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MODELLING THE ECONOMIC POTENTIAL OF THE AGRICULTURAL SECTOR IN THE CARPATHIAN REGION OF UKRAINE

Purpose. *The purpose of the study is to assess and forecast the economic potential of the agricultural sector in the Carpathian region of Ukraine based on economic-and-mathematical modelling.*

Methodology / approach. *The results of the study were obtained based on the development of an economic-and-mathematical model for searching for the optimal production structure in the agricultural sector of the Carpathian region of Ukraine. It was based on the criterion of maximising the value of the final product, taking into account three levels of productivity, variability of sales prices for each type of product, and established restrictions on the level of marginal prices, available area for growing crops, food needs of the population of the region, and other regulations that affect the forecasting of economic potential.*

Results. *According to the results of the study, it was determined that the economic potential of the agricultural sector of the studied region with optimal use of 2.7 million hectares of various types of agricultural land is from EUR 6.3 to 10 billion in terms of the value of the final product, depending on the achieved level of production productivity and taking into account the variability of sales prices. An increase in the region's economic potential is possible based on a change in the sectoral structure of production in favour of increasing the volume of livestock products, the sale of which receives a higher value per 1 hectare of land compared to the cultivation of fodder grains for export. An increase in the share of vegetable fruit and berry plantings in the structure is also justified, including using part of the pastures and hayfields that are not used for fodder production.*

Originality / scientific novelty. *For the first time, a forecast of the economic potential of the agricultural sector of the Carpathian region of Ukraine was carried out based on the developed economic-and-mathematical model. The model takes into account different levels of cultivation productivity for each type of product and the variability of sales prices while achieving the optimal balance of crop and livestock production to ensure food security for the population of the region and the formation of export opportunities.*

Practical value / implications. *The obtained research results will contribute to making informed strategic decisions in implementing effective agrarian and food policy. It contributes to increasing the economic potential of the agricultural sector in the Carpathian region of Ukraine based on achieving a higher level of efficiency in the use of agricultural land, labour, and material and technical resources.*

Keywords: *economic potential, agricultural sector, agricultural products, price, production structure, Carpathian region.*

1. INTRODUCTION

The Carpathian region of Ukraine, which includes Lviv, Ivano-Frankivsk, Zakarpattia, and Chernivtsi regions, has a significant unrealised economic potential for the development of agriculture. It is characterised by unique natural and climatic conditions that allow growing a wide range of food and feed crops to meet the needs of the domestic market and the processing industry. The region accounts for about 6.7 % of all agricultural land in the state, including 5.2 % of arable land, with a specific weight in the structure of the value of agricultural products of more than 11 % before the start of the full-scale war. Despite the lower level of soil quality compared to other regions, the average yield of the main crops grown by enterprises is one of the highest in Ukraine due to a more favourable climate, particularly in terms of rainfall. Almost half of the region is occupied by forests, and more than a third is occupied by mountainous areas. A relatively high share of pastures and hayfields is favourable for the development of cattle breeding and sheep breeding. However, in the sectoral structure of agriculture in the region, crop production prevails over livestock production in a ratio of 3 to 1, with a gradual deepening of specialisation in the cultivation of vegetables and export-oriented grain and industrial crops.

In our opinion, the actual structure of agricultural production in the region is unbalanced and requires systematic optimisation. It is necessary to take into account ensuring the food security of the local population by the main types of food products, changes in the level of profitability of agricultural lands and orientation towards achieving a higher value of produced products. Accordingly, research on modelling the economic potential of the agricultural sector in the Carpathian region becomes relevant. It is also important to find the optimal structure of land use, planning the production volumes of crop and livestock products at different levels of productivity with the achievement of the most favourable balance to substantiate the priority areas of further development of the agricultural industry.

The purpose of the study is to assess and forecast the economic potential of the agricultural sector of the Carpathian region of Ukraine based on economic-and-mathematical modelling.

2. LITERATURE REVIEW

Studies of the potential of the agricultural sector and its components are presented in many scientific works. In particular, a group of scientists from the Institute of Regional Studies of the National Academy of Sciences of Ukraine led by V. Kravtsiv conducted comprehensive studies of current problems and prospects for the development of the Carpathian region, including the assessment of the potential of agricultural production [1]. Scientists L. Sas et al. assessed the resource potential of agricultural enterprises in the Carpathian region [2]. Based on simulation modelling, L. Zaburanna predicted options for the development of agriculture in the region, taking into account macroeconomic policy instruments [3]. E. Laveykina and I. Tekynyuk investigated the prospects for the development of the Carpathian region and assessed its natural resource potential [4]. Many articles by Ukrainian scientists present research

results on essential components of agricultural production potential, including at the level of enterprises in the industry. For example, V. Miroshnichenko defines the main approaches to assessing the financial potential of agricultural enterprises [5]. I. Yepifanova and V. Dzhedzhula investigate the methodology for determining innovation potential [6]. In her work, T. Matsybora substantiated the formation and development of the investment potential of the agricultural sector of Ukraine [7]. S. Stepanenko identifies the elements and features of the formation of the resource potential of agricultural enterprises [8]. Other Ukrainian scientists focus on studying the economic potential of the agricultural sector of Ukraine with the determination of the main directions and reserves of growth [9; 10].

In addition, systematic studies of the export potential of the agricultural sector of Ukraine are being conducted, taking into account the development of globalisation processes in the world economy [11–13]. The ecological features of the formation of land use in the regions of Ukraine have been studied [14]. It is worth highlighting studies on indicators of assessing economic and environmental potential in the agro-industrial complex [15], features of the process of reproducing the potential of agricultural enterprises [16], as well as establishing the primary factors and conditions for the formation and increase of potential, to ensure the sustainable development of enterprises in the industry [17]. However, these studies are characterised by an analytical and general theoretical and methodological orientation. They are without determining specific values of indicators of the economic potential of the agricultural sector of Ukraine or individual regions based on the use of specialised economic-and-mathematical models.

It is worth highlighting several applied economic studies on optimising agricultural land use and the production industry structure. In particular, J. Zarod uses a multi-criteria optimisation model to plan agricultural production [18]. X. Pan, and J. Chen identified the main directions for optimising the agricultural industry structure [19]. Studies on the economic modelling of agricultural production [20; 21] and optimisation of the structure of agricultural land use [22–26] have become widespread. Studies have been conducted on optimising the structure of agricultural land use and production volumes in large enterprises in Central and Eastern Europe [27], particularly in Ukraine [28]. Separately, it should be noted that the study of value optimisation for the agri-food sector is based on the use of the circular economy approach [29].

However, organisational and economic directions for increasing the potential of the agricultural sector of individual regions of Ukraine remain insufficiently studied. In particular, optimising the production structure with the search for an inter-sectoral balance that will contribute to ensuring food security and forming export opportunities with the most rational use of the resources involved. Accordingly, our study is based on the established hypothesis, which consists of substantiating and assessing the impact of optimising the production structure on increasing the economic potential of the agricultural sector in the Carpathian region of Ukraine. It is under conditions of variability of sales prices and taking into account different levels of productivity of

crop and livestock production with the establishment of cause-and-effect relationships between input variables and the result of optimisation.

This study provides answers to the following relevant research questions:

1. How significant are the reserves for the economic potential of the agrarian sector in the Carpathian region of Ukraine based on the optimisation of the production industry structure according to the criterion of the maximum value of the final product?

2. What are the limits of the growth of the economic potential of the agrarian sector of the region, depending on the achieved production productivity levels and considering price variability?

3. What is the optimal balance between crop production and livestock farming in the region's industry structure of the agricultural output?

4. What areas of agricultural production can ensure the most significant growth of the sector's economic potential according to the established optimisation criterion?

