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Grain Yield as an Indicator of The Drought in Kazakhstan

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Abstract

Drought is one of the major natural disasters in Kazakhstan and it has a great impact on agricultural sector. At the same time, agriculture is greatly dependent on water resources. As for the irrigated agriculture, glaciers in the mountains are the major storage of water resources and they are extremely sensitive to climate. Either natural drought or climate change-induced may pose a great threat to agriculture of Kazakhstan. This paper focuses on their optimal parameterization of atmospheric drought, identification of coherence between one of the best and representative agro climatic index for the territory of North Kazakhstan - Selyaninov Hydrothermal Coefficient (SHC) and crop yield fluctuation in Kazakhstan. For the assess of favorability or dryness extent in the vegetation period (including total drought) was use of a relative indicator of weather share in the formation of wheat yield in some years concerning the relative long-term conditions.

A number of actors that can be dived into two components in any given year influences productivity: the level of farming and weather conditions. Accordingly, long-term time series of yield can be dived into two components: fixed and random. The actual yield of the crop regarded as the sum of the fixed and random variable.

Based on the average regional spring wheat from the 1970 to 2010's. Parameters were calculated proportion weather yield formation – weather share indicator (WSI, %) in eight main grain areas. Next years were identify with severe droughts and average for the period under review. The analysis have shown that droughts are quite common on the territory of Republic. Calculated proportion indexes of weather in shaping the crop yield in eight main grain regions of Kazakhstan. Revealed the frequency of strong and medium drought, bringing considerable damage to agriculture in these areas. Changes of WSI were identified for climate analysis.

For an assessment of drought variability for the considered period repeatability of years with significant (strong and average) droughts on the sliding 20-year periods has been calculated.

It was revealed that the major agricultural regions of Kazakhstan are distinguished by extreme instability grain yields. The coefficient of variation of productivity of spring wheat, characterizing the variability of this value over time and space, in areas of North Kazakhstan for the period 1970-2010 ranged from 25 to 42%.In order to assess the changes in drought cycles in the last 45 year, we calculated repetitive years with significant (strong and medium) droughts.

Correlation analysis of crop productivity of grain produce in the North and South Kazakhstan with agro climatic indicators showed direct linear functional correlation.

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Key Words: Atmospheric Drought, weather share indicator, crop productivity, Selyaninov Hydrothermal Coefficient (*SHC*), Kazakhstan.

1. INTRODUCTION

Drought is one of major natural disasters in Kazakhstan and it influences a lot to agricultural sector which is the most vulnerable part of the economy to drought. As for the irrigated agriculture, glaciers in the mountains are the major storage of water resources and they are extremely sensitive to climate (Report, 2009). Either natural drought or climate change-induced variation in glaciers may pose a great threat to agriculture of Kazakhstan. This paper focuses on their optimal parameterization of atmospheric drought, identification of coherence between standardized moisture index and crop yield fluctuation as well as analyzing the large-scale atmospheric processes related to drought in Kazakhstan.

Grain production is one of strategic branches of the Republic on which condition the food security of Kazakhstan, the income and employment of the population, development of the accompanying branches (animal husbandry, poultry farming, food and processing industry depends. In recent years the grain varieties occupy over 80% of a cultivated area of crops.

Dryness degree substantially defines productivity of crops. At the international level the assessment of food security is made by two criteria: volumes of the world grain reserves passing till the following productivity (the passing grain reserve for 60 days, or 17% of annual consumption is considered safe; level of world yield of grain on average per capita (safe counts 1000 kg of grain per capita).

2. MATERIAL AND METHODS

Conventional single universal index in Kazakhstan to characterize the conditions of aridity / moisture does not currently exist. Different researchers use different methods of parameterization (Klimenko, 2011; Palmer, 1965; Ped, 1975; Selyaninov, 1981, Gringof et al., 1987; Salnikov et al., 2013, Kazadjiev et al., 2012, Salnikov V. et al.,2015). The literature teems with innumerable drought indexes, and none of these indices is free of limitations (Heim, 2002; Keyantash and Dracup, 2002; Quiring, 2009; Vasiliades et al., 2011; Asadi Zarch et al., 2014). In the DRI model, Zhang (2004) used both daily rainfall and ratio of rainfall to water requirement during the crop growing season to define the drought variables. On the other hand, Li et al. (2009) employed the Palmer drought severity index (PDSI). Drought is a relative condition of balance between rainfall and evapotranspiration in a particular area (Wilhite and Glantz, 1985; Wilhite, 2000). According to Elagib (2014), the aridity index (*AI*) of the United Nations Environment Programme (*UNEP*) which is the ratio of rainfall to reference evapotranspiration was chosen to define the drought conditions.

