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OPTIMIZATION MODEL AND ASSESSMENT OF INTER-BRANCH DEVELOPMENT OF AGRICULTURAL ENTERPRISES

The connected development of fodder crops cultivation and increase of profitability in meat and milk cattle husbandry is considered. Optimization model for sown areas of fodder crops is proposed. Stability assessments of breakeven and expanded reproduction of beef and milk production are given. Recommendations on practical use of the obtained results are presented.

Keywords: *profitability; fodder crops; optimization model; cattle husbandry; expanded reproduction.*

JEL classification: C61; Q12.

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ОПТИМІЗАЦІЙНА МОДЕЛЬ ТА ОЦІНЮВАННЯ МІЖГАЛУЗЕВОГО РОЗВИТКУ СІЛЬСЬКОГОСПОДАРСЬКИХ ПІДПРИЄМСТВ

У статті розглянуто зв'язаний розвиток вирощування кормових культур та підвищення рентабельності м'ясо-молочного скотарства. Запропоновано модель оптимізації посівних площ кормових культур. Оцінено стабільність беззбитковості та розширеного відтворення для виробництва яловичини та молока. Наведено рекомендації щодо практичного застосування одержаних результатів.

Ключові слова: *рентабельність; кормові культури; модель оптимізації; скотарство; розширене відтворення.*

Форм. 7. Рис. 2. Табл. 1. Літ. 19.

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ОПТИМИЗАЦИОННАЯ МОДЕЛЬ И ОЦЕНКА МЕЖОТРАСЛЕВОГО РАЗВИТИЯ СЕЛЬСКОХОЗЯЙСТВЕННЫХ ПРЕДПРИЯТИЙ

В статье рассмотрено связанное развитие выращивания кормовых культур и повышение рентабельности мясо-молочного скотоводства. Предложена модель оптимизации посевных площадей кормовых культур. Оценена стабильность безубыточности и расширенного воспроизводства при производстве говядины и молока. Даны рекомендации по практическому использованию полученных результатов.

Ключевые слова: *рентабельность; кормовые культуры; модель оптимизации; скотоводство; расширенное воспроизводство.*

Problem setting. Contemporary economic challenges imply passing from traditional principles to ecological ones in the world agriculture. In Ukraine it means that strict application of crop rotation schemes for soil recultivation should be considered while growing fodder crops instead of every year production of technical ones. Such an approach will support agriculture's sustainable development, since the present share of Ukrainian animal husbandry decreased to merely 30%. Respectively, national inner market is saturated with meat and milk at the level of 70–80% (Ekonomichna statystyka. Silske hospodarstvo, ukrstat.gov.ua, 2016). Under crisis conditions Ukrainian enterprises cannot take additional risks of unprofitable production. They need well grounded solutions, which might help unite their renovation plans in crop

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and animal branches. Mathematical simulation could offer a calculated clarification for balancing the demand and proposition of fodder crops. These arguments gave impulse for conducting a new research based on modelling fodder crops production, as science should react quickly and effectively support important practical tasks.

Recent publications analysis. Parts of the problem of coordinating fodder crops production with the increase in milk and meat livestock productivity have been considered by many scientists. Namely, A. Barvinskyj (2013), P.I. Boiko et al. (2014), O.V. Khodakivska (2015) and others focused their researches on ecological improvements in national land use by means of implementing optimal crop rotation schemes for natural renovation of humus and soil fertility. Recent mathematical simulations on balanced crop production connected with ecological and economic criteria have been carried out by I. Shcherbata and M. Shcherbatyi (2013), N.K. Vasylieva (2013) and many others. Definitions of strategic goals as well as developments of economic instruments for their fulfillment in increasing effectiveness of fodder crop production created the key issues. Those issues have been studied by I.V. Kishchak (2008), M.M. Kropyvko (2015), V.F. Petrychenko and O.V. Korniychuk (2012), N. Vasylieva (2016).

V.S. Diiesperov (2016) argues that the state of livestock breeding is the most crucial one among all branches of Ukrainian animal husbandry. According to M.Yu. Kurinna (2015), A.M. Uhnivenko and D.K. Nosevych (2013), N.I. Shyian (2015), one of the key reasons of unprofitable beef production in Ukraine is expensive forage. Its share in cost structure increased up to almost 60%, while sown area of fodder crops in Ukraine decreased from 40% to 8% during 1990–2015. Similarly, M.V. Kalinchyk et al. (2013), N.I. Shyian (2014) O.M. Suprun et al. (2015), T.I. Yavorska and L.A. Zahnitko (2015) and others have grounded that balanced nutrition and cost (i.e., biotechnological and economic forage characteristics) determine competitive milk production. The problem of coordinating fodder crops production with an increase of milk and meat livestock productivity is a very essential one. According to N.Vasylieva, I. Vinichenko and L. Katan (2015), in order to get the largest synergy effect from solving this problem, one must apply a complex approach of advanced information technologies and mathematical methods. These technologies and methods must support mutual development of crop and animal husbandries.