Modelling the economic potential of the agricultural sector of the Carpathian region is also a continuation of our previous research related to the assessment of the export potential of livestock production in Ukraine [30], modelling the economic efficiency of pork production [31], and forecasting the profitability index of the output of the main types of livestock products in Ukraine [32]. It subsequently influenced the development of a model for forecasting the economic potential of the agricultural sector using the example of a separate region with optimisation of the structure of production according to the criterion of achieving maximum value under established resource and market constraints.

3. METHODOLOGY

The economic potential of the agricultural sector in the Carpathian region can be determined based on the developed economic-and-mathematical model. It is based on the optimisation of crop and livestock production structure according to the criterion of maximising the total value. The main variables in the model are 60 different types of agricultural products that can be produced in the regions included in the studied region with certain recommended restrictions on the minimum permissible volume to ensure food security for the region's population and minimise logistical costs.

The economic potential of the agrarian sector is a dynamic category that shows the maximum value of products produced by all business entities over a specific period based on the optimal combination and use of the involved factors of production by the established resource, technological, market, and other restrictions.

The presented model covers three main approaches to determining and assessing economic potential (resource, production, and market). The methodology takes into account restrictions on the leading resource in agriculture – land and the productivity of its use under three options. It further determines the maximum production volumes of crop and livestock products according to the production approach, and a change in market supply will affect the projected sales price of products, which will affect economic potential. The model also considers restrictions on demand for basic types of food products within the regional market that needs to be provided.

Achieving the maximum value of the produced products occurs through the optimal distribution of limited areas of various types of agricultural land that are suitable for growing food and fodder crops, using them as pastures, and harvesting feed for livestock in the required volumes, but taking into account variable product sales prices.

The recommended volume of crop production is divided into food crops. They are intended to meet the needs of the region's population and form export potential in the event of a possible surplus. As well as fodder crops intended for animal feed and ensure the production of livestock products in the amount necessary to guarantee the region's food security and possible export formation, if appropriate.

The model determines the optimal ratio between crop production and livestock production, which will ensure the maximum value of the final product, taking into account the limitations. The basis for the effective distribution of limited areas of agricultural land is the indicator of the final value of the produced product per 1 hectare of area. Accordingly, the production of such agricultural products capable of ensuring the highest value of this indicator will be prioritised.

An essential factor that balances the results of the modelling is the variability of the sales price of products, which will change depending on the change in production volumes for each type of product. Thus, with a significant increase in the production of a specific type of agricultural product compared to the baseline of the previous year, the price of such products will decrease. It will facilitate the search for other alternative combinations and production structures, in which it is possible to achieve the established optimisation criterion. Vice versa, with a decrease in the production of inexpensive products relative to the baseline level, their price is predicted to increase, considering the elasticity coefficient. Therefore, it is necessary to find the optimal distribution of agricultural land to achieve such a production structure that will ensure the maximum final value of the produced product. For this purpose, the most significant number of commodity items should be taken into account, the total value of which will allow the optimisation criterion to be achieved. Accordingly, the objective function of the model can be described by formula (1):

$$Opt_k = \sum_{i=1}^{n} P_{ik} \cdot Q_{ik} \rightarrow max, \quad (1)$$

where Opt_k – total value of agricultural production at the *k*-th productivity level, EUR;

P_{ik} – predicted sales price of the *i*-th type of agricultural product at the *k*-th productivity level, EUR/t;

Q_{ik} – optimal production volume of the *i*-th type of agricultural product at the *k*-th productivity level, t.

The model also takes into account different levels of productivity of agricultural production. For the crop sector, this is the level of crop yield. For the livestock sector, it is the feed cost for the production of 1 ton of products by the main species. Of course, with a low level of productivity, it is necessary to allocate more land areas to ensure

the production of recommended volumes of crop and livestock products. In addition, vice versa: when a high level of productivity is achieved, the production volume will increase. Depending on the achieved level of productivity, the optimal structure of production and the economic potential of the region's agricultural sector will change, taking into account formula (2):

$$Q_{ik} = L_{ik} \cdot S_{ik}, \quad (2)$$

where L_{ik} – yield of the *i*-th type of agricultural crops at the *k*-th level of productivity;

S_{ik} – the optimal area of agricultural land for growing the *i*-th type of agricultural crops at the *k*-th level of productivity, (in the model these are variables x_1 – area for growing feed wheat, x_2 – feed barley, x_3 – fodder corn, x_4 – fodder oats, x_5 – edible wheat, x_6 – edible barley, x_7 – edible oats, x_8 – edible corn, x_9 – edible rye, x_{10} – sunflower, x_{11} – soy, x_{12} – green fodder, x_{13} – roughage, x_{14} – fodder root crops, x_{15} – millet, x_{16} – buckwheat, x_{17} – leguminous crops, x_{18} – sugar beet, x_{19} – winter rapeseed, x_{20} – Sinapis, x_{21} – flax oil, x_{22} – potato, x_{23} – cucumbers and gherkins, x_{24} – tomatoes, x_{25} – cabbage, x_{26} – beetroot, x_{27} – carrot, x_{28} – onion, x_{29} – garlic, x_{30} – sweet and bitter capsicum, x_{31} – cabbage, x_{32} – aubergine, x_{33} – pumkin, x_{34} – water melon and melon, x_{35} – other vegetables, x_{36} – apples, x_{37} – pears, x_{38} – plums, x_{39} – sour cherries, x_{40} – cherries, x_{41} – apricots, x_{42} – peach, x_{43} – strawberries, x_{44} – raspberry and blackberry, x_{45} – currant, x_{46} – gooseberry, x_{47} – blueberry, x_{48} – bilberries, x_{49} – walnut, x_{50} – hazelnut, x_{51} – winery, x_{52} – other fruit and berry crops, x_{53} – hop growers), hectares. The dependence of the obtained results of optimising the production structure on the achieved level of productivity is described based on the formula (3):

$$Q_{ik} = IF(Lp = 1; L1_i \cdot S_{ik}; 0) + IF(Lp = 2; L2_i \cdot S_{ik}; 0) + \\ + IF(Lp = 3; L3_i \cdot S_{ik}; 0), \quad (3)$$

where Lp – level of productivity (yield) of agricultural crops (in the model, it takes on a value from 1 to 3);

$L1_i$ – the first (low) level of yield of the *i*-th type of agricultural crops, t;

$L2_i$ – second (average) level of yield of the *i*-th type of agricultural crops, t;

$L3_i$ – the third (high) yield level of the *i*-th type of agricultural crops, t.

The modelling provides several options for using limited areas of agricultural land. The choice and balance between them depends on the profitability of land use per 1 ha, which is influenced by the planned sales price of products and the achieved level of production productivity. As an example, land can be used to grow food crops to meet the needs of the regional consumer market and the possible formation of export potential. In addition, growing fodder crops can provide livestock with feed and the corresponding production of livestock products in a volume. It will primarily be sufficient to meet the needs of the regional market and the possible formation of export potential under the condition of a surplus of products and a relatively higher level of profitability compared to other areas of agricultural production per 1 ha of area. It ultimately will determine the optimal structure between crop production and livestock production, including by individual areas of production. Accordingly, considering the

needs of fodder crops for the development of the livestock industry, including by individual species, it is determined based on formulas 4 and 5:

$$Q_{ik} = IF(Lp = 1; L1_i \cdot S_{ik}; 0) + IF(Lp = 2; L2_i \cdot S_{ik}; 0) + \\ + IF(Lp = 3; L3_i \cdot S_{ik}; 0) - QAhp_{ik}, \quad (4)$$

where $QAhp_{ik}$ – the volume of the *i*-th type of forage crops at the *k*-th level of productivity necessary to ensure the feeding of farm animals and the production of livestock products (this formula is used only to determine the optimal volume of forage crop production), t;

$$QAhp_{ik} = \sum_{i=1}^{n} Q \frac{N_{ijk} \cdot Fq_{ij}}{100} \cdot QPa_{jk}, \quad (5)$$

where QN_{ijk} – normative average costs of the *i*-th type of feed for the production of 1 t of the *j*-th type of livestock products at the *k*-th level of productivity, t;

Fq_{ij} – share of the *i*-th type of feed for the production of the *j*-th type of livestock products in the structure of the feeding ration (does not depend on the achieved level of productivity), %;

QPa_{jk} – the optimal volume of production of the *j*-th type of livestock product at the *k*-th level of productivity (in the model these are variables x_{54} – milk production volume, x_{55} – beef and veal, x_{56} – pork, x_{57} – lamb, x_{58}–other types of meat, x_{59} – poultry meat, x_{60} – eggs), t.

