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ASSESSMENT OF THE IMPACT OF CHANGES IN PRODUCTION CONDITIONS ON WHEAT YIELD CAPACITY LEVEL

ӨНДІРІСТІК ЖАҒДАЙЛАРДЫҢ БИДАЙ ӨНІМДІЛІГІ ДЕҢГЕЙІНІҢ ӨЗГЕРУІНЕ ӘСЕР ЕТУІН БАҒАЛАУ

ОЦЕНКА ВЛИЯНИЯ ИЗМЕНЕНИЯ ПРОИЗВОДСТВЕННЫХ УСЛОВИЙ НА УРОВЕНЬ УРОЖАЙНОСТИ ПШЕНИЦЫ

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Abstract. Due to the need to satisfy the population with high-quality foodstuffs, wheat is the important crop in ensuring the country's food security. In order to find alternative ways to increase its profitability, it is necessary to study the influence of various factors on yield capacity as one of the main productive indicators of crop production development on the basis of establishing a quantitative interaction. The article includes calculations which have been done to evaluate the interaction between production, including hydrothermal indices and grain yields aimed to evaluate and select the most important factors for inclusion into the econometric model, and significant differences have been found in the correlation between grain yields and hydrothermal indicators in the periods before and after 90-ies which resulted from the changes in economic and climatic conditions, used production technologies.

Аңдатпа. Халықты сапалы тағам өнімдерімен қанағаттандыру қажетінде елімізді азық-түлік қауіпсіздігімен қамтамасыз етудегі маңызды орын бидайға беріледі. Оның түсімділігін көтерудің альтернативті жолдарын іздеу үшін сандық өзара байланысты жасау арқылы өсімдік шаруашылығын дамытудың негізгі нәтижелі көрсеткіштерінің бірі ретінде өнімділікті арттыруға түрлі факторлардың әсер етуін зерттеу қажет. Мақалада эконометрикалық үлгіге ең маңызды деген факторларды бағалау және таңдау мақсатында өндірістік, оның ішінде гидротермикалық көрсеткіштер мен астық түсімділігі байланысын бағалау бойынша есептер берілген. Бұл ретте өндірістің пайдаланылған технологияларының экономикалық және климаттық жағдайлардың өзгеруіне байланысты 90-шы жылдарға дейін және кейінгі кезеңдердегі астық өнімділігі мен гидротермикалық көрсеткіштер арасындағы корреляциялық тәуелділіктің елеулі айырмашылықтары байқалды.

Аннотация. Необходимость удовлетворения населения качественными продуктами питания отводит пшенице важное место в обеспечении продовольственной безопасности страны. Для поиска альтернативных путей повышения ее доходности требуется исследование влияния различных факторов на повышение урожайности как одного из основных результативных показателей развития растениеводства на основе установления количественной взаимосвязи. В статье проведены расчеты по оценке связи производственных, в том числе гидротермических показателей, и урожайности зерновых с целью оценки и отбора наиболее важных факторов для включения в эконометрическую модель, при этом обнаружены существенные различия корреляционной зависимости между урожайностью зерновых и гидротермическими показателями в периоды до и после 90-х годов, в связи с изменениями экономических и климатических условий, используемых технологий производства.

Key words: food security, farming system, agricultural machinery, technology, labor productivity, yield capacity, grain, natural and climatic conditions.

Түйінді сөздер : азық-түлік қауіпсіздігі, егіншілік жүйесі, ауылшаруашылық техника, технологиялар, еңбек өнімділігі, өнімділік, дақылдар, табиғи-климаттық жағдайлар.

Ключевые слова: продовольственная безопасность, система земледелия, сельскохозяйственная техника, технологии, производительность труда, урожайность, зерновые, природно-климатические условия.

Introduction.

Crop cultivation technologies development should be treated in the context of broader concept of crop farming system which includes crop rotations and methods of land cultivation as its major elements. These elements are inseparable from each other.

It is generally accepted that the history of crop farming system development in the grain-producing region – the Northern Kazakhstan – got started in the middle of the 50-s when so called virgin lands campaign was launched and millions of hectares of new lands were plowed up. In 1990 grain crops took up 23,8 millions hectares, from which 13,3 millions ha were occupied by spring wheat. In so doing, in the Northern Kazakhstan there were 14,8 million ha under grains, including 10,2 million ha allocated for spring wheat. At the same time, it should be noted that grain production in the region has much longer history: for instance, in 1940 grain crops took 5,8 million hectares spring wheat occupying 3,2 million ha (National economy…, 1990) [1].