The research objective is to conduct mathematical simulation of fodder crops cultivation for providing maximal volumes of beef and milk and to evaluate the stability of breakeven status and expanded reproduction in the cattle husbandry subsector.

Key research findings. Degradation of fodder crops sown areas demonstrates a positive connection with losses of cattle and cows – 6.3 and 3.7 times during 1990–2015. It is in parallel to diminishing volumes of beef and milk in Ukraine (4.8 and 2.2 times accordingly) at the same time (Ekonomichna statystyka. Silske hospodarstvo, ukrstat.gov.ua, 2016).

For grounding the plans of fodder crops growing it is relevant to apply a nonlinear mathematical simulation. Namely, let us consider X_i ($X_i \geq 0$) that denote sown areas of crops for K_1 concentrated, K_2 juicy, K_3 rough and K_4 green fodders. Each crop is characterized by fodder units (a_i) and cost (b_i) per 1 ha, $i = 1, ..., K_1 + K_2 +$

$K_3 + K_4$. Every type of the considered fodder crops is defined by its permitted lower (L_j) and upper (U_j) shares in the forage structure, $j = 1, ..., 4$. Let S be a general sown area under fodder crops at an agricultural enterprise, F – its use of fodders per 1 centner of the considered animal product (meat or milk) with a sale price P (per 1 centner). The total activity effectiveness is evaluated by R – the profitability level of animal husbandry at an investigated agricultural enterprise, where C corresponds to the share of fodders in the cost structure of a chosen animal product.

Thus, the proposed optimization model for the inter-branch development of some agricultural enterprise gets the following form: to find such values of variables X_i ($X_i \geq 0$), $i = 1, ..., K_1 + K_2 + K_3 + K_4$, that maximizes the criterion

$$R = (\sum_i a_i X_i / F \times P) / (\sum_i b_i X_i / C) \times 100 - 100 \to \max \quad (1)$$

under restrictions

$$\sum_i X_i = S; \quad (2)$$

$$L_1(\sum_i a_i X_i) \leq \sum_{i=1}^{K_1} a_i X_i \leq U_1(\sum_i a_i X_i); \quad (3)$$

$$L_2(\sum_i a_i X_i) \leq \sum_{i=K_1+1}^{K_1+K_2} a_i X_i \leq U_2(\sum_i a_i X_i); \quad (4)$$

$$L_3(\sum_i a_i X_i) \leq \sum_{i=K_1+K_2+1}^{K_1+K_2+K_3} a_i X_i \leq U_3(\sum_i a_i X_i); \quad (5)$$

$$L_4(\sum_i a_i X_i) \leq \sum_{i=K_1+K_2+K_3+1}^{K_1+K_2+K_3+K_4} a_i X_i \leq U_4(\sum_i a_i X_i). \quad (6)$$

The described model (1)–(6) has been tested at the state enterprise "Research agricultural holding "Polivanovka" in Magdalinovka district of Dnipropetrovsk region. All data for calculations have been submitted by the enterprise's executives. The enterprise's sown area is over 3,300 ha. It has been recommended to implement a crop rotation scheme with 25% of sown areas under fodder crops, i.e. $S = 825$ ha for applying ecological standards of land-use. "Research agricultural holding "Polivanovka" breeds cattle for beef and milk. Its share of fodders in the cost structure amounts to 57.8%, i.e. in calculations $C = 0.578$.

The set of fodder crops options included:

1) maize and winter wheat among the concentrated forage ($K_1 = 2$) with the shares $L_1 = 0.1$ and $U_1 = 0.2$;

2) corn silage, gourds crops (pumpkin and marrow squash) among the juicy forage ($K_2 = 3$) with the shares $L_2 = 0.2$ and $U_2 = 0.4$;

3) alfalfa hay, winter wheat straw, and haylage among the rough forage ($K_3 = 3$) with the shares $L_3 = 0.1$ and $U_3 = 0.2$;

4) maize green fodder, alfalfa green fodder, and Sudanese grass green fodder among the green forage ($K_4 = 3$) with the shares $L_4 = 0.2$ and $U_4 = 0.4$.

The following distribution of sown areas has been obtained after calculations which have been carried out in "LibreOffice Calc" (Table 1).