The model also justifies the optimal structure of the use of the agricultural land area of the region. It is possible to produce such a set of different types of crop and livestock products that will ensure the maximum value of the final product, taking into account the variability of the sale price and the achieved level of production productivity. Also, agriculture's sectoral orientation determines the optimal production structure during modelling. In crop production, optimisation is carried out in different areas of possible cultivation of food and fodder crops, which corresponds to the values of the variables ($x_1 \dots x_{53}$). In livestock farming, the most profitable option is determined by the choice between the production of different types of products – beef, pork, poultry, lamb, other types of meat, milk, and table eggs, which corresponds to the variables ($x_{54} \dots x_{60}$). Also, the level of volumes and structure of livestock production by main species will affect the volumes and structure of crop production. Particularly, it is in the direction of growing forage crops necessary to ensure animal feeding.

Price planning, when modelling the economic potential of the regional agricultural sector, considers the coefficient of price elasticity caused by a change in the volume of domestic supply. The Carpathian region is an integral part of the aggregate national market of Ukraine. Therefore, in order to take into account the impact of changes in production volumes for various types of agricultural products, the final value of the forecasted prices is adjusted, taking into account the coefficient of the region's share in the total production volumes of agricultural products in Ukraine for each type. Accordingly, the higher the region's share in the production of a particular kind of agricultural product, the higher the impact on the forecasted price

and vice versa (formula 6):

$$P_{ik} = IF\left(Q_{ik} > (Qb_i \cdot Fb_i); \left(\frac{Q_{ik} - Qb_i \cdot Fb_i}{Q_{ik} + Qb_i} \cdot 100 \cdot Ep\frac{b_i \cdot Pb_i}{100} \cdot (-1) + Pb_i\right); 0\right) + IF\left(Q_{ik} < (Qb_i \cdot Fb_i); \left(\frac{Qb_i \cdot Fb_i - Q_{ik}}{Q_{ik} + Qb_i} \cdot 100 \cdot Ep\frac{b_i \cdot Pb_i}{100} + Pb_i\right); 0\right) + IF(Qb_i \cdot Fb_i = Q_{ik}; Pb_i), \quad (6)$$

where Qb_i – production volume of the i-th type of agricultural product in the base year, t;

Fb_i – the share of the volume of the *i*-th type of agricultural product that falls on the Carpathian economic region in the structure of the total volume of production of the *i*-th type of agricultural product in Ukraine;

Pb_i – sales price of the *i*-th type of agricultural product in the base year, EUR/t;

Epb_i – the percentage change in the selling price of the *i*-th type of agricultural product accounts for 1 percent of the change in the production volume of the *i*-th type of agricultural product, %.

Unfortunately, due to the full-scale war that Ukraine has been involved since 2022, it is difficult to predict with high accuracy the level of production volumes of individual types of agricultural products in other regions. Therefore, in the model, when determining the predicted prices, taking into account the weighting coefficients, the option of static production volumes in the other areas of Ukraine is considered. Therefore, in the priority of our future research, for greater accuracy of modelling, this calculation method will be used taking into account the areas of agricultural land of the entire controlled part of Ukraine after the end of active hostilities. It will allow us to expand the vector of our research and make it more comprehensive and large-scale. The expanded view of the model of the formation of the economic potential of the studied region of Ukraine, taking into account the variability of the sales price of products and the achieved level of productivity, can be described by formula (7):

$$Opt_k = \sum_{i=1}^{n} IF\left(Q_{ik} > (Qb_i \cdot Fb_i); \left(\frac{Q_{ik} - Qb_i \cdot Fb_i}{Q_{ik} + Qb_i} \cdot 100 \cdot Ep\frac{b_i \cdot Pb_i}{100} \cdot (-1) + Pb_i\right); 0\right) + IF\left(Q_{ik} < (Qb_i \cdot Fb_i); \left(\frac{Qb_i \cdot Fb_i - Q_{ik}}{Q_{ik} + Qb_i} \cdot 100 \cdot Ep\frac{b_i \cdot Pb_i}{100} + Pb_i\right); 0\right) + IF(Qb_i \cdot Fb_i = Q_{ik}; Pb_i) \cdot [IF(Lp = 1; L1_i \cdot S_{ik}; 0) + IF(Lp = 2; L2_i \cdot S_{ik}; 0) + IF(Lp = 3; L3_i \cdot S_{ik}; 0) - QAhp_{ik}] \rightarrow max. \quad (7)$$

To ensure the food needs of the population of the region in the main types of agricultural products, the following restrictions have been established regarding the minimum values of production volumes in tons: milk production volume ≥ 2,280,000; beef and veal ≥ 150,000; pork ≥ 150,000; lamb ≥ 30,000; other types of meat ≥ 30,000; poultry meat ≥ 120,000; table eggs ≥ 97,440; potatoes ≥ 744,000; sunflower ≥ 78,000; sugar beet ≥ 480,000; total volume of other vegetables ≥ 966,000; total volume of all types of berries ≥ 270,000; volume of food grains ≥ 606,000; total volume of all kinds of fruits ≥ 270,000; total volume of all kinds of meat ≥ 480,000; total area of used land $\sum_{i=1}^{n} L_{ik} = 2{,}781{,}000$.

Given the variability of prices depending on the level of projected production

volumes, to find the optimal structure of agricultural land use in the region, it is advisable to establish additional restrictions on the maximum price value for different types of products, below which they should not fall. This restriction is introduced to ensure a minimum level of profitability of production and avoid possible losses due to excessive production, which will cause a significant collapse in sales prices. Accordingly, $P_{ik} \geq Pm_i$, where (Pm_i) is the maximum (minimum) price value of the i-th type of agricultural product, EUR/t (formula 8):

$$Pm_i = P_{ik} \cdot k_i, \quad (8)$$

where k_i – price adjustment coefficient of the i-th type of agricultural product.

The model adopts approximate values of adjustment coefficients to determine the minimum allowable value of the sales price for each group of agricultural products. For grain crops, the coefficient values are set at 0.75, for vegetable and industrial crops – 0.65, for fruit and berry crops – 0.6, and for the main livestock products – 0.7. Setting limit prices will affect the optimal balance between the volumes of different groups of agricultural products. It will not allow the structure to shift, favouring several of the most profitable production areas. On the contrary, it will affect the expansion of diversification and increase the average economic efficiency level of the region's agricultural sector. The primary input information for developing the model, which will affect the level of forecasted prices for determining the economic potential of the agricultural industry, is given in Tables 1, 2, and 3.

The yield level of the main types of agricultural crops is divided into three conditional levels. It will determine the results of the economic potential modelling in the future. The first level of yield characterises the current state of productivity of agricultural land use on which food and fodder crops are grown in the region or close to it, depending on the product type. The second level characterises the yield that can be achieved in the short and medium term for most enterprises in the industry. This is possible if there are favourable natural and climatic conditions and further development of crop cultivation technologies.

