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AGRICULTURAL LAND-USE OPTIMIZATION BY FARMS BASED ON QUALITY MANAGEMENT: LINES OF RESEARCH

Abstract: *The paper is aimed at justifying the need for having an increased focus on quality issues in agriculture, as well as developing a scientific approach to optimizing the agricultural land-use by farms based on quality management. With this aim in mind, the authors successively solve two problems. The first problem is associated with the study of the impact of fertilizer application on the efficiency of agricultural land-use and on the quality of agricultural products. The second problem consists in providing operational recommendations for the optimization of agricultural land use by farms based on quality management in order to simultaneously solve the problem of ensuring food security as well as the problem of rural development (on the basis of improvement of farm business performance).*

The authors have considered a science-based approach towards the land use optimization by farms with the most effective application of fertilizers in a certain scientifically based crop rotation system which gives the maximum profit per hectare of arable land used by basic regional crops - fall rye, barley and potato; besides, this approach ensures their high quality. Following the results of the study, it has been concluded that application of mineral fertilizers is a powerful factor contributing to the improvement of the quality of agricultural products through increasing their micronutrient content and ensuring their safety. Therefore, an increase in application of mineral fertilizers is fundamental for the proposed scientific approach to optimizing the agricultural land use by farms based on quality management.

Key words: *The marginal and the maximum returns; Optimal crop rotation; Optimization model; Correlation factor; Economic returns; Plot of land.*

1. Introduction

Agricultural land-use is characterized by a complex intertwinement of various phenomena and processe. They are formed, on the one hand, under the influence of certain existing economic relations of land user with the environment, where land plays the most important role, and on the other hand, relations between land users regarding the appropriation of a product of land, and, finally - relations between land users and state and municipal authorities that are intended to regulate these relations.

The working hypothesis of the research is based on the following generic approach.

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Currently, the principal directions of implementation of state land policy only partially (if at all) cover most of the pressing issues in the field of land use, including those identified by the Strategy for Sustainable Development of Rural Territories of the Russian Federation for the Period up to 2030 and the Basic principles of state policy of the Russian Federation concerning the use of the land fund for 2012-2020, in particular, issues related to quality management of agricultural products which deserve high attention in order to ensure national food security of the Russian Federation. The application of fertilizers should be treated not only as an instrument for the increase in productivity of agricultural land use, but also as an instrument for the improvement of quality of agricultural products, which is no less (and maybe even more) important from the perspective of ensuring national food security.

The problem of this study consists in the fact that, since the collapse of the Soviet Union there has been a significant reduction in the area of the used agricultural land in the territory of Russia; the size of crop areas has decreased by 37.86 million ha since 1990. At this stage, there are 35.2 million ha of underutilized land (arable land) and 4.4 million ha of useless land arable land (layland). Mineral fertilizers were applied only on 47% of all crop areas; organic fertilizers were applied on 8.2% of all crop areas. That said, 62% of mineral fertilizers were applied as compared to the figure for 1990 which amounts to 55 kg/ha; 43% organic fertilizers were applied (1.5 ton/ha). The presence of layland and yielding agricultural land which are not used in agricultural production is an integrated index of socioeconomic and environmental origin of these phenomena conditioned by unfavourable agro-climatic conditions, and, as a consequence, low profitability of agricultural production. The presence of abovementioned phenomena in the territory of the region leads to the increase in the total number of low-income families, low quality of life, outward migration flaw, degradation of human potential, degradation in size and disappearance of big and small villages, absence of demand for agricultural land and land lots intended for agricultural production, insecurity of rural living and the mass migration of people from rural areas.

The paper is aimed at justifying the need for having an increased focus on quality issues in agriculture, as well as developing a scientific approach to optimizing the agricultural land-use by farms based on quality management. With this aim in mind, the authors successively solve two problems. The first problem is associated with the study of the impact of fertilizer application on the efficiency of agricultural land-use and on the quality of agricultural products. The second problem consists in providing operational recommendations for the optimization of agricultural land use by farms based on quality management in order to simultaneously solve the problem of ensuring food security as well as the problem of rural development (on the basis of improvement of farm business performance).

2. Materials and method

The aspects of economic returns from the use of agricultural land have been considered in the works of such researchers as (Reddy & Amarender, 2013; Reddy & Amarender, 2012; Gurmanpreet, 2013). Issues related to quality management of agricultural products are discussed in a number of publications (Bogoviz et al., 2019; Cortés et al., 2019; El-Mesery et al., 2019; Jödicke et al., 2019; Morozova et al., 2018).