Table 1. **Plan of fodder crops cultivation in "Polivanovka",** *authors'*

Name of a fodder crop	X_i, ha	a_i, centners of fodder units per 1 ha	b_i, ths UAH per 1 ha
Maize for concentrated forage	118.46	54.30	9.04
Corn silage for juicy forage	85.08	45.60	8.23
Marrow squash for juicy forage	85.08	30.00	9.25
Alfalfa hay for rough forage	125.38	51.30	3.30
Maize for green forage	205.50	27.90	3.69
Alfalfa for green forage	205.50	34.70	5.01

The conducted simulation by means of models (1)–(6) has presented a more pessimistic situation for beef production in the "Research agricultural holding "Polivanovka", where the use of fodders and sale price were $F = 13.2$ centners of fodder units and $P = 3.385$ ths UAH per centner of beef in slaughter weight early in 2016. In this case the profitability level would be only $R = 0.04\%$.

The conducted simulation has presented a more optimistic situation for milk production in "Polivanovka", where the use of fodders and sale price were $F = 1.01$ centners of fodder units and $P = 0.436$ ths UAH per centner of milk early in 2016. In this case the profitability level would be $R = 68.43\%$.

Reserves for further improvement in effectiveness of beef and milk production can be found in the:

1) decrease in the use of fodders per centner of product by means of implementing economical technologies;

2) increase in sale prices due to improving marketing activity.

Thus, "Research agricultural holding "Polivanovka" has got recommendations to provide the coefficient $F = 12$ centners of fodder units per centner of beef in slaughter weight, for even smaller values were demonstrated by producers in Poltava and Cherkasy regions. The sale price should be increased up to $P = 4$ ths UAH per centner of beef in slaughter weight, as such values were fixed in Chernivtsi and Sumy regions, and also in Kyiv early in 2016 (Ekonomichna statystyka. Silske hospodarstvo, ukrstat.gov.ua, 2016). In this way the holding could maintain the profitability level of beef production over $R = 30\%$.

In milk production "Polivanovka" has got recommendations to provide the coefficient $F = 0.95$ centners of fodder units per centner of milk, for the same or even smaller values were demonstrated by producers in Cherkasy, Dnipro, Kharkiv, Kirovohrad, Luhansk, Rivne, and Sumy regions in 2014. The sale price should be increased up to $P = 0.5$ ths UAH per centner of milk, as Ukrainian average sale price increased up to 0.53 ths UAH per centner of milk early in 2016 (Ekonomichna statystyka. Silske hospodarstvo, ukrstat.gov.ua, 2016). In this way they could maintain the profitability level of milk production over $R = 105\%$.

It should be noted that Ukrainian beef production has been unprofitable (at the level of –21 ... –61%) since 1995, while profitability of Ukrainian milk production has been changing periodically from 2% to 18% during the last 5 years (Ekonomichna statystyka. Silske hospodarstvo, ukrstat.gov.ua, 2016). To provide effective production

under crisis conditions agricultural enterprises must be capable of evaluating the stability level of their own activity, especially for breakeven point and expanded reproduction. It can be done by means of the following formula

$$K = (100 + r)/(100 + R), \quad (7)$$

where r and R are the minimal sufficient and maximal possible profitability levels.

By means of such assessments agricultural enterprises will get information on their reserves of part sales, available discounts and own reassuring in case of temporary decrease of animal productivity. According to the given prospective profitability, "Research agricultural holding "Polivanovka" has chosen to aim at 20% of expanded reproduction for its beef segment and 80% – for its milk segment. In total, this proportion is maintained by own funds (50%) and investment (50%).

In case of beef production for $R = 30.06\%$ the evaluated by (7) breakeven stability level with $r = 0\%$ has amounted $K_0^{beef} = 0.77$. The assessment of stability for expanded reproduction with $r = 20\%$ has got the value $K_{20}^{beef} = 0.92$.

Graphical illustrations on mutual impacts of shares of sales and incomes per fodder unit for K_0^{beef} and K_{20}^{beef} are given in Figure 1.

