with the need to divide the set of observed objects or phenomena described by a certain set of features into the most homogeneous (on these grounds) groups with several attributes, such a process we analyzed as a ranking tool in [14]. The value of such ranking is that for the obtained groups it is often possible to construct quite simple models of functional rela-tions. For example, when cultivating grain crops, much attention is paid not on-ly to increasing the amount of grain produced, but also to improving its quality. Quality of grain of wheat, as well as other agricultural production, in many re-spects depends on soil and climatic conditions of the area of its cultivation. One of the main prerequisites for the development and improvement of the metho-dology of grain quality assessment based on factor analysis is considered by us in [15].

Thus, for any grain there are so-called generally accepted indicators of quality which in many respects depends on soil and climatic conditions of the area of its cultivation. They are extremely important as they allow making preliminary idea of a condition of grain, to resolve an issue of possibility of its acceptance on storage and the storage it without loss of quality.

It is with their definition that the evaluation of each batch of grain begins, and on them the direction for placing grain in storages is given.

3. Purpose of Our Research

The purpose of our research was the relationship of indicators of quality of grain of wheat and agrometeorological vegetation period in the three Northern re-gions of the Republic of Kazakhstan.

4. Object of the Experience

The object of the experience provided wheat grains recommended for cultivation in the Northern region of the Republic of Kazakhstan. Weather conditions of the growing season of wheat grain during the field experiments differed in hydro-thermal parameters, which allowed a fairly objective assessment of the impact of weather factors on the quality of wheat grain.

The study of climatic conditions in terms of air temperature, precipitation and relative humidity was carried out in Akmola region from 1994 to 2015, in Kos-tanay region—from 1996 to 2015, in North-Kazakhstan region—from 2005 to 2015.

5. Research Result

The dependence is studied using the methods of mathematical modeling and computing techniques. Since we could not find such works in the literature, it was important to find the most significant, informative factors of weather condi-tions affecting the grain glassiness. In nature, these relationships are usually non-linear, as a result of the search for dependencies carried out using comput-ers, using a nonlinear regression analysis of several functions, the method of se-lection of equations that most adequately describe the relationship between the values (**Table 1**).

Table 1 shows the results of grain quality assessment of soft wheat varieties in the Northern zones of the Republic of Kazakhstan.

Since the formation of glassy grain of soft wheat depends on a number of weather factors, for the description this effect on the vitreous of several variables, —we used the method of multiple regression analysis using application pro-grams as Exsel, Statistika (**Table 1**).

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This link is described by the multiple regression equation of the form:

For Akmola region—$Y = 19.59657 + 0.00627*x1 + 0.66039*x2 + 0.34466*x3$, value $F(3,16) = 6.4500$, significance level $p < 0.00454$, $R2 = 0.547$ show that the constructed regression is significant.

For Kostanay region—$Y = 29.28470 + 0.00825*x1 + 0.55304*x2 + 0.17286*x3$; $F(3,14) = 1.4142$ $F(3,14) = 1.4142$, $p < 0.28024$, $R2 = 0.233$ of the equation is sig-nificant.

Table 1. Regression models of the influence of weather factors on the grain glassiness during the growing season of soft wheat in the northern zone of the Republic of Kazakhstan.

Akmola region (1994-2015 гг.)						
N = 20	Regression Summary for Dependent Variable: Y2—Vitreousity, % (Akmola region) R = 0.73985409 R2 = 0.54738407 Adjusted R2 = 0.46251859 F(3,16) = 6.4500 p < 0.00454 Std.Error of estimate: 0.77579					
	b*	Std.Err. of b*	b	Std.Err. of b	t(16)	p-value
Intercept			19.59657	10.52919	1.861166	0.081197
X1—the amount of precipitation, mm	0.211492	0.186526	0.00627	0.00553	1.133843	0.273564
X2—air temperature, ˚C	0.752275	0.183963	0.66039	0.16149	4.089271	0.000856
X3—relative humidity of air, %	0.321971	0.172608	0.34466	0.18477	1.865327	0.080581
Kostanay Region (1996-2015 гг.)						
N = 18	Regression Summary for Dependent Variable: Y2—Vitreousity, % (Kostanay Region) R = 0.48225595 R2 = 0.23257080 Adjusted R2 = 0.06812169 F(3,14) = 1.4142 p < 0.28024 Std.Error of estimate: 2.3851					
	b*	Std.Err. of b*	b	Std.Err. of b	t(14)	p-value
Intercept			29.28470	11.25110	2.602831	0.020862
X1—the amount of precipitation, mm	0.149295	0.241798	0.00825	0.01337	0.617438	0.546858
X2— air temperature, ˚C	0.398858	0.255169	0.55304	0.35380	1.563114	0.140342
X3—relative humidity of air, %	0.436908	0.247948	0.17286	0.09810	1.762097	0.099863
North-Kazakhstan region (2005-2015 гг.)						
N = 9	Regression Summary for Dependent Variable: Y2—Vitreousity, % (North-Kazakhstan region) R = 0.65085468 R2 = 0.42361181 Adjusted R2 = 0.07777890 F(3,5) = 1.2249 p < 0.39206 Std.Error of estimate: 1.1762					
	b*	Std.Err. of b*	b	Std.Err. of b	t(5)	p-value
Intercept			37.07419	31.77867	1.166637	0.295968
X1—the amount of precipitation, mm	0.376798	0.870646	0.00637	0.01471	0.432780	0.683206
X2—air temperature, ˚C	0.334661	0.842769	0.39557	0.99616	0.397096	0.707680
X3—relative humidity of air, %	0.413951	1.229435	0.09356	0.27788	0.336700	0.750015