For the first time, a research was carried out by means of analysis of indicators for the development of the model of agricultural land-use optimization in the European north-eastern part of Russia. The research was carried out in the farms of the Udmurt Republic and the Kirov Region. The following methods were used:

- economic and mathematical method, in the first place, linear programming method with the analysis of dependence of the influence of costs per 1 ha of arable land on the unit cost of the volume of gross output based on development of economic and statistic models with the use of MS Excel.
- economic and statistic and monographical research methods were used in the analysis of indicators of economical optimization of land-use.
- abstract and logical method has been used in the selection of indicators of the assessment of the optimization level of agricultural land-use, development of the form of assessment of the degree of optimization of land-use.

Assessment of the land use optimization level in the farms of the Udmurt Republic and the Kirov Region has been made for basic regional crops for which the marginal and the maximum returns have been determined. The development of a model of land-use optimization is based on reported financials, which makes it possible to determine the optimal values of indicators of returns from the use of arable land, as well as the cost of production for each natural climatic subzone of the region.

The dependence between the costs of production of crops and volumes of gross output was studied with the use of correlation-regression analysis and dispersion analysis. This method has also been used for the determination of dependence of the yield of cereals and grain legumes and qualitative indicators of agricultural products on fertilizer application.

3. Results

3.1. The study of the impact of fertilizer application on the efficiency and quality in agriculture

We shall determine the impact of application of mineral fertilizers on the yield of cereals and qualitative indicators of agricultural products in the Udmurt Republic and in the Kirov Region of the Russian Federation. For this end, we shall use statistical data from the Federal State Statistics Service of the Russian Federation (Rosstat). In addition, we shall assess the impact of application of mineral fertilizers on qualitative indicators of agricultural products suggested by The Economist Intelligence Unit (2019) – the presence of micronutrients and food safety that are measured in points by expertise (in this paper, we have determined their values in accordance with the information from the Federal Supervision Agency for Customer Protection and Human Welfare (Rospotrebnadzor, 2019). Initial values for the study are presented in Tables 1 and 2.

The results of our correlation and regression analysis and dispersion analysis for the Udmurt Republic are presented in Tables 3-5, and the results of our correlation and regression analysis and dispersion analysis for the Kirov Region are presented in Tables 6-8.

We have used the data from Table 3 to develop the following model of paired linear regression: y_1=1,0513+0,9046*x_1. The derived P-Value of the calculated coefficient which coincides with significance F and is equal to 0.0011 (is less than or equal to 0.05) is a reflection of the fact that the coefficient is statistically significant at the significance level α=0,05. Further, regard must be paid to the fact that the confidence limits for the calculated regression coefficient do not contain contradicting results - both the lower and the upper limits are positive. This points to the statistical insignificance of the calculated regression coefficient.

The derived value of the multivariate R=0.8692 testifies that the substitution of dependent variable by 86.92% results from the change in the explanatory variable. Standardized (reduced) coefficient of determination (0.7249) suggests that the formulated regression is close to initial values, and the random component is small; therefore, the number of the calculated regression coefficient is high. Since R-square and Adjusted R-square are almost identical (they are equal to 0.7554 and 0.7249 respectively), this is indicative of the regression model obtained.

Table 1. Changes in the amount of application of mineral fertilizers, yield of cereals, and qualitative indicators of agricultural products in the Udmurt Republic in 2005-2018.

Year	Application of mineral fertilizers per 1 hectare of agricultural crops, kg	Yield of cereals in weight after processing, dt from 1 hectare of harvested area	Presence of micronutrients in agricultural products, points, 1-100	Safety of agricultural products, points, 1-100
	x_1	y_{11}	y_{12}	y_{13}
2005	16.2	12.2	33.1	58.1
2010	15.8	11.4	32.3	56.7
2011	14.9	17.2	30.4	53.5
2012	11.9	13.8	24.3	42.7
2013	12.1	10.1	24.4	43.1
2014	15.6	17.0	31.5	55.6
2015	14.2	14.8	28.6	50.6
2016	14.5	15.0	29.3	51.7
2017	19.9	19.8	40.1	70.9
2018	27.3*	26.1*	55.1*	97.3*

*forecast (made by us under otherwise equal conditions).
Source: compiled by the authors based on information provided by Rosstat (2019) and Rospotrebnadzor (2019).

Table 2. Changes in the amount of application of mineral fertilizers, yield of cereals, and qualitative indicators of agricultural products in the Kirov Region in 2005-2018.