The third level of land use productivity is characterised by a relatively high crop yield index, which can potentially be achieved by most agricultural enterprises in the region in the long term. This is achievable provided technological modernisation of production using innovative technologies for land cultivation and growing crops at all stages of their growth, using high-quality seed material with high productivity potential. Of course, with the development of technologies in agricultural production, the indicated highest level of productivity is not limited. It only defines a certain average level that most producers of products can achieve, depending on specialisation.

When planning the value of products, it is essential to note the influence of the studied region on the level of sales prices, taking into account the specific weight indicator in the total volume of agricultural production in Ukraine. According to the results of 2023, the largest share of the region among crop production was observed in the cultivation of cabbage (37.2 %), apples (35.3 %), and pears (27.7 %). The share in the cultivation of table beets, cucumbers, potatoes, plums, and walnuts was relatively high – about 20 %. It is typical for crop production's fruit and vegetable specialisation.

Table 1

Input data for modelling the economic potential of the crop production industry of the Carpathian region (food and industrial crops)

Product name	Crop yield level, t/ha			Base price, EUR/t	Limit price, EUR/t	The region's share in total national production*	Price change by 1 % change in supply, %
	1	2	3				
Millet	3	4	5	200	150	0.1**	0.1
Buckwheat	1.9	2.2	2.5	420	315	0.07109	1
Legumes	2	2.5	3	430	323	0.065829	0.1
Sugar beet	55	67.5	80	40	30	0.111573	1
Sunflower	2.5	3	3.5	570	428	0.024645	0.1
Soybean	2.3	2.8	3.2	500	375	0.163947	0.1
Winter rapeseed	3	3.6	4.2	550	413	0.084147	0.1
Mustard	1	1.4	1.8	900	675	0.1	0.1
Oil flax	1.1	1.5	1.9	560	420	0.1	0.1
Potatoes	22	28	34	160	104	0.192285	1.5
Cucumbers and gherkins	23	27	32	280	182	0.215601	2
Tomatoes	26	34	42	400	260	0.124771	2
Cabbage	28	34	41	200	130	0.372229	1.5
Table beet	23	28	35	155	101	0.21606	1.5
Table carrots	21	26	32	160	104	0.196419	1.5
Onions	20	25	31	230	150	0.146845	1
Garlic	8	10	12	1600	1040	0.1	1
Capsicum pepper	40	55	70	345	224	0.1	2
Table zucchini	22	28	32	200	130	0.1	1
Eggplants	20	24	28	220	143	0.1	1
Table pumpkins	26	30	35	90	59	0.1	1
Watermelons	21	25	31	215	140	0.1	1
Melons	20	24	30	250	163	0.1	1
Apples	17	25	32	280	168	0.352759	1
Pears	15	24	31	345	207	0.276523	1
Other fruit and berry crops	16	25	30	400	240	0.1	1
Plums	13	22	30	480	288	0.217675	1
Sour cherries	12	17	22	410	246	0.160377	1
Cherries	10	15	20	400	240	0.154639	1
Apricots	11	18	24	585	351	0.038229	1
Peaches	12	19	25	555	333	0.039063	1
Strawberries	9	11	14	1100	660	0.160221	1.5
Raspberries and blackberries	9	12	15	1050	630	0.142857	1.5
Currants	10	15	20	720	432	0.153846	1.5
Gooseberries	9	14	19	850	510	0.1	1.5
Blueberries	8	10	12	2200	1320	0.1	1.5
Bilberries	7	9	11	1940	1164	0.1	1.5
Walnuts	8	10	12	510	306	0.231198	1
Hazelnuts	1.5	2	2.5	2050	1230	0.1	0.7
Vineyards	20	30	40	550	330	0.132997	1
Hops	0.9	1.1	1.3	12500	750	0.1	1
Edible wheat	6	8	10	200	150	0.068903	0.1
Edible barley	4.5	5.5	6.5	210	158	0.062444	0.1
Edible corn	8	10	12	190	143	0.070172	0.1
Edible oats	3	3.5	4	190	143	0.13395	0.1
Edible rye	3.5	4.5	5.5	210	158	0.058599	0.1

Notes. * Compiled based on data [33]; ** in the absence of statistical data, a conditional value is accepted 0.1.

Source: own research.

Table 2

Input data for modelling the economic potential of the crop production industry of the Carpathian region (forage crops)

Product name	Crop yield level, t/ha			Base price, EUR/t	Limit price, EUR/t	The region's share in total national production*	Price change per 1 % change in supply, %
	1	2	3				
Feed wheat	6.0	8.0	10.0	165	124	0.068903	0.1
Feed corn	8.0	10.0	12.0	174	131	0.070172	0.1
Feed barley	4.5	5.5	6.5	175	131	0.062444	0.1
Feed oats	3.5	4.0	4.5	160	120	0.133950	0.1
Green fodder	25	30.0	35.0	51	38	-	0.5
Coarse fodder	7.0	8.0	9.0	76	57	-	0.5
Root crops	35.0	45.0	55.0	82	62	-	0.5

Note. * Compiled based on data [33].

Source: own research.

Since the cultivation of the main grain and legume crops due to the relatively small areas of arable land compared to the central, eastern, or southern regions of Ukraine is traditionally at a low level with a specific weight of 6–7 %, except oats and soybeans (13–16 %). The values of the region's shares for some types of vegetables and berries due to the lack of specific data due to the generalisation of statistical information during modelling were taken as 10 % (0.1).

Table 3

Input data for modelling the economic potential of the livestock industry in the Carpathian region

Product name	Level of feed costs for livestock production, units/kg			Base price, EUR/t	Limit price, EUR/t	The region's share in total national production*	Price change per 1 % change in supply, %
	1	2	3				
Milk	1.0	0.9	0.8	400	280	0.165094	0.1
Cattle meat	7.2	7.0	6.8	4400	3080	0.247392	0.4
Pork	3.3	3.1	2.9	3550	2485	0.204949	0.5
Lamb	7.0	6.9	6.8	4270	2989	0.361111	0.3
Poultry	3.2	3.0	2.8	2290	1603	0.082506	0.6
Eggs	2.5	2.4	2.3	1360	952	0.1266	0.5
Other meat	5.4	5.2	5.0	4130	2891	0.164706	0.2
Wool	-	-	-	3010	2107	0.361111	0.1

Note. * Compiled based on data [32].

Source: own research.

For enterprises that produce livestock products, three levels of productivity have also been determined by the feed consumption indicator per unit of output. It depends on many technological factors, namely, animal housing conditions, feed quality, the level of balance of animal feeding rations, veterinary support, the use of breeds characterised by high productivity, and many other factors. The described productivity levels in crop production and livestock breeding will significantly affect the results of

modelling the economic potential of the region's agricultural sector. It will substantiate its quantitative and cost values, including for each type of product.

In the region's livestock sector, the development of pig farming prevails, with a share of about 20 % of the total production in Ukraine. The region's beef, lamb, and wool production share is relatively high. However, it is worth noting the relatively low level of development of poultry farming in the region, which accounts for only 8 % of the total production in Ukraine. The region's share in the production of table eggs is also low – up to 13 %. Milk production is about 16 % of the total production in the state. Accordingly, the most decisive influence of agricultural producers in the region's livestock sector will be noted in planning prices for lamb, wool, beef, and pork.