For an assessment of the mode of moistening of the agricultural regions of Kazakhstan the agroclimatic index– Selyaninov Hydrothermal Coefficient (*SHC*) was used:

$$SHC = \frac{\sum r}{0,1\sum t},$$

$\sum r$ – the sum of rainfall for the vegetative period (mm);
$\sum t$ – the sum of temperatures for the same period (°C).

Conditions of moistening of crops for the vegetative period on hydrothermal coefficient of Selyaninov will is superfluous damp at *SHC* > 2, moderately damp at *SHC* > 1 and droughty at *SHC* >1 (1,0–0,8 – moderately dry, 0,8–0,6 – dry, 0,6–0,5 –average drought, 0,5–0,4 – strong (severe) drought, *SHC* < 0,4 – extreme drought). This coefficient isn't used for an assessment of conditions of moistening of winter, spring and fall when average daily air temperature lower than 10 °C.

For an assessment of degree of usefulness or dryness of the vegetative period (including the total drought) we suggest to use a relative indicator of a share of weather in formation of an yeild of a spring wheat in separate years of rather mean annual conditions.

The relative indicator of a share of weather (*WSI*) in formation of an yield production of concrete year can be calculated as a deviation from average trend productivity ($\overline{Ytr}$) on a difference actual fact (*Yf*) and trend (*Ytr*) value of productivity, transferred to percent of rather average trend productivity ($\overline{Ytr}$), for the long-term period:

$$WSI = \left(\frac{\overline{Ytr} + (Yf - Ytr)}{\overline{Ytr}} \right) * 100 - 100.$$

For an assessment of degree of a drought the gradation similar to A.V. Protserov's criteria are used (decrease in an average crop yield to 20% – weak drought, from 20 to 50% –average drouht and more than 50% – strong drought) (Polevoy, 1992).

Considering that in the adverse weather phenomena in Kazakhstan the drought has a share of 80%, on values of an indicator of a share of weather in formation of a crop yield (*WSI*, %) can estimate drought degree on the following gradation:

lower minus 50 – strong drought;
minus 49 ÷ minus 20 –average drought;
minus 19 ÷ 0 – weak drought (weak moistening) or other adverse weather phenomena;
it is more than 0 – weather conditions are more favorable than mean annual values.

3. RESULTS AND DISCUSSION

In Kazakhstan the main grain cultiveted areas are three regions: Kostanay, Akmola and North Kazakhstan regions (Fig. 1) on the example of which the analysis of efficiency of *SHC* has been made.

Productivity in each concrete year is formed under the influence of a complex of factors which can be divided into two components: level of the standard of farming and weather conditions (Dmitrieva, 1985). Respectively a long-term time number of productivity can be divided into two components: stationary and non-stationary. The actual productivity of a crop is considered as the sum of a stationary and random variable. The coefficient of a variation of sprind wheat productivity characterizing variability of this size in time and space on regions of Northern Kazakhstan during 1970-2010 varied from 25 to 42% (The North Kazakhstan – 25%, Akmola – 32%, Kostanay – 34%, Pavlodar – 41% and Karaganda – 42%). For comparison such coefficient of a variation of productivity in the central regions of the USA makes 10%, in a steppe zone of Ukraine – 24%, Western Siberia – 20-25%, the Urals and Central Volga – 25-35% (Heim, 2002; Klimenko, 2011). In the Southern Kazakhstan the coefficient of a variation of productivity of grain crops at the expense of irrigation lands is slightly less, from 27% to 30% (Almaty – 27%, Southern Kazakhstan – 30%, Jambyl – 28%). Such instability of productivity of grain crops, first of all, is caused by