Year	Application of mineral fertilizers per 1 hectare of agricultural crops, kg	Yield of cereals in weight after processing, dt from 1 hectare of harvested area	Presence of micronutrients in agricultural products, points, 1-100	Safety of agricultural products, points, 1-100
	x_2	y_{21}	y_{22}	y_{23}
2005	14.4	13.6	27.8	49.7
2010	19.3	15.7	37.3	66.6
2011	27.6	21.2	53.4	95.2
2012	25.5	17.4	49.3	87.8
2013	20.8	14.2	40.5	71.6
2014	25.1	21.1	48.8	86.4
2015	24.4	18.9	47.5	84.0
2016	27.0	17.1	52.5	92.9
2017	27.6	19.0	53.7	95.0
2018	28.2*	21.1*	54.9*	97.1*

*forecast (made by us under otherwise equal conditions).
Source: compiled by the authors based on information provided by Rosstat (2019) and Rospotrebnadzor (2019).

Table 3. The results of correlation and regression analysis and dispersion analysis of the impact of application of mineral fertilizers on the yield of cereals in the Udmurt Republic

Regression statistics						
Multiple R	0.8692					
R-square	0.7554					
Adjusted R-square	0.7249					
Standard error	2.4519					
Observations	10					
Dispersion analysis						
	df	*SS*	*MS*	*F*	*Significance F*	
Regression	1.0000	148.5564	148.5564	24.7106	0.0011	
Residue	8.0000	48.0947	6.0118			
Total	9.0000	196.6511				
	Coefficients	*Standard error*	*t Stat*	*P-Value*	*Lower 95%*	*Upper 95%*
Y-intercept	1.0513	3.0556	0.3441	0.7397	-5.9950	8.0976
x1	0.9046	0.1820	4.9710	0.0011	0.4850	1.3243

Source: calculated by the authors.

The experimental F-test value calculated by us (24.7106) exceeds the tabular value, which for a predetermined level of significance α=0.05 and k_1=m=10 and k_2=n–m–1=10–2–1=7 is equal to F_{tabl} = 3.64. Hence, the derived regression equation is statistically significant. For a more accurate assessment of statistical significance of each regression coefficient, we shall compare the derived experimental Student's test value (4.9710) with the tabular value, which for a predetermined level of significance α = 0.05 and n-2=10-2 = 8 degrees of freedom is equal to 2.306. As you can see, the experimental Student's test value does not exceed the tabular value which proves the statistical significance of the derived regression equation.

Thus, an increase in application of mineral fertilizers per 1 hectare of agricultural crops per 1 kg in the Udmurt Republic contributes to an increase in the yield of cereals in weight after processing by 0.9046 dt from 1 hectare of harvested area.

We have used the data from Table 4 to develop the following model of paired linear regression: y_1=0,3181+2,0068*x_1. The derived P-Value of the calculated coefficient which coincides with significance F and is equal to 7.51264E-15 (tends to zero, is less than or equal to 0.05) is a reflection of the fact that the coefficient is statistically significant at the significance level α=0,05.

Further, regard must be paid to the fact that the confidence limits for the calculated regression coefficient do not contain contradicting results - both the lower and the upper limits are positive. This points to the statistical insignificance of the calculated regression coefficient.

The derived value of the multivariate R=0.9998 testifies that the substitution of dependent variable by 86.92% results from the change in the explanatory variable. Standardized (reduced) coefficient of determination (0.9995) suggests that the formulated regression is close to initial values, and the random component is small; therefore, the number of the calculated regression coefficient is high. Since R-square and Adjusted R-square are almost identical (they are equal to 0.9995 and 0.9996 respectively), this is indicative of the regression model obtained.

Table 4. The results of correlation-regression analysis and dispersion analysis of the impact of application of mineral fertilizers on the presence of micronutrients in agricultural products in the Udmurt Republic.

Regression statistics						
Multiple R	0.9998					
R-square	0.9996					
Adjusted R-square	0.9995					
Standard error	0.1929					
Observations	10					
Dispersion analysis						
	df	*SS*	*MS*	*F*	*Significance F*	
Regression	1	731.0532	731.0532	19642.5174	7.51264E-15	
Residue	8	0.2977	0.0372			
Total	9	731.3509				
	Coefficients	*Standard error*	*t Stat*	*P-Value*	*Lower 95%*	*Upper 95%*
Y-intercept	0.3181	0.2404	1.3229	0.2224	-0.2364	0.8725
x1	2.0068	0.0143	140.1518	7.51264E-15	1.9738	2.0398

Source: calculated by the authors.