4. RESULTS

4.1. Analysis of the structure of land areas, production volumes, and the value of products of the agricultural sector in the Carpathian region. The Carpathian region includes Zakarpattia, Ivano-Frankivsk, Lviv, and Chernivtsi regions. Together, they amount to over EUR 2.1 billion in the value of agricultural products produced at the end of 2022. It includes EUR 1.47 billion in crop production, which is 2.2 times more than the value of livestock production. According to Tables 4 and 5, the Lviv region is characterised by the largest agricultural land fund among other areas of the region. It is noticeably reflected in the economic potential of the development of the agricultural sector. About 44–47 % of all arable land, pastures, and hayfields are concentrated in the region, and a third of perennial plantations. Regarding the structure of the value of agricultural products produced in the region, the region occupies a share of about 45 %. The amount is almost EUR 1 billion, of which 73 % is crop production and 27 % is livestock.

Table 4

Area of agricultural land by region of the Carpathian region as of 2023, thousand hectares

Name	Regions				Total
	Zakarpattia	Ivano-Frankivsk	Lviv	Chernivtsi	
Total area, thousand hectares	1275.3	1392.7	2183.1	809.6	5660.7
Agricultural farms	450	621	1240	470	2781
including – arable land and fallow land	200	403	771	331	1705
– hayfields	94	82	195	41	412
– pastures	129	121	251	68	569
– perennial plantations	27	15	23	30	95
forests	724	635	694	746	2799

Source: compiled based on data [33].

The second largest region in terms of agricultural land, including arable land, is the Ivano-Frankivsk region, with a share of 22–23 %. It affects the formation of about 24 % of the value of all agricultural products produced in the region, amounting to over EUR 500 million, with the share of crop production and livestock production in the

structure at 63 % and 37 %, respectively. The third place in terms of agricultural land area and value of produced products in the region is occupied by the Chernivtsi region. It accounts for up to 20 % of the share of arable land, 10–12 % of hayfields and pastures, and over 30 % of the region's perennial plantings.

Table 5

The value of agricultural production by region of the Carpathian region as of the end of 2022

Industry name	Value of products by region, million EUR*				Total
	Zakarpattia	Ivano-Frankivsk	Lviv	Chernivtsi	
Livestock	131.315	190.831	258.415	95.650	676.211
Crop production	156.419	328.350	714.721	278.233	1477.723
Total agriculture	287.734	519.180	973.137	373.883	2153.934
Per 1 ha of land area, EUR	639	836	785	795	775
Industry name	Structure of the value of manufactured products by region, %				Total
Livestock	19.42	28.22	38.22	14.15	100.0
Crop production	10.59	22.22	48.37	18.83	100.0
Total agriculture	13.36	24.10	45.18	17.36	100.0
Industry name	Share of agricultural sectors in the structure of the value of manufactured products by region, %				Total
Livestock	45.64	36.76	26.55	25.58	31.39
Crop production	54.36	63.24	73.45	74.42	68.61
Total agriculture	100.0	100.0	100.0	100.0	100.0

Note. * The conversion of product values from UAH to EUR was carried out at the current exchange rate (27.45 UAH/1EUR) as of the end of 2022.

Source: compiled based on data [33].

The value of agricultural products manufactured in the region amounted to over EUR 370 million, about 19 % of the overall structure, with a similar ratio of crop production and livestock production to the Lviv region. The smallest fund of agricultural land is concentrated in the Zakarpattia region, which accounts for only 12 % of the region's arable land, about 23 % of hayfields and pastures, and 28 % of perennial plantings. The region's share in the structure of the value of agricultural products produced was over 13 % (EUR 288 million), with a more balanced ratio of crop production and livestock farming compared to other regions.

For further optimisation of the production structure, it is worth paying attention to the indicator of the actual value of agricultural products per 1 hectare of area by region when conducting a general analysis of land use efficiency. The highest given value per unit of area is characteristic of the Ivano-Frankivsk region – about 836 EUR hectare. This indicator is within 780–800 EUR/hectare in the Lviv and Chernivtsi regions. Relatively low land use efficiency is observed in the Zakarpattia region – up to 640 EUR/hectare, which is associated with relatively higher shares of pastures and hayfields in the structure of the land fund compared to other regions. Using arable land and perennial plantations largely allows for higher value of produced products per unit of land area. According to the results of the modelling, three options for the optimal

production structure were obtained. They will determine the economic potential of the agricultural sector of the Carpathian region of Ukraine, taking into account the productivity levels of growing products and the variability of sales prices. The optimisation results consider the specified restrictions on the direct provision of food security for the main types of food products for the region's population of 6 million people. The economic potential of the region's agricultural sector was modelled according to the criterion of maximising the value of the final product. It was based on the available area of agricultural land according to 2023 data, on which it was possible to grow various food and fodder crops.

4.2. Results of modelling the production volumes of agricultural products taking into account three levels of productivity. When the first level of productivity of crop and livestock production in the region is reached, according to the modelling results (Tables 6, 7), more than 757 thousand hectares will be planted with fodder grain crops, the leading share of which will be barley. This takes into account the optimal structure and volume of livestock farming, where pig farming accounts for the largest share. The total volume of fodder grain crops grown is forecast at 4.1 million tons. Additionally, for livestock needs, it is necessary to use more than 236 thousand hectares of pastures and 385 thousand hectares of hayfields, which will allow to obtain up to 6 million tons of green mass of forage and 2.7 million tons of hay annually.

Table 6

Projected planting areas and crop production volumes, taking into account the achieved productivity level (forage crops)

Product type	Yield levels					
	1		2		3	
	Area, hectares	Volume, t	Area, hectares	Volume, t	Area, hectares	Volume, t
Feed wheat	190424	1142544	205030	1640238	224021	2240210
Feed corn	149196	1193569	174162	1741616	203235	2438823
Feed barley	303984	1367928	367126	2019195	342986	2229407
Feed oats	114317	400108	97908	391632	91240	410581
Green fodder	236654	5916351	185275	5558250	148576	5200148
Coarse fodder	385226	2696582	316297	2530377	262686	2364172
Root crops	20771	726994	15094	679215	11481	631435
Total	1400572	13444076	1360892	14560523	1284225	15514776

Source: own research.

It is worth noting that when modelling the economic potential of the agricultural sector, only a general limitation on the area of agricultural land in the region is considered. Accordingly, the possibility of changing the purpose of individual types of land is allowed to achieve the maximum value of the optimisation criterion. Thus, if necessary, part of the areas occupied by pastures or hayfields can be used to create perennial plantings, develop greenhouses for the production of closed-soil vegetables. Part of the areas can be plowed for growing other crops but within the limits that are sufficient to primarily meet the needs of livestock in the procurement of feed on a specific optimal scale.

Table 7

Projected planting areas and crop production volumes, taking into account the achieved productivity level (food and industrial crops)