Literature review.

Similar studies and calculation methods of the impact of production conditions on wheat productivity level were carried out in the following works (Nagy and Sanders, 1990; Morgounov *et al.*, 2005) [1,2]. Different studies have assessed impacts of climate change on wheat productivity. Knight *et al*. (1978) [3,4] analyzed the potential for wheat production in various regions of Alaska on the basis of air temperature. Ashfaq *et al.* (2011) [5] studied that the climate change is the major determinant of wheat productivity at each stage of wheat growth. The majority of the existing methods are dedicated to labour productivity calculation as such and to its dynamics. At present the following researchers are studying the impact of production practices on labour productivity in Kazakhstan and throughout the Central Asian states (Shegebaev, 1997; Baydildina *et al.*, 2000; Meng, 2000; Morgounov *et al.*, 2007) [6,7,8,9]. Peer-reviewed journals have a small number of publications that touch upon the research question one way or the other; it is necessary to point out first of all the following works (Griffith *et al.*, 1995; De Beurs and Henebry, 2004, Kussainov *et al.*, 2015) [10,11,12,13].

The purpose of the paper is to study of crop farming system development in Northern Kazakhstan and to examine the impact of changing production conditions (specifically weathe r conditions and production practices) on wheat productivity level.

The problem features.

To carry out our research on the measurement of the impact of production factors, including wheat growth technologies, the agricultural enterprise “Rodina” LLP was selected as the most appropriate site since it has a relatively more reliable and fuller database.

The significant feature of the research problem is also its main difficulty. This is virtual impossibility of performing an experiment, whose primary aim is to compare and assess the efficiency of different agricultural technologies, under current socio-economic conditions. Furthermore, it is difficult to find enterprises with comparable conditions, that is, an enterprise where, for example, only an intensive technology is used or simplified, or a resource-saving technology is used.

Therefore, the only possible way to solve this problem is to conduct a comparative analysis within the frames of an individual enterprise, with reference to retrospective historical data covering a considerable period of time, including the 1960s-70s (the time when conservation tillage technology was used), the 1980s (intensive technology), the 1990s - the beginning of the 2000s (simplified technology), and the early 2000s and up to the present (resource-saving technology). The crucial factors which affect wheat productivity level are considered to be weather hydrothermal production conditions. The calculation of the change in wheat productivity level given the use of a new technology is based on an econometric model.

Evaluation and concretization of factors to be involved in the model.

The selection of weather conditions periods to be involved in the model: Five precipitation periods were used for comparison in this model:

October – April; May-July; October– July; May-August; October– August.

Average precipitation according to different technology application periods are presented in table 1.

The structural analysis of hydrothermal conditions for 1971-2012 shows that there are considerable differences in the correlation between grain productivity and hydrothermal indicators during the period before and after the 1990s (due to the changes in economic and climatic conditions, as well as in production technologies application):

The above-mentioned circumstances require improvement of analytical methods and econometric model calibration, which seeks to establish a correlation between production results and economic production conditions.

Table 1 – Average precipitation according to different technology application periods, 1971-2012

Indicator	Technologies application period			
	conservation tillage technology	intensive technology	simplified technology	minimal technology
Average precipitation October-July (mm)	254.2	259.9	266.1	269.0
Average temperature in June (C˚)	18.9	19.8	18.9	20.0

a) Data from Zelinogradsky district at large:

Years	Precipitation					Temperature in June	Temperature in July
	october-april	may-july	october-july	may-august	october-august		
1971-1991	0.65	0.66	0.75	0.56	0.69	-0.38	-0.38
1992-2012	0.03	0.47	0,37	0.39	0.33	-0,75	-0.29
1971-2012	0.31	0.51	0.55	0.43	0.51	-0,55	-0.29

b) Data from agricultural enterprise “Rodina” LLP:

Years	Precipitation					Temperature in June	Temperature in July
	october-april	may-july	october-july	may-august	october-august		
1971-1991	0.62	0.47	0.60	0.37	0.54	-0.40	-0.05
1992-2012	0.09	0.60	0.46	0.44	0.37	-0.63	-0.28
1971-2012	0.30	0.55	0.53	0.42	0.46	-0.49	-0.21

As can be seen from Table 1, the highest correlation is observed between wheat productivity level and the amount of precipitation during the period from October to July, and in May-July (according to data on Zelinogradsky district at large as well as according to an individual enterprise). Given that the wheat productivity level is affected by both the accumulated moisture and precipitation amount in the vegetation period, we had to include in the econometric model the amount of precipitation for the period from October to July as one of the factors.