The experimental F-test value calculated by us (19642.5174) exceeds the tabular value, which for a predetermined level of significance α=0.05 and k_1=m=10 and k_2=n–m–1=10–2–1=7 is equal to F_{tabl} = 3.64. Hence, the derived regression equation is statistically significant. For a more accurate assessment of statistical significance of each regression coefficient, we shall compare the derived experimental Student's test value (140.1518) with the tabular value, which for a predetermined level of significance α = 0.05 and n-2=10-2 = 8 degrees of freedom is equal to 2.306. As you can see, the experimental Student's test value does not exceed the tabular value which proves the statistical significance of the derived regression equation.

Thus, an increase in application of mineral fertilizers per 1 hectare of agricultural crops per 1 kg in the Udmurt Republic contributes to an increase in the presence of micronutrients in agricultural products by 2.0068 points.

We have used the data from Table 5 to develop the following model of paired linear regression: y_1=0,3318+3,5515*x_1. The derived P-Value of the calculated coefficient which coincides with significance F and is equal to 1.09492E-16 (tends to zero, is less than or equal to 0.05) is a reflection of the fact that the coefficient is statistically significant at the significance level α=0,05. Further, regard must be paid to the fact that the confidence limits for the calculated regression coefficient do not contain contradicting results - both the lower and the upper limits are positive. This points to the statistical insignificance of the calculated regression coefficient.

The derived value of the multivariate R=0.9999 testifies that the substitution of dependent variable by 99.99% results from the change in the explanatory variable. Standardized (reduced) coefficient of determination (0.9998) suggests that the formulated regression is close to initial values, and the random component is small; therefore, the number of the calculated regression coefficient is high. Since R-square and Adjusted R-square are almost identical (they are equal to 0.9998 and 0.9999 respectively), this is indicative of the regression model obtained.

The experimental F-test value calculated by us (56546.5573) exceeds the tabular value, which for a predetermined level of significance α=0.05 and k_1=m=10 and k_2=n–m–1=10–2–1=7 is equal to F_{tabl} = 3.64. Hence, the derived regression equation is statistically significant. For a more accurate assessment of statistical significance of each regression coefficient, we shall compare the derived experimental Student's test value (237.7945) with the tabular value, which for a predetermined level of significance α = 0.05 and n-2=10-2 = 8 degrees of freedom is equal to 2.306. As you can see, the experimental Student's test value does not exceed the tabular value which proves the statistical significance of the derived regression equation.

Thus, an increase in application of mineral fertilizers per 1 hectare of agricultural crops per 1 kg in the Udmurt Republic contributes to improving the safety of agricultural products by 3.5515 points.

Table 5. The results of correlation and regression analysis and dispersion analysis of the impact of application of mineral fertilizers on the yield of cereals in the Udmurt Republic

Regression statistics						
Multiple R	0.9999					
R-square	0.9999					
Adjusted R-square	0.9998					
Standard error	0.2012					
Observations	10					
Dispersion analysis						
	df	*SS*	*MS*	*F*	*Significance F*	
Regression	1	2289.6356	2289.6356	56546.2273	1.09492E-16	
Residue	8	0.3239	0.0405			
Total	9	2289.9595				
	Coefficients	*Standard error*	*t Stat*	*P-Value*	*Lower 95%*	*Upper 95%*
Y-intercept	0.3318	0.2508	1.3229	0.2224	-0.2465	0.9100
x1	3.5515	0.0149	237.7945	1.09492E-16	3.5171	3.5859

Source: calculated by the authors.

We have used the data from Table 6 to develop the following model of paired linear regression: y_1=5,5093+0,5178*x_2. The derived P-Value of the calculated coefficient which coincides with significance F and is equal to 0.0034 (is less than or equal to 0.05) is a reflection of the fact that the coefficient is statistically significant at the significance level α=0,05. Further, regard must be paid to the fact that the confidence limits for the calculated regression coefficient do not contain contradicting results - both the lower and the upper limits are positive. This points to the statistical insignificance of the calculated regression coefficient.

The derived value of the multivariate R=0.8230 testifies that the substitution of dependent variable by 82.30% results from the change in the explanatory variable. Standardized (reduced) coefficient of determination (0.6370) suggests that the formulated regression is close to initial values, and the random component is small; therefore, the number of the calculated regression coefficient is high. Since R-square and Adjusted R-square are almost identical (they are equal to 0.6370 and 0.6773 respectively), this is indicative of the regression model obtained.

The experimental F-test value calculated by us (16.7930) exceeds the tabular value, which for a predetermined level of significance α=0.05 and k_1=m=10 and k_2=n–m–1=10–2–1=7 is equal to F_{tabl} = 3.64. Hence, the derived regression equation is statistically significant. For a more accurate assessment of statistical significance of each regression coefficient, we shall compare the derived experimental Student's test value (4.0979) with the tabular value, which for a predetermined level of significance α = 0.05 and n-2=10-2 = 8 degrees of freedom is equal to 2.306. As you can see, the experimental Student's test value does not exceed the tabular value which proves the statistical significance of the derived regression equation.