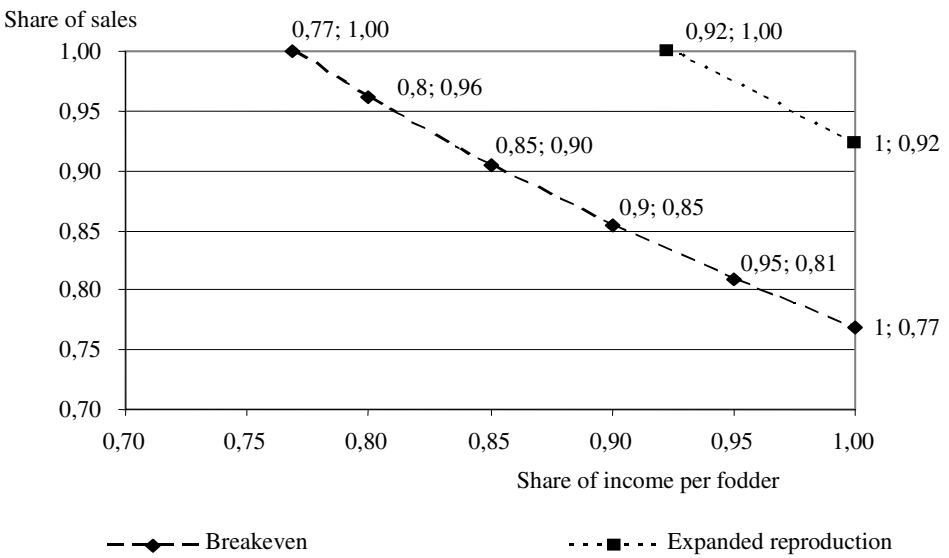

Figure 1. **Stability assessment for beef production,** *authors'*

In case of milk production for $R = 105.36\%$ the evaluated by (7) breakeven stability level with $r = 0\%$ has amounted $K_0^{milk} = 0.49$. Assessment of stability for expanded reproduction with $r = 80\%$ has got the value $K_{80}^{milk} = 0.88$.

Graphical illustrations on mutual impacts of shares of sales and incomes per fodder unit for K_0^{milk} and K_{80}^{milk} are given in Figure 2.

Conclusions. Crisis conditions and nonobservance of ecological and technological principles have strengthened the misbalance between crop and animal produc-

tions in Ukraine. In such a case scientific substantiation should generate recommendations on inter-branch development in agriculture. Therefore, optimization model for fodder crops sown areas has been proposed with restrictions by types and nutrition characteristics of forages used in meat and milk cattle husbandry. With practical application it made possible to distribute 25% of arable lands under fodder crops and provide breakeven beef production, and over 68% of profitability in the milk segment.

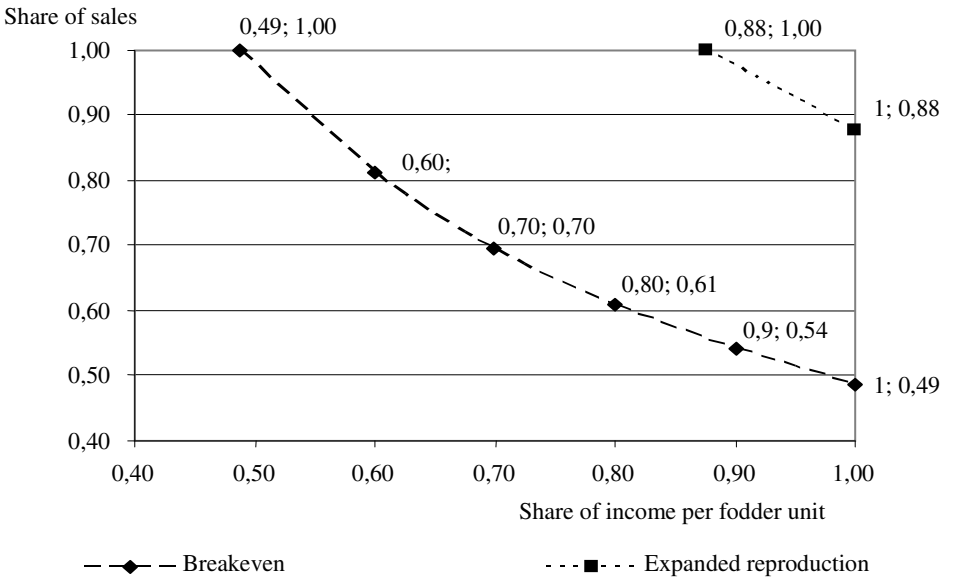

Figure 2. **Stability assessment for milk production,** *authors'*

The main reserve for further increase in animal husbandry profitability has been connected with enlargement of incomes per fodder unit, which also maintains some level of stability for breakeven and expanded reproduction. The practical application of the constructed assessments has given reserves in part sales, price discounts, and diminished animal productivity starting with 0.77–0.92 for beef production and 0.49–0.88 for the milk segment.

The obtained results and practical challenges confirm the effectiveness of mathematical applications of profitable improvements in Ukrainian agriculture, especially in its underdevelopment segments. Thus, it has been planned to generalize this positive experience in the form of a mathematical simulation of renovation development for further application in the national sheep husbandry too.

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