The correlation between wheat productivity and temperature regimes was evaluated according to different vegetation months. In this case, the closest correlation (and feedback correlation) is observed in the «wheat productivity – temperature in June» pair, both on the enterprise level and across the district at large. It follows that average air temperature in June needs to be included in the model as a temperature factor.

The choice of the selected above variables is consistent with the conclusions of agronomists: the critically sensitive period for spring wheat is related to the soil humidity level. This period is the stage of tillering and heading, when the reproductive organs form. If there is not a sufficient amount of moisture in the soil at this stage, the potential seed productivity sharply decreases. Given the conditions in Akmolinskaya oblast, this stage occurs in July; the crucial stage of wheat formation is the tillering stage, which depends on temperature. High temperature at this time sharply reduces the wheat productivity level. This stage takes place in June.

Evaluation of other factors to be included in the model.

The application of fertilizers, including minerals, plays a significant role in increasing wheat productivity, as well as labour productivity. This study did not determine the correlation between crop productivity and the amount of fertilizers used.

In additional to factors that can be evaluated quantitatively, our study considered the importance of qualitative parameters: wheat varieties used, agricultural technologies, machinery and equipment. These qualitative parameters can be included in the model in the form of so called categorical variables which take value 1, if used, and 0 if they are not used in wheat production in the enterprise under investigation during certain periods of time. In the given research, periods of use of certain groups of wheat varieties almost perfectly match the transition periods from one technology to another.

During the 70s, the wheat varieties: "Saratovskaya" and "Zelinnaya" were used; during this time conservation tillage technology of wheat production was common. During the 80s, a time of intensive technology, the following wheat varieties were used: "Saratovskaya", "Zelinnaya", "Yubileynaya" and "Omskaya". During the 90s, the use of simplified technology was accompanied by the use of the following wheat varieties: "Zelinnya", "Yubilieynaya" and "Omskaya". During the 2000s, when agriculture made a transition to a resource-saving technology, still another group of wheat varieties was used: "Omskaya", "Astana", "Svetlanka" and "In Memory of Aziyev". Therefore, values of categorical binary variables that correspond to certain technologies and wheat varieties will match. This circumstance leads to the multicollinearity problem of factor variables in the model. The problem can be easily solved by eliminating a wheat variety variable from the model. However, in this case the numerical value of coefficient for factor variable on technologies will have its effect on the resulting characteristic of not only the technology itself but on the wheat varieties, too. As for the agricultural machinery, it should be noted that it is impossible to calculate separately the impact of technology and new machinery on the labour inputs rate in the production, since the development of these two components is intertwined and continually progressing. We should bear in mind the above mentioned circumstances while interpreting the results of the problem solution.

Construction of econometric model to examine the impact of technology on wheat productivity

The relation between wheat productivity and production factors in this numerical research model includes these important variables:

√ Quantitical variables – precipitation from October to July and the temperature regime in June;

√ Categorical variables – growth technology (including used classes), which is included in the model as a binary variable and taking value 1, if used, and 0 if not used in any of the analytical periods.

Formally this model looks like:

$$Y = b_0 + \sum b_i X_i + \sum b_j T_j \quad (1)$$

Where Y – crop productivity, centners per hectar;

X_j - quantitical variables depended on natural conditions and resource costs (precipitation and temperature regime);

T_j - categorical variables (cultivation technologies used);

$b_0,\ b_i, b_j$ - parameters (coefficients) of the model.

The parameters b_i with the quantitical variables X_i show the value of wheat productivity change Y depending on the change of the value of corresponding factors per unit.

The parameters b_j with the variables T_j confirm the change in wheat productivity level Y when using the corresponding wheat growth technology.

Results and discussion.

Evaluation of parameters and calibration of the relationship model (1) under conditions of "Rodina" LLP, located in the Zelingradsky district of Akmolinskaya oblast (province), has been carried out on the basis of the specified production data for 1971-2012. Related data is given in table 2.