Thus, an increase in application of mineral fertilizers per 1 hectare of agricultural crops per 1 kg in the Kirov Region contributes to an increase in the yield of cereals in weight after processing by 0.5178 dt from 1 hectare of harvested area.

Table 6. The results of correlation and regression analysis and dispersion analysis of the impact of application of mineral fertilizers on the yield of cereals in the Kirov Region

Regression statistics						
Multiple R	0.8230					
R-square	0.6773					
Adjusted R-square	0.6370					
Standard error	1.6988					
Observations	10					
Dispersion analysis						
	df	*SS*	*MS*	*F*	*Significance F*	
Regression	1	48.4639	48.4639	16.7930	0.0034	
Residue	8	23.0877	2.8860			
Total	9	71.5516				
	Coefficients	*Standard error*	*t Stat*	*P-Value*	*Lower 95%*	*Upper 95%*
Y-intercept	5.5093	3.0785	1.7896	0.1113	-1.5898	12.6083
X2	0.5178	0.1263	4.0979	0.0034	0.2264	0.8091

Source: calculated by the authors.

We have used the data from Table 7 to develop the following model of paired linear regression: y_1=-0,2599+1,9522*x_1. The derived P-Value of the calculated coefficient which coincides with significance F and is equal to 1.51654E-15 (tends to zero, is less than or equal to 0.05) is a reflection of the fact that the coefficient is statistically significant at the significance level α=0,05. Further, regard must be paid to the fact that the confidence limits for the calculated regression coefficient do not contain contradicting results - both the lower and the upper limits are positive. This points to the statistical insignificance of the calculated regression coefficient.

The derived value of the multivariate R=0.9999 testifies that the substitution of dependent variable by 99.99% results from the change in the explanatory variable.

Standardized (reduced) coefficient of determination (0.9997) suggests that the formulated regression is close to initial values, and the random component is small; therefore, the number of the calculated regression coefficient is high. As R-square and Adjusted R-square coincide (they constitute 0.9997), this is indicative of the regression model obtained.

The experimental F-test value calculated by us (29307.8755) exceeds the tabular value, which for a predetermined level of significance $\alpha=0.05$ and $k_1=m=10$ and $k_2=n-m-1=10-2-1=7$ is equal to $F_{tabl} = 3.64$. Hence, the derived regression equation is statistically significant. For a more accurate assessment of statistical significance of each regression coefficient, we shall compare the derived experimental Student's test value (171.1954) with the tabular value, which for a predetermined level of significance $\alpha = 0.05$ and n-2=10-2 = 8 degrees of freedom is equal to 2.306. As you can see, the experimental Student's test value does not exceed the tabular value which proves the statistical significance of the derived regression equation.

Thus, an increase in application of mineral fertilizers per 1 hectare of agricultural crops per 1 kg in the Kirov Region contributes to an increase in the presence of micronutrients in agricultural products by 1.9522 points.

Table 7. The results of correlation-regression analysis and dispersion analysis of the impact of application of mineral fertilizers on the presence of micronutrients in agricultural products in the Kirov Region

Regression statistics						
Multiple R	0.9999					
R-square	0.9997					
Adjusted R-square	0.9997					
Standard error	0.1533					
Observations	10					
Dispersion analysis						
	df	*SS*	*MS*	*F*	*Significance F*	
Regression	1	688.9590	688.9590	29307.8755	1.51654E-15	
Residue	8	0.1881	0.0235			
Total	9	689.1471				
	Coefficients	*Standard error*	*t Stat*	*P-Value*	*Lower 95%*	*Upper 95%*
Y-intercept	-0.2599	0.2778	-0.9355	0.3769	-0.9006	0.3808
x2	1.9522	0.0114	171.1954	1.51654E-15	1.9259	1.9785

Source: calculated by the authors.

We have used the data from Table 8 to develop the following model of paired linear regression: $y_1=0,1777+3,4362*x_1$. The derived P-Value of the calculated coefficient which coincides with significance F and is equal to 8.91043E-20 (tends to zero, is less than or equal to 0.05) is a reflection of the fact that the coefficient is statistically significant at the significance level $\alpha=0,05$. Further, regard must be paid to the fact that the confidence limits for the calculated regression coefficient do not contain contradicting results - both the lower and the upper limits are positive. This points to the statistical insignificance of the calculated regression coefficient.

The derived value of the multivariate R=0.9999 testifies that the substitution of dependent variable by 99.99% results from the change in the explanatory variable.