Product type	Yield levels					
	1		2		3	
	Area, hectares	Volume, t	Area, hectares	Volume, t	Area, hectares	Volume, t
Millet	→min	0	→min	0	→min	0
Buckwheat	→min	0	→min	0	→min	0
Legumes	→min	0	→min	0	→min	0
Sugar beet	8727	480000	7111	480000	6000	480000
Sunflower	280992	702480	327661	982984	342554	1198939
Soybean	405655	933007	511838	1433147	612373	1959594
Winter rapeseed	→min	0	→min	0	→min	0
Mustard	→min	0	→min	0	→min	0
Oil flax	→min	0	→min	0	→min	0
Potatoes	289008	6358183	249868	6996306	244874	8325720
Cucumbers and gherkins	12209	280802	10511	283791	9560	305926
Tomatoes	17574	456924	13439	456924	10879	456924
Cabbage	27692	775373	23474	798125	21732	890996
Table beet	12086	277981	10364	290188	9832	344108
Table carrots	12644	265517	10812	281109	10310	329906
Onions	20093	401858	17859	446477	18991	588717
Garlic	346	2769	277	2769	231	2769
Capsicum pepper	1250	50000	909	50000	714	50000
Table zucchini	8821	194067	8299	232374	8644	276616
Eggplants	469	9376	577	13846	490	13725
Table pumpkins	1055	27431	864	25914	1487	52062
Watermelons	4430	93035	3882	97057	4334	134347
Melons	554	11081	577	13846	462	13846
Apples	44601	758219	39722	993040	39730	1271345
Pears	6729	100931	5997	143917	5314	164733
Other fruit and berry crops	521	8333	333	8333	278	8333
Plums	10602	137829	7889	173567	5786	173567
Sour cherries	8610	103322	7824	133002	7650	168300
Cherries	2297	22966	2370	35548	2635	52702
Apricots	3300	36300	2017	36300	1513	36300
Peaches	772	9266	493	9367	375	9367
Strawberries	3512	31609	2874	31609	2258	31609
Raspberries and blackberries	1967	17701	1564	18764	1251	18764
Currants	1120	11201	944	14164	708	14164
Gooseberries	432	3888	321	4500	237	4500
Blueberries	500	4000	400	4000	333	4000
Bilberries	14286	100000	11111	100000	9091	100000
Walnuts	6843	54742	6044	60438	6372	76466
Hazelnuts	4117	6175	4770	9540	6851	17128
Vineyards	11455	229100	7637	229100	5728	229100
Hops	4861	5833	3889	5833	3241	5833
Edible wheat	67333	404000	50500	404000	40400	404000
Edible barley	→min	0	→min	0	→min	0
Edible corn	25250	202000	20200	202000	16833	202000
Edible oats	→min	0	→min	0	→min	0
Edible rye	57714	202000	44889	202000	36727	202000
Total	1380427	13769299	1420110	15703879	1496778	18618406

Source: own research.

For the cultivation of sunflower and soybeans, the processing of which produces valuable protein supplements for livestock (cake, meal), it is necessary to allocate more than 281 and 406 thousand hectares. It will allow the harvesting of about 700 thousand tons of sunflower and more than 930 thousand tons of soybeans. An important crop that is traditionally grown in significant volumes by farms in the region is potatoes. For their cultivation up to 289 thousand hectares have been allocated according to the modelling results, with a projected yield of 6.36 million tons. It will fully meet the consumer needs of the population not only of the studied region but also partially of other regions of Ukraine. In particular the southern ones, in which this crop is grown in insufficient volumes to cover the needs of the local market. In the future, with an increase in the level of productivity, it is predicted that the area under potatoes will decrease to 245 thousand hectares. However, the volume of cultivation will increase to 8.3 million tons, which will affect the growth of the region's share of this crop in the total national production.

To produce sugar in volumes that will meet the population's demand and the food industry, the region needs to grow sugar beets of at least 480 thousand tons in an area ranging from 6-8.8 thousand hectares, depending on the achieved yield level. It is proposed to allocate more than 113 thousand hectares for growing other types of vegetables in open and closed soil. When the first yield level is reached, it will allow the collection of a total of more than 2.7 million tons of products, the leading share of which will be cabbage, onions, and tomatoes. When the second yield level is reached, the projected area will decrease to 94 thousand hectares with a cultivation volume of up to 2.9 million tons. Further increase in productivity to level 3, even with a decrease in the area of plantings to 92 thousand hectares, will contribute to an increase in the volume of cultivation to 3.3 million tons.

According to the optimisation carried out at the first level of productivity, almost 142 thousand hectares of land are required. It includes more than 125 thousand hectares of perennial plantings of fruit trees and berries to grow a wide range of fruit and berry crops. A significant share of land among fruit crops will be for growing apples – more than 44.6 thousand hectares, with a projected gross yield of about 760 thousand tons. However, a gradual increase in yield will make it possible to obtain more than 1.2 million tons of apples with smaller planting areas with significant export potential.

In the southern part of the studied region, taking into account favourable climatic conditions, it is possible to grow grapes in the amount of about 230 thousand tons on an area of over 11 thousand hectares. It is also likely to cultivate watermelons and melons on an area of 5 thousand hectares, which will allow harvesting more than 100 thousand tons of valuable food products to meet up to 50 % of the needs of the domestic market of Ukraine. A gradual increase in yield will lead to a rise in gross harvests of watermelons and melons to almost 150 thousand tons.

An increase in productivity to the second level due to restrictions on the domestic consumer market and avoiding a significant decrease in sales prices will lead to a reduction in areas for most fruit and berry crops to 121 thousand hectares. At the third level, it will lead to 115 thousand hectares, but without losses in the volume of

production. It is worth noting the orientation towards increasing the area of perennial plantations for hazelnut cultivation from 4 to 7 thousand hectares, increasing the gross yield of products to 17.2 thousand tons. Walnut cultivation in more static areas will reach from 54 thousand tons at the first level of productivity to over 76 thousand tons when growing to the third level. To provide raw materials for the needs of the flour and cereal food industry of the region, it is necessary to grow food varieties of grain crops on an area of about 150 thousand hectares upon reaching the first level of yield. It will ensure a gross harvest of at least 800 thousand tons of products. A gradual increase in productivity will affect the reduction of the recommended sowing areas for growing food grains to 94 thousand hectares.

The cultivation of crops such as millet, buckwheat, legumes, winter rapeseed, mustard, oilseed flax, and food varieties of barley and oats due to their relatively low value per 1 hectare of land area compared to other types of crops is recommended to be reduced to a minimum to achieve the maximum value of the optimisation criterion at all levels of productivity. However, with an increase in average sales prices for the specified types of agricultural products, their sowing areas may be revised upwards. According to the modelling results (Table 8), there is a focus on increasing livestock production with a logical increase in the area of land for growing forage crops, as well as soybeans and sunflowers.

Table 8

Forecasted volumes of livestock production, taking into account the achieved level of productivity, tons

Product type	The volume of livestock production, taking into account the achieved level of technological productivity of feed use		
	1	2	3
Milk	2280000	2280000	2280000
Cattle meat	150000	150000	150000
Pork	667326	1195320	1325550
Lamb	30000	30000	30000
Poultry	157674	338413	819589
Eggs	140637	256096	640887
Other meats	30000	30000	30000
Wool	3750	3750	3750
Total	3459387	4283579	5279776

Source: own research.

Upon reaching each of the three productivity levels, based on the yield obtained, the production of up to 2.4 million tons of milk is predicted. It meets the local market's needs in raw materials and processing into dairy products. Beef production is forecast at about 150 thousand tons, and lamb and other types of meat – at 30 thousand tons each. The output of these livestock products is inferior in profitability per 1 hectare of forage land compared to the production of pork, poultry, and eggs. Their volumes will increase with each level of productivity. Thus, at the first level of productivity, the optimal production is 667 thousand tons of pork, up to 160 thousand tons of poultry, and over 140 thousand tons of eggs.

Increasing the productivity level to level 2 will increase the production volumes of pork and eggs relative to the first level by 80 % and poultry meat by more than 2 times. Further, an increase in the productivity level to the third level will allow for further increase in the production potential in pig farming relative to the second level by 11 %. Moreover, it will significantly increase the potential in poultry farming for meat and eggs by 2.4–2.5 times based on a more extensive feed base, which will be available because of increasing the yield of fodder crops. The total projected production volume of all types of livestock products at the first level of productivity was up to 3.5 million tons, with a further increase to 4.3 and 5.3 million tons with an increase in the productivity of agricultural production. An increase in the productivity level to the second or third level due to an increase in the projected production volumes of pork, poultry meat, and eggs will affect the growth of the area of crops of grain fodder crops, as well as sunflower and soybeans. However, the static nature of the projected production volumes of milk, beef, and lamb with increasing productivity will lead to a reduction in the required areas of pastures and hayfields. In addition, it can cause the transfer of part of the areas to growing other crops with a change in their intended purpose.