Table 2 – Parameters of the relationship model between wheat productivity and production factors in Agrofirma "Rodina" LLP (basic technology- conservation tillage technology)

Item №	Factors	Values of parameters
1	Hydrothermal production conditions:	
1.1	precipitation (October-July)	0.03
1.2	Temperature (June)	-0.88
2	Production technology:	
2.1	Intensive	0.47
2.2	Simplified	1.56
2.3	Minimized	3.51
3	Free coefficient	20.74

Source: Kussainov *et al.*, 2015

The econometrical relationship model in numerical format looks like:

Y=20.74+0.47*IT+1.56*ST+3.51*MT+0.03*P-0.88*T,

Where IT - intensive technology,

ST – simplified technology,

MT - minimized technology,

P - precipitation,

T - temperature.

Multiple correlation coefficient is high enough (0,69); determination coefficient is 0.47. The assessment of the relationship model according to Fisher's criteria shows that on the level of trust of 0.05 received equation is rele-vant and gives reliable enough results (estimated rate $F_{est.}$ =8,28 for F_{table} =2,42).

Results of the relationship model callibration, presented in Table 2, suggest the following: the increase of the total amount of precipitation that fall from October to July by one millimeter from its average provides wheat productivity growth by 0.03 c/ha; the increase of air temperature in June by one degree from its average leads to the crop productivity decrease by 0.88 c/ha; the transition to intensive technology in the early 80s led to the wheat productivity increase of 0.47 c/ha in comparison with conservation tillage technology; simplified technology pro-vided wheat yield growth by 1.56 c/ha in com-parison with conservation tillage technology; the substitution of conservation tillage technology with minimized technology increases wheat productivity by 3.51 c/ha. The influence of various factors on wheat productivity formation is shown in table 3.

Table 3 – Change of wheat productivity level under the alteration of production conditions in “Rodina” LLP (1971-2012)

New/old Technology	Wheat yield growth, c/ha, on account of change of:			Total growth	Wheat productivity under new/ old conditions, c/ha
	precipita-tion	tempe-rature	techno-logy		
Intensive/No till	0.14	-0.81	0.47	-0.2	10.3/10.5
Simplified/Intensive	0.16	0.83	1.09	2.08	12.4/10.3
Minimized/Simplified	0.07	-1.01	1.95	1.01	13.4/12.4

Source: Kussainov *et al.*, 2015

It follows from Table 3 that on account of average annual precipitation in the period of using intensive technology, wheat productivity increased by 0.14 c/ha in comparison with conservation tillage technology; productivity decreased because of less favorable temperature (-0.81 c/ha), which had been compensated by productivity growth because of the use of a more progressive technology (0.47 c/ha); and overall growth made up 0.2 c/ha, which means that average productivity in the period of intensification decreased from 10.5 c/ha to 10.3 c/ha in comparison with the conservation tillage technology application period.

After the transition from intensive to simplified technology, average productivity increased by 0.16 c/ha because of the large amount of precipitation during the simplified technology application period; productivity increased by 0.83 c/ha because of the favorable temperature regime in June, and the use of simplified technology increased productivity growth by 1.09 c/ha; overall growth made up 2.08 c/ha; and the average productivity during the simplified technology application period equaled to 12.4 c/ha.

During the minimal technology application period, wheat productivity increased by 0.07 c/ha because of the high amount of precipitation; productivity decreased because of a less favorable temperature regime (-1.01 c/ha), and new technology caused growth in productivity by 1.95 c/ha; overall growth made up 1.01 c/ha. The average productivity during the minimized technology application period equaled to 13.4 c/ha.

Conclusions.

Currently, there is no clear perception among Kazakh agricultural entrepreneurs that the rational crop diversification requires a careful analysis of the covariance between the economic outcomes from growing different crops. Moreover, the producers attitude to risk should be taken into account when making business decisions (Hardacker et al., 2004, Lien and Hardaker, 2001, Schoney et al., 1994, Kussainov, 2001, 2003, 2014, Moldashev, 2011, Khan and Asanova, 2011) [14,15,16,17,18, 19,20,21]. Taking into account these factors in the process of decision making allows to determine a rational crop structure which ensures greater income stability. It makes sense to note that the optimal crop structure changes when shifting from one technology to another. The possibility of an economically unacceptable outcome is significantly reduced when using resource-saving technologies . It is becoming obvious for kazakh farmers that when selecting crops for cultivation it is necessary to proceed, first of all, from the market prospects and the degree and sustainability of economic benefits.

It should also be noted that the economic feasibility considerations dictate the need to test new technologies and crop rotations in the experimental fields of research institutions only after the thorough economic analysis of the crops structure and combination has been held. Only this approach ensures the practical usefulness and relevance of the experiments.

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