For the North-Kazakhstan region—$Y = 37.07419 + 0.00637*x1 + 0.39557*x2 + 0.09356*x3$, $F(3,5) = 1.2249$, $p < 0.39206$, $R2 = 0.424$ of the equation is significant. The coefficient b* shows the relative strength of the effect of each fea-ture—argument on the resultant feature, and (Std.Err. of Beta)—is their stan-dard deviations.

An increase in the glassiness by 1% leads to an increase in the glassyness by 0.00627 mm, 0.66039% and 0.34666% respectively in the Akmola region. A similar analysis can be made for other regions.

Please see the **Figures 1**-3—Dependence of the glassiness of the grain from rainfall, mm (X1) and air temperature, (t˚C) for the period of vegetation of soft wheat are represented graphically.

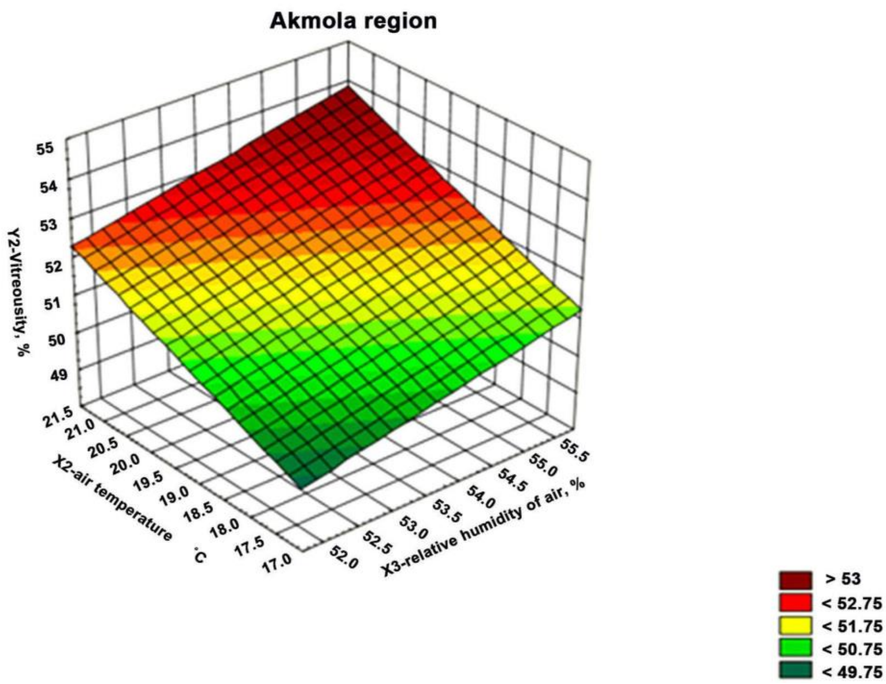


Figure 1. Y2—Vitreousity, % = 19.8741 + 0.3815*X3 + 0.5902*X2.