4.3. Results of modelling the value of agricultural products and land use efficiency. The projected total value of crop production under the first option of the production structure will amount to up to EUR 4.5 billion in 2024 prices (Tables 9, 10). The second option of the structure, which is determined when a higher level of productivity is achieved, increases crop production's value by 17.5 %. An increase in productivity to the third level will contribute to an increase in the economic potential of the crop production sector of the region by another 14 % compared to the previous option. It will allow obtaining over EUR 6 billion in the current value of products. According to the results of the modelling, the value of fodder crops for livestock needs will be estimated at EUR 1.1 billion under the first optimisation option. The second and third options will be valued at over EUR 1.4 billion and EUR 1.6 billion, which correspond to higher levels of productivity and projected volumes of livestock production according to the determined structure.

Table 9

Projected value of crop production depending on the achieved level of productivity (forage crops)

Product type	Yield levels					
	1		2		3	
	Price, EUR/t	Value, EUR	Price, EUR/t	Value, EUR	Price, EUR/t	Value, EUR
Feed wheat	165	188765981	165	270382782	164	368328147
Feed corn	174	208169459	174	303145313	174	423463869
Feed barley	172	235895127	171	345627138	171	380791822
Feed oats	153	61144464	153	59887230	153	62696823
Green fodder	46	271560539	46	255123666	46	238686788
Coarse fodder	68	182019308	68	170800451	68	159581592
Root crops	48	34895714	48	32602312	48	30308908
Total	X	1182450592	X	1437568892	X	1663857949

Source: own research.

Table 10

Projected value of crop production depending on the achieved level of productivity (food and industrial crops)

Product type	Yield levels					
	1		2		3	
	Price, EUR/t	Value, EUR	Price, EUR/t	Value, EUR	Price, EUR/t	Value, EUR
Millet	202	0	202	0	202	0
Buckwheat	450	0	450	0	450	0
Legumes	433	0	433	0	433	0
Sugar beet	85	40718407	85	40718407	85	40718407
Sunflower	568	399004935	567	557097759	566	678378091
Soybean	496	462576930	491	703811762	487	954501564
Winter rapeseed	555	0	555	0	555	0
Mustard	970	0	970	0	970	0
Oil flax	566	0	566	0	566	0
Potatoes	166	1052518284	160	1116454184	148	1232183074
Cucumbers and gherkins	232	65156786	231	65455033	221	67474409
Tomatoes	260	118800303	260	118800303	260	118800303
Cabbage	174	134886582	171	136719279	161	143403282
Table beet	176	48802584	172	50000186	159	54634503
Table carrots	190	50361366	185	52021580	171	56572290
Onions	172	69301074	166	74260823	149	87959186
Garlic	1040	2880000	1040	2880000	1040	2880000
Capsicum pepper	267	13325000	267	13325000	267	13325000
Table zucchini	154	29830220	145	33713250	136	37688425
Eggplants	165	1544788	143	1980000	144	1969748
Table pumpkins	97	2654050	97	2518911	90	4684782
Watermelons	161	15017205	159	15454301	141	19006043
Melons	177	1960852	163	2250000	163	2250000
Apples	227	171814684	202	200126021	178	226507406
Pears	260	26288808	222	31929080	207	34099800
Other fruit and berry crops	240	2000000	240	2000000	240	2000000
Plums	322	44324142	288	49987200	288	49987200
Sour cherries	302	31242364	274	36405848	246	41401800
Cherries	331	7605710	287	10192467	242	12773702
Apricots	351	12741300	351	12741300	351	12741300
Peaches	335	3099593	333	3119100	333	3119100
Strawberries	660	20862000	660	20862000	660	20862000
Raspberries and blackberries	654	11575180	630	11821091	630	11821091
Currants	497	5570935	432	6118691	432	6118691
Gooseberries	554	2155540	510	2295000	510	2295000
Blueberries	1320	5280000	1320	5280000	1320	5280000
Bilberries	1164	116400000	1164	116400000	1164	116400000
Walnuts	433	23698173	418	25278734	382	29202072
Hazelnuts	1821	11246065	1684	16062088	1465	25097297
Vineyards	330	75603000	330	75603000	330	75603000
Hops	7500	43750000	7500	43750000	7500	43750000
Edible wheat	190	76675504	190	76675504	190	76675504
Edible barley	196	0	196	0	196	0
Edible corn	179	36258194	179	36258194	179	36258194
Edible oats	193	0	193	0	193	0
Edible rye	191	38487731	191	38487731	191	38487731
Total	X	3276018289	X	3808853827	X	4386909995

Source: own research.

The value of grown soybeans and sunflowers, the processing of which produces valuable feed additives (cake, meal), will also increase in proportion to the increase in the production of pork, poultry, and eggs. The value of grown potatoes will be within EUR 1–1.2 billion at average prices of 148–166 EUR/t. An increase in potato cultivation volumes under the third optimisation option will contribute to a decrease in average sales prices. A similar price decrease is predicted for most grown vegetables, fruits, and berries. The total value of other vegetables will not change significantly. It will be within EUR 535–585 million depending on the level of productivity, and the largest share in the value structure will be the harvest of cabbage and tomatoes.

The economic potential in terms of the value of grown fruit and berry crops in the region upon reaching the first level of productivity is projected at EUR 635 million. It is expected to reach to EUR 700 and 745 million with increased productivity at the two higher levels. The most significant positions in the value structure of fruit and berry crops are the volumes of growing apples, bilberries, and grapes. It is worth highlighting the prospects for increasing niche crops that are not widely grown in the region, in particular hops, for the needs of the food industry at a value of over EUR 44 million. According to the modelling results, the volumes of cultivation of most types of fruit and berry crops in the region are not only sufficient to fully meet the needs of the local market. It can also partially cover the needs of other areas of Ukraine and have a positive impact on the growth of export potential. To meet the food needs of the local market, the value of food grain is projected to be at the level of EUR 150 million.

Under the first optimisation option, the value of livestock production will exceed EUR 4.1 billion and is projected to increase to EUR 5.8 and 7.2 billion, respectively, according to the results of the second and third options (Table 11). Close parity between livestock and crop production is predicted under the first option. However, with increasing productivity levels and, accordingly, the feed base, the modelling results show the feasibility of shifting the balance in favour of livestock production with the formation of significant export potential.

Table 11

Projected value of livestock production depending on the achieved level of productivity

Product type	Performance level					
	1		2		3	
	Price, EUR/t	Value, EUR	Price, EUR/t	Value, EUR	Price, EUR/t	Value, EUR
Milk	388	884108092	388	884108092	388	884108092
Cattle meat	4048	607250478	4048	607250478	4048	607250478
Pork	2837	1893495391	2535	3029983793	2485	3293991750
Lamb	3451	103516103	3451	103516103	3451	103516103
Poultry	2237	352734279	2087	706287767	1815	1487692095
Eggs	1324	186267075	1250	320154039	1092	699751565
Other meats	3530	105893597	3530	105893613	3530	105893597
Wool	2990	11211318	2990	11211318	2990	11211318
Total	X	4144476333	X	5768405203	X	7193414998

Source: own research.