Standardized (reduced) coefficient of determination (0.9999) suggests that the formulated regression is close to initial values, and the random component is small; therefore, the number of the calculated regression coefficient is high. Since R-square and Adjusted R-square are almost identical (they are equal to 0.9999), this is indicative of the regression model obtained.

The experimental F-test value calculated by us (334827.0087) exceeds the tabular value, which for a predetermined level of significance α=0.05 and k_1=m=10 and k_2=n–m–1=10–2–1=7 is equal to F_{tabl} = 3.64. Hence, the derived regression equation is statistically significant. For a more accurate assessment of statistical significance of each regression coefficient, we shall compare the derived experimental Student's test value (578.6424) with the tabular value, which for a predetermined level of significance α = 0.05 and n-2=10-2 = 8 degrees of freedom is equal to 2.306. As you can see, the experimental Student's test value does not exceed the tabular value which proves the statistical significance of the derived regression equation.

Thus, an increase in application of mineral fertilizers per 1 hectare of agricultural crops per 1 kg in the Udmurt Republic contributes to improving the safety of agricultural products by 3.4362 points.

Table 8. The results of correlation and regression analysis and dispersion analysis of the impact of application of mineral fertilizers on the yield of cereals in the Kirov Region

Regression statistics						
Multiple R	1.0000					
R-square	1.0000					
Adjusted R-square	1.0000					
Standard error	0.0798					
Observations	10					
Dispersion analysis						
	df	*SS*	*MS*	*F*	*Significance F*	
Regression	1	2134.5476	2134.5476	334827.0087	8.91043E-20	
Residue	8	0,0510	0.0064			
Total	9	2134.5986				
	Coefficients	*Standard error*	*t Stat*	*P-Value*	*Lower 95%*	*Upper 95%*
Y-intercept	0.1777	0.1447	1.2281	0.2543	-0.1560	0.5113
x2	3.4362	0.0059	578.6424	8.91043E-20	3.4225	3.4499

Source: calculated by the authors.

Thus, on the basis of the results of the study, inference should be drawn that the application of mineral fertilizers determines not only the yield of cereals, but also the quality of agricultural products. Therefore, the optimization of agricultural land use by farms based on quality management should imply an increase in application of mineral fertilizers by farms.

3.2. Scientific approach to optimizing the agricultural land use by farms based on quality management

Optimal crop rotation in the Udmurt Republic (the costs amounted to 19403 rubles) in comparison with conventional crop rotation (the costs amounted to 19063 rubles) has nearly identical level of costs, while net profit was increased by 2.2 times. Hence, this crop rotation makes it possible to earn profit from 1 ha of arable land which is more than twice higher. In the Udmurt Republic, the weighted average maximum profit with optimal crop rotation has been determined, which amounted to 81453,5 rubles per 1 hectare of arable land with the maximum profit from rye - 7800 rubles/ha, barley – 5900 rubles/ha, and potato – 105.0 thousand rubles/ha. The weighted average maximum profit in the Kirov Region amounted to 81,676 rubles/ha; the maximum profit: for rye - 6000 rubles/ha with costs of 12000 rubles/ha, barley - 6000 rubles/ha with costs of 10000 rubles/ha, and potato – 90.0 thousand rubles/ha with costs of 20000rubles/ha

Diagrammatical optimization model of land economics has been tested experimentally by three crops included in tilled crop rotation in the Udmurt Republic and the Kirov Region. For empirical calculations, the second category of land has been adopted, since it occupies 51% of the area of arable land in the region with the use of four-year crop rotation. The economical efficiency of optimal crop rotation in comparison with conventional crop rotation in the Udmurt Republic and the Kirov Region was determined alongside with development of flow process charts for each crop.

An interpreted model of crop rotation optimization in land-use has been developed for a particular farm with due account for soil characteristics of its arable land. The analysis of cumulative data on the amount of costs for the production of gross crop output in the Udmurt Republic and the Kirov Region has demonstrated that there was a steady tendency to the increase in the costs for production.