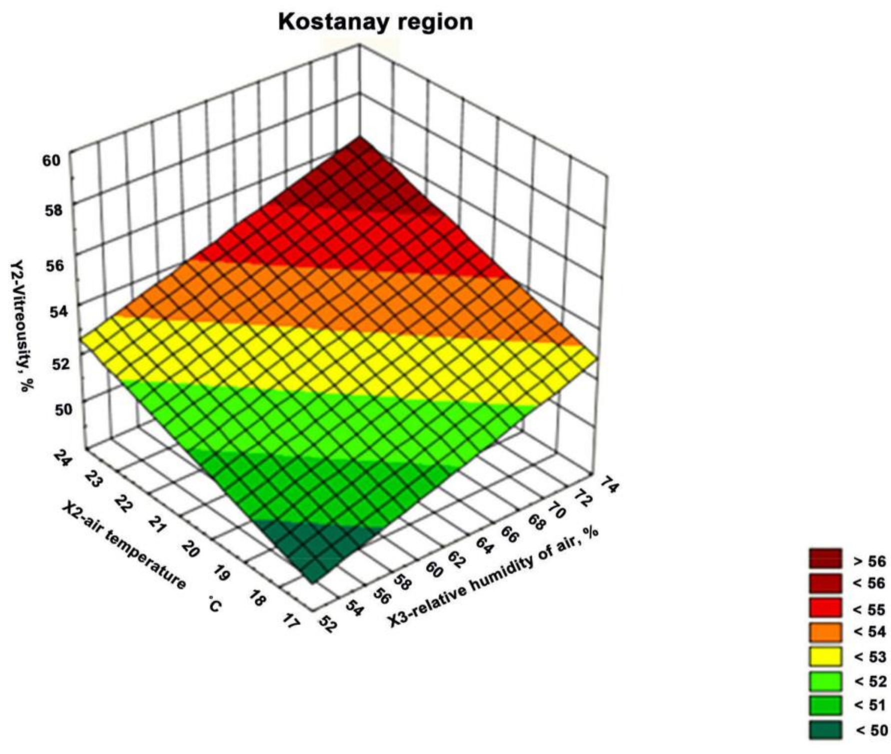


Figure 2. Y2—Vitreousity, % = 31.9146 + 0.1678*X3 + 0.4985*X2.

The correlation analysis of long-term data made it possible to establish the presence of the dependence of the grain quality indicators on the natural and climatic conditions during the vegetation period (**Table 2** and graphics).

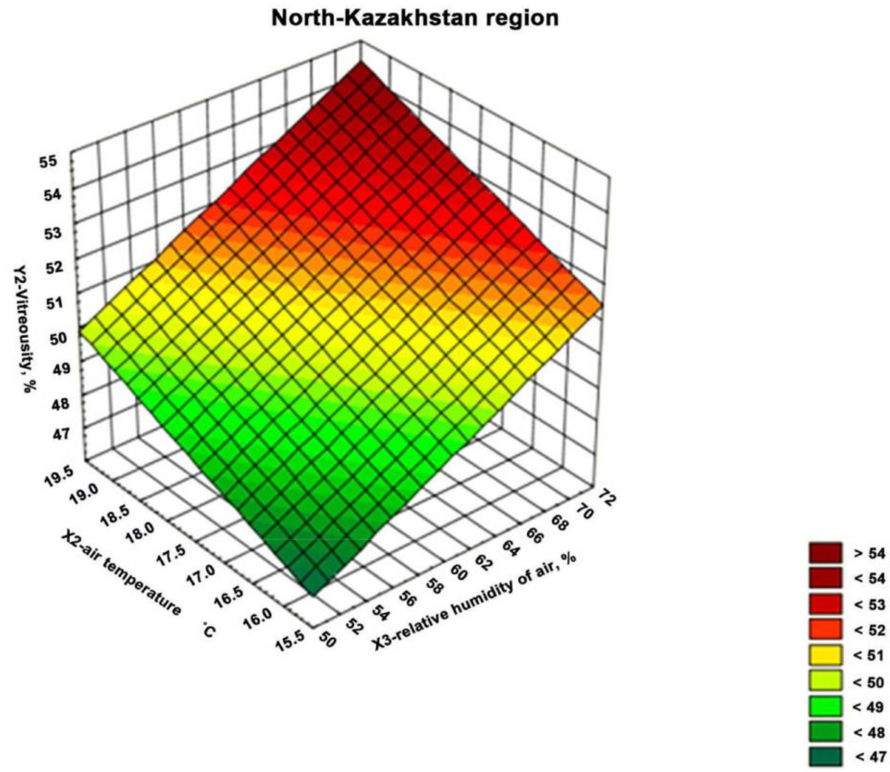
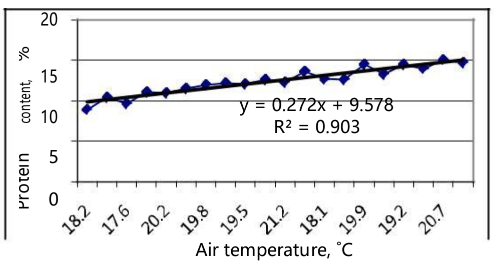
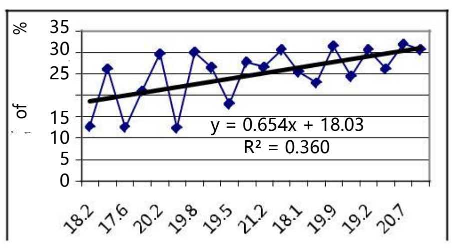