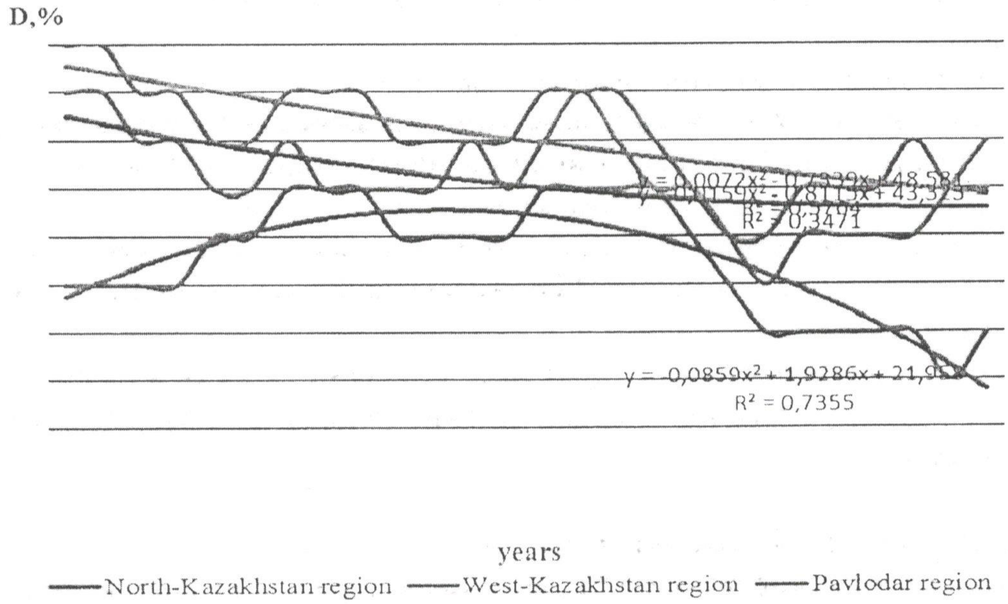

Figure 4 – Repeatability of years with strong and medium droughts (D, %) on the sliding 20-year periods, from 1966 to 2010

Table 2 – Correlation coefficients of mean wheat productivity and Selyaninov's index (SHC) in some regions of Kazakhstan

Region	*SHC*
North Kazakhstan	0,62
Akmola	0,55
Kostanay	0,67
Pavlodar	0,24
Almaty	0,57
South Kazakhstan	0,51
Zhambyl	0,49

The close connection between agroclimatic indicators and grain crop productivity is revealed in Northern Kazakhstan where calculating indexes of moisture was considered whith an atmospheric precipitation of the warm period of year . Especially high coefficients were in the Kostanay region, in the Pavlodar region - rather low.

In the main agricultural regions of Kazakhstan the factor limiting productivity of spring wheat was moisture. But, if in the South Kazakhstan sowings of agricultural crops use irrigation system, then because of big acreage of wheat and a lack of water in the north, such system is unacceptable. Thereof, results of many researches on an assessment of agroclimatic conditions of crop productivity formation in Northern Kazakhstan have shown that the light factor defines fluctuations of spring wheat productivity to 8%, thermal – 12%, moistening – 80% (Gringof et al., 2005). At such cases, as the generalized criterion of a drought it is possible to consider the level of decrease crop productivity depending on weather conditions (Dmitrieva, 1985). Results of the droughts revealed on spring wheat

Kazakhstan, it is generally connected with a lack of moisture, the level of a crop yield of the main growing up crops shows degree of moisture content of the vegetative period, i.e. it can serve as an indicator of the total drought. But for this purpose from full value of productivity it is necessary to separate a share of weather conditions that will be coordinated with opinion (Baisholanov et al., 2015; Salnikov et al., 2015)

The analysis has shown that in the territory of the republic the drought sets in very often. Probability of establishment of a drought on the most part of the territory the crop cultivated areas of Kazakhstan makes 1 time in 7 years. It is established that for an assessment of degree of a drought it is expedient to use a weather share indicator in formation of crop yield (*WSI*). In the last twentieth anniversaries *WSI* tended to decrease in Pavlodar and West Kazakhstan areas, i.e. in these areas usefulness of climate for formation of crop yield of wheat has decreased, however in North Kazakhstan *WSI* area have practically not changed. In this regard, the closest correlation between agro climatic indicators and productivity of grain crops is revealed in North Kazakhstan, spring wheat yield of these years didn't fall lower than 9,0-10,0 c/hectare.

In the main agricultural regions of Kazakhstan, as well as in some other regions of the globe, the main factor limiting crop production of summer crop yield is moisture (Heim, 2002; Zhang, 2004; Perevedentsev et al., 2012; Elagib, 2014; Xu et al., 2014). Results of the droughts revealed on productivity have been compared to results of an assessment of moisture content of the territory of North Kazakhstan on Selyaninov Hydrothermal Coefficient (*SHC*). The analysis of comparison has shown that droughts on *SHC* are confirmed by data on a drought on productivity of grain. On the example of adverse years (2008, 2009) distribution of *SHC* values across the territory of Kazakhstan is presented and use for drought monitoring is shown.

The received results of research prove that Selyaninov Hydrothermal Coefficient (*SHC*) should be used as the indicator of a drought and in forecasting of productivity of the main the crop cultivated areas of the Republic.

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