According to the data on dependence of the costs of production of crops and the volumes of gross output the correlation field of dependences of values under study was built, where a nonlinear statistical dependence can be clearly seen in the form of a polynomial between indicators under study; we can see that linear and logarithmic dependence do not meet the values of costs for the production of crop output, determined in the capacity of a factor flag, to the fullest extent. The models of dependence of the volume of gross output from the volume of costs of farms of the Udmurt Republic and the Kirov Region have been developed in the form of a polynomial of degree 2 based on the cumulative data. The polynomial trend is used to describe the values of time series, alternately increasing and decreasing. In practical terms, polynomial models are very useful for the solving problems of agricultural land-use optimization and management of agrotechnical, technological processes in the agro-industrial complex. Diagrammatic representations of these models demonstrate that relation between the costs and the value of gross output of rye and barley is very substantial; the correlation factor for rye is ($r = 0.958$), while the correlation factor for barley is ($r = 0.954$). As for potato, there is a noticeable relation ($r = 0.555$). The correlation factor for the model in the form of a polynomial of degree 2 has a value of 0.958 for rye, which is also indicative of high quality of the developed model, since 95.8% of values with a result flag can be attributable to the values with a factor flag, the role of which is played by the costs for the cultivation of rye. The correlation factor for barley is 0.954, which is also indicative of high quality of the developed model. The correlation factor for potato is 0.555, which is indicative of an evident relation only. We should take note not only of the high complexity of the developed models for rye and barley, but also of their higher accuracy. In general, a visual analysis of developed polynomial models leads to a conclusion about the most accurate and advanced models – in the form of polynomials of degree 2, rather than about a simple linear model; the non-random nature of the relationship between the volumes of gross output and the costs for their production should be noted as well.

Hence, the developed dependence models in the form of polynomials of degree 2 for rye, barley and potato are very important. Two ranges can be identified on the dependency graph of the gross crop output. The most optimal returns can be ovbserved in the zone of break-even production of output - the productivity value of cultivated plot of land whereby the net profit reaches its maximum level. In the Udmurt Republic, the maximum profit from rye can be made at costs equal to 25.6 thousand rubles/ha, barley – 14.0 thousand rubles/ha, potato – 200.0 thousand rubles/ha, while the cropping power accordingly amounts to 33.4 thousand rubles/ha, 19.9 thousand rubles/ha, 280.0 thousand rubles/ha. The highest break-even land productivity value with the cultivation of rye is 43.5 thousand rubles/ha, barley – 26.9 thousand rubles/ha, potato – 505.0 thousand rubles/ha. The crop yield in this case is 73 hundreds kilograms, 37.1 hundreds kilograms and 503.5 hundreds kilograms per hectare respectively. On the rye and barley diagrams, with costs of 3500 rubles/ha and 1700 rubles/ha of harvested acreage, break-even land productivity value can be observed. The second range is the zone of stable production of output. In this case, rye will reach the most optimal economic returns with the price of production of 15.0 thousand rubles/ha, barley - the price of production of 10.0 thousand rubles/ha, potato - with the price of production of 160.0 thousand rubles/ha. The cropping power of 1 ha of harvested acreage amounted to 21.2 thousand rubles, 15.2 thousand rubles and 235.0 thousand rubles respectively at that. According to the analysis, the profitability factor in this zone is higher than that in the zone of break-even production. The relation between the costs and the cost of gross output of rye and barley is very substantial; there is a noticeable relation in the case of the potato.

Main conclusion: assessment of the land use optimization level in the farms of the Udmurt Republic and the Kirov Region must be made with the most effective application of fertilizers in a certain scientifically based crop rotation system which gives the maximum profit per hectare of arable land used by basic regional crops - fall rye, barley and potato.

Classification of regional farms has been performed in the Udmurt Republic and the Kirov Region by the level of intensification of arable farming. According to the calculations, only 6% of farms belong to group 1 with extensive technology, 12% belong to group 3 with intensive technology, while 82% belong to group 2 with conventional technology of all farms under discussion engaged in production of fall rye and barley. This is a fairly good figure for the regions.

Development of diagrammatical optimization models for the Udmurt Republic and the Kirov Region has made it possible to reveal the trends presented below:

1. The product cost, with account of cost of goods sold in the farms under discussion depends very heavily on its location, in particular, on the agro-climatic subzone of the region:

- in the farms which use extensive technology, it amounted to (for example, in the Udmurt Republic) - 5517 rubles per hectare. Agro-climatic subzone 2 is rather unfavorable for the production of crop output;
- in the farms which use conventional technology (for example, in the Udmurt Republic) - 2905 rubles/ha respectively, since they are located in agro-climatic subzone 1;
- in the farms (for example, in the Udmurt Republic) from 13856 rubles/ha, since they are located in agro-climatic subzone 4 which is the most favorable for the production of crop output;
- in the farms which use intensive technology (for example, in the Udmurt Republic) - from 9173 to

18077 rubles/ha respectively (all farms under discussion are located in agro-climatic subzone 3).

2. The costs for mineral fertilizers (in the Udmurt Republic and the Kirov Region), the amount of which directly influences the volume of gross output, regardless of agro-climatic subzones; at the same time, no change in the volumes of gross output can be observed in group 1 with extensive technology; there is a linear relation with the increase of the volumes of gross output in group 2, while in group 3 there is a polynomial dependence: the higher are the costs for mineral fertilizers, the larger are the volumes of gross output.