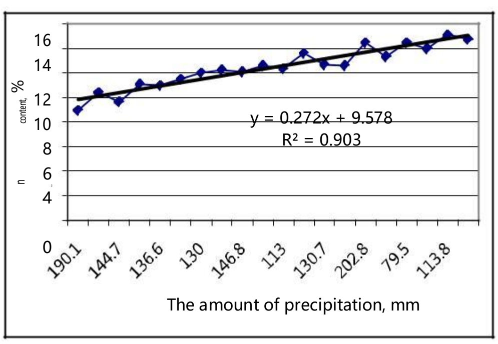
Figure 3. Y2—Vitreousity, % = 25.0994 + 0.2041*x + 0.7486*y.

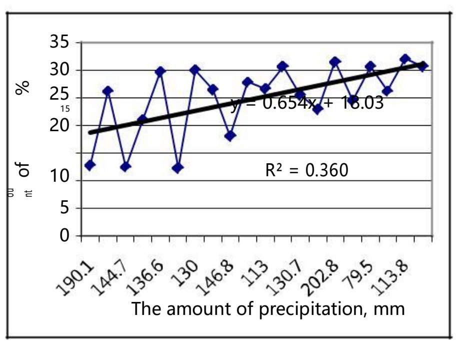
Table 2. Dependence of quality indicators of grain from meteorological parameters during the growing season.

Research area	Index during the growing season	Protein content, %			Mass fraction of gluten, %		
		r*	parameters of the regression equation**		r*	parameters of the regression equation**	
			a	b		a	b
Aktobe region during 1994-2013	average daily air temperature, ˚C	0.90	0.27	9.58	0.36	0.65	18.03
	amount of precipitation, mm	0.90	0.27	9.58	0.36	0.65	18.03









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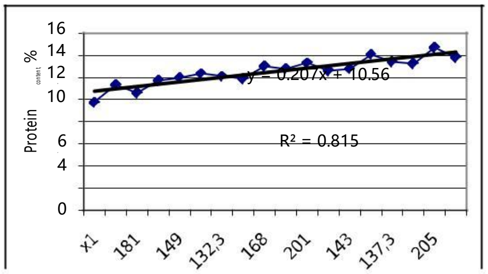
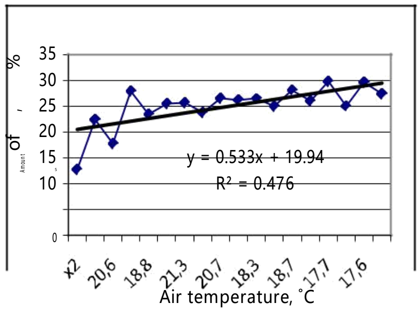
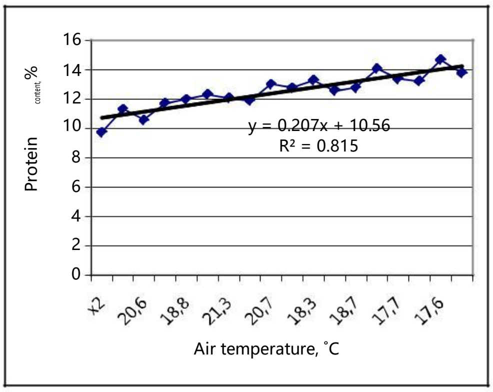
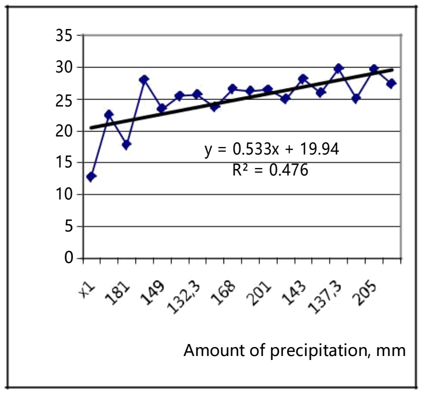
Kostanay region during 1996-2013	average daily air temperature, ˚C	0.81	0.21	10.56	0.48	0.53	19,95
	amount of precipitation, mm	0.82	0.21	10.56	0.48	0.53	19,95

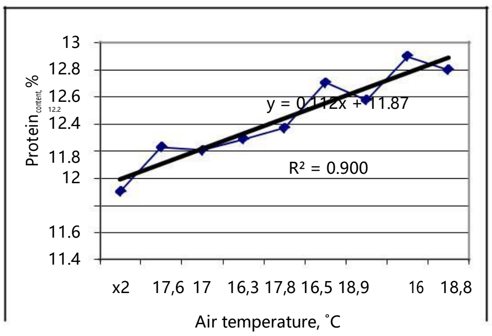


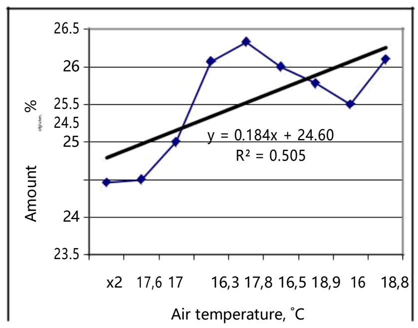


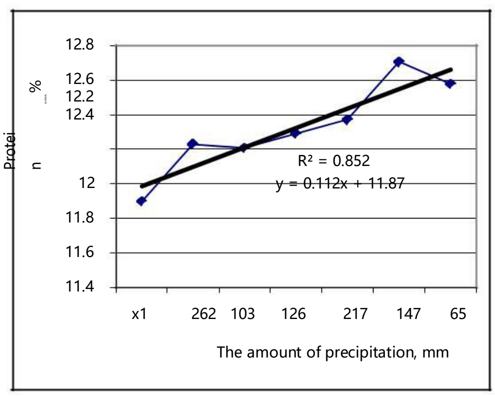


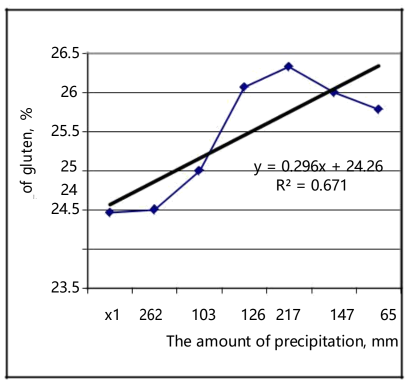


North-Kazakhstan during 2005-2013	average daily air temperature, ˚C	0.90	0.11	11.88	0.50	0.18	24,61
	amount of precipitation, mm	0.85	0.11	11.88	0.67	0.30	24,26









Note: r*—correlation coefficient; **—type of regression equation y = ax + в.

Table 3. Dependence of grain quality indicators on the amount of precipitation and air temperature during the growing season.

N = 20	Regression Summary for Dependent Variable: Y3—Amount of gluten, % (Akmola region) R = 0.23750872 R2 = 0.05641039 Adjusted R2 = ----- F(2,17) = 0.50815 p < 0.61046 Std.Error of estimate: 6.6214					
	b*	Std.Err. of b*	b	Std.Err. of b	t(17)	p-value
Intercept			−3.81125	29.71275	−0.128270	0.899441
X1—the amount of precipitation, mm	0.085746	0.257198	0.01549	0.04648	0.333386	0.742920
X2—air temperature, ˚C	0.258543	0.257198	1.38292	1.37572	1.005231	0.328880

$r = 0.056$, $F(2,17) = 0.50815$, $p < 0.61046$. The equation is statically not significant.

There was revealed correlation between the protein content in the grain of the average daily air temperatures during the growing season ($r = 0.90$). With the increase in air temperature during the growing season of grain it increases the protein content.

The correlation coefficient between the mass fraction of gluten in the grain and the air temperature during the growing season was (**Table 3**).

Influence of water regime on grain quality $r = 0.90$. With the increase in the amount of precipitation during the growing season of grain, the protein content in the grain increases.

The change in the protein content under the influence of precipitation occurs with a simultaneous change in the mass fraction of gluten in the grain.

Thus, the correlation coefficient between the mass fraction of gluten and the average daily air temperature and precipitation amounted to $r = 0.36$.

6. Conclusion

Thus, the above correlation dependences between indicators of grain quality on climatic conditions during vegetation period are rectilinear and described for the conditions of Akmola, Kostanay and North-Kazakhstan regions of the Republic of Kazakhstan by the regression equations with the appropriate parameters, which allowed a fairly objective assessment of the impact of weather factors on the quality of wheat grain.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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