3. The price of production in the farms of group 1 with extensive technology is fairly low (for example, in the Udmurt Republic, the average value is 8081 rubles/ha), in the farms of group 2 which use conventional technology (for example, in the Udmurt Republic, the average value is 9369 rubles/ha) which is 15% higher than in group 1, while in group 3 with intensive technology (for example, in the Udmurt Republic, the average value is 17607 rubles/ha) which is twice as high, which proves the advantage of this technology over other technologies.

Therefore, the following conclusion can be made: the economical essence of the degree of intensitication of arable farming consists in the system of economic indicators, characterizing the process of improvement of accepted technologies, accompanied by the increase in the volume of gross cr``op output with the simultaneous decrease in the production cost for the unit based on the increase in the economic fertility of soil.

The results pilot testing in the Kirov Region have been used for the assessment of the condition of agricultural land of a farm being a land user; in addition, the groups of these land users have been categorized by agro-climatic subzones of the Kirov Region with account of efficiency of arable land. A group of land users of agro-climatic subzone 6 stands first in the final ranking; thus, their process of production of crop output was awarded the top assessment, and as a result, they have the best condition of agricultural land. Agro-climatic subzone 6 includes the farms of Malmyzhsky and Vyatskopolyansky Districts of the Kirov Region (Table 9, 10), located in the southern part of the region, the area of arable land amounts to 145 thousand hectares; 50 % in the crop structure falls on grain crops.

Table 9. Percentage change in the main categories of crop production in the districts of agro-climatic subzone 6 of the Kirov Region, %

Districts / Figures	Total product yield	Product yield per 1 ha	Total production cost	Unit cost	Average price	Gross output
Malmyzhsky District	80.7	82.7	166.4	207.0	189.4	152.7
Vyatskopolyansky District	89.7	93.3	132.8	148.2	172.2	154.3

Red color – maximum value
Green color – minimum value

Table 10. Growth rate of gross output in the districts of agro-climatic subzone 6 of the Kirov Region, %

Districts / years	2009	2010	2011	2012	2013	2014	2015
Malmyzhsky District	100	39	359	60	119	150	107
Vyatskopolyansky District	100	8	1606	79	117	129	95

Red color – maximum value
Green color – minimum value

This ranking is only indicative of the economic assessment of the condition of agricultural land and leaves out the environmental assessment.

4. Conclusion

The essence of economic returns from the use of arable land as the main factor of the condition of agricultural land makes it possible to determine the financial and business condition of an economic entity - a land user, to give an estimate to managerial human resources of a particular entity. The calculation of indicators of economic returns from the use of arable land with different levels and options of intensification of production of crop output is the first stage in the process of provision of a rationale for the most optimal condition of agricultural land.

The model of optimization of economy of agricultural land-use is based on the comparison of values of output indicators with labor and capital costs for the production and sales of products from the plot of land. The function of returns of a plot of land describes the relation between the increments in the amounts of capital and labor invested in the land, and changes in the volume of gross output and the net profit of farms of the region that are included in a particular natural climatic subzone. Diagrammatical model made it possible to determine the maximum returns, optimal economic returns and the corresponding most optimal, marginal costs of capital and labor. The quantitative data values obtained as a result of development of various modified diagrammatical cost optimization models have the most accurate values of indicators depending on the level of technology applied. The output of research products is as follows:

1. The system of classification of farms by the level of intensification of arable farming at the level of an economic entity.

2. Parameters of the land use optimization level in the farms by basic regional crops for the conditions of the European north-eastern part of the Russian Federation.

3. The form of assessment of the most optimal crop rotations and the basic approaches to the development of the models of economic agricultural land-use optimization.

As a result - “The optimal agricultural land-use can be deemed to be such land-use in which the returns from the land due to labor and capital invested in it do not drop below the marginal returns for a particular farming technology”.

Harmonization of the basic provisions of agricultural land-use optimization is also necessary; in other words, its content should be brought in line with international standards to ensure optimum in the production of crop output and mutual understanding of results of research referred to the standard of uniform rules of optimization of the economy of agricultural land-use in Russia. Harmonization can be quite as much referred to economical regulations.

At the same time, application of mineral fertilizers is a powerful factor contributing to the improvement of the quality of agricultural products through increasing their micronutrient content and ensuring their safety. Therefore, an increase in application of mineral fertilizers is fundamental for the proposed scientific approach to optimizing the agricultural land use by farms based on quality management.

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