The main share in the value structure of livestock products will fall on pork and milk under the first optimisation option. Under the other two options, which are determined by higher productivity levels, a gradual increase in the share of pork and poultry products is also predicted. In general, the value of pork produced using feed grown in the region will potentially range from EUR 1.9 to 3.3 billion in a relatively competitive range of wholesale sales prices (2485–2840 EUR/t). The economic potential of poultry farming is most noticeable under the third optimisation option. It is at EUR 1.5 billion in the value of poultry meat at average prices within 1800 EUR/t and up to EUR 700 million in the value of eggs produced at a price of about 1100 EUR/t. The value of milk produced for the needs of the local food market of the region will be about EUR 900 million at prices below 390 EUR/t. The projected value of beef, lamb, and other types of meat is also projected at a static level regardless of the selected optimisation option following the specified production volumes. It should be noted that when the average sales prices of livestock products and the main types of fodder crops change, other options for the optimal production structure and value are possible, affecting the industry's economic potential.

The modelling results depend on the profitability of agricultural land, which is influenced by the level of crop yields and projected sales prices. Therefore, for a more detailed analysis of the research results, compare the value structure of produced products and the structure of sown areas (Tables 12, 13). The highest ratio coefficient, according to the results obtained, is observed in the cultivation of fruit and berry crops and vegetables, namely bell peppers, tomatoes, garlic, blueberries, bilberries, grapes, and hops, with the coefficient values depending on the achieved level of productivity within 4.12–8.46. A low level of the coefficient, which is less than 1 regardless of the optimisation options, is characteristic of the cultivation of fodder and food grains, the cultivation of soybeans, sunflowers, and root crops, as well as the use of pastures and hayfields for the preparation of feed.

Table 12

Structure of agricultural land area and value of crop production in the Carpathian region of Ukraine based on modelling results (forage crops)

Product type	Yield levels								
	1			2			3		
	Structure, %								
	Land	Value	k*	Land	Value	k*	Land	Value	k*
Feed wheat	6.847	4.234	0.62	7.373	5.154	0.70	8.055	6.087	0.76
Feed corn	5.365	4.669	0.87	6.263	5.778	0.92	7.308	6.999	0.96
Feed barley	10.931	5.291	0.48	13.201	6.588	0.50	12.333	6.293	0.51
Feed oats	4.111	1.371	0.33	3.521	1.141	0.32	3.281	1.036	0.32
Green fodder	8.510	6.091	0.72	6.662	4.863	0.73	5.343	3.945	0.74
Coarse fodder	13.852	4.083	0.29	11.374	3.256	0.29	9.446	2.637	0.28
Root crops	0.747	0.783	1.05	0.543	0.621	1.14	0.413	0.501	1.21

Note. * k – ratio of the share of crop production in the value structure to its share in the structure of sown areas.

Source: own research.

Table 13

Structure of agricultural land area and value of crop production in the Carpathian region of Ukraine based on modelling results (food and industrial crops)

Product type	1 level			2 level			3 level		
	Structure, %								
	Land	Value	k*	Land	Value	k*	Land	Value	k*
Millet	0	0	0.38	0	0	0.43	0	0	0.46
Buckwheat	0	0	0.53	0	0	0.52	0	0	0.54
Legumes	0	0	0.54	0	0	0.57	0	0	0.60
Sugar beet	0.314	0.913	2.91	0.256	0.776	3.03	0.216	0.673	3.12
Sunflower	10.104	8.949	0.89	11.782	10.619	0.90	12.318	11.211	0.91
Soybean	14.587	10.375	0.71	18.405	13.415	0.73	22.020	15.775	0.72
Winter rapeseed	0	0	1.04	0	0	1.06	0	0	1.07
Mustard	0	0	0.60	0	0	0.72	0	0	0.80
Oil flax	0	0	0.39	0	0	0.45	0	0	0.49
Potatoes	10.392	23.607	2.27	8.985	21.280	2.37	8.805	20.364	2.31
Cucumbers and gherkins	0.439	1.461	3.33	0.378	1.248	3.30	0.344	1.115	3.24
Tomatoes	0.632	2.665	4.22	0.483	2.264	4.69	0.391	1.963	5.02
Cabbage	0.996	3.025	3.04	0.844	2.606	3.09	0.781	2.370	3.03
Table beet	0.435	1.095	2.52	0.373	0.953	2.55	0.354	0.903	2.55
Table carrots	0.455	1.130	2.48	0.389	0.992	2.55	0.371	0.935	2.52
Onions	0.723	1.554	2.15	0.642	1.415	2.20	0.683	1.454	2.13
Garlic	0.012	0.065	5.42	0.010	0.055	5.50	0.008	0.048	6.00
Capsicum pepper	0.045	0.299	6.64	0.033	0.254	7.70	0.026	0.220	8.46
Table zucchini	0.317	0.669	2.11	0.298	0.643	2.16	0.311	0.623	2.00
Eggplants	0.017	0,035	2.06	0.021	0.038	1.81	0.018	0.033	1.83
Table pumpkins	0.038	0.060	1.58	0.031	0.048	1.55	0.053	0.077	1.45
Watermelons	0.159	0.337	2.12	0.140	0.295	2.11	0.156	0.314	2.01
Melons	0.020	0.044	2.20	0.021	0.043	2.05	0.017	0.037	2.18
Apples	1.604	3.854	2.40	1.428	3.815	2.67	1.429	3.743	2.62
Pears	0.242	0.590	2.44	0.216	0.609	2.82	0.191	0.564	2.95
Other fruit and berry crops	0.019	0.045	2.37	0.012	0.038	3,17	0.010	0.033	3.30
Plums	0.381	0.994	2.61	0.284	0.953	3.36	0.208	0.826	3.97
Sour cherries	0.310	0.701	2.26	0.281	0.694	2.47	0.275	0.684	2.49
Cherries	0.083	0.171	2.06	0.085	0.194	2.28	0.095	0.211	2.22
Apricots	0.119	0.286	2.40	0.073	0.243	3.33	0.054	0.211	3.91
Peaches	0.028	0.070	2.50	0.018	0.059	3.28	0.013	0.052	4.00
Strawberries	0.126	0.468	3.71	0.103	0.398	3.86	0.081	0.345	4.26
Raspberries and blackberries	0.071	0.260	3.66	0.056	0.225	4.02	0.045	0.195	4.33
Currants	0.040	0.125	3.13	0.034	0.117	3.44	0.025	0.101	4.04
Gooseberries	0.016	0.048	3.00	0.012	0.044	3.67	0.009	0.038	4.22
Blueberries	0.018	0.118	6.56	0.014	0.101	7.21	0.012	0.087	7.25
Bilberries	0.514	2.611	5.08	0.400	2.219	5.55	0.327	1.924	5.88
Walnuts	0.246	0.532	2.16	0.217	0.482	2.22	0.229	0.483	2.11
Hazelnuts	0.148	0.252	1.70	0.172	0.306	1.78	0.246	0.415	1.69
Vineyards	0.412	1.696	4.12	0.275	1.441	5.24	0.206	1.249	6.06
Hops	0.175	0.981	5.61	0.140	0.834	5.96	0.117	0.723	6.18
Edible wheat	2.421	1.720	0.71	1.816	1.461	0.80	1.453	1.267	0.87
Edible barley	0	0	0.55	0	0	0.57	0	0	0.59
Edible corn	0.908	0.813	0.90	0.726	0.691	0.95	0.605	0.599	0.99
Edible oats	0	0	0.36	0	0	0.36	0	0	0.35
Edible rye	2.075	0.863	0.42	1.614	0.734	0.45	1.321	0.636	0.48
Total	100	100	X	100	100	X	100	100	X

Source: own research.

Given this, it is advisable to grow these crops with a low ratio coefficient in volumes sufficient to cover the needs of the local food market and processing enterprises and provide a feed base to promote the development of export-oriented livestock farming. However, most of the fodder crops grown in the region are aimed at export instead of ensuring the growth of local livestock production, which gives a higher value of products per 1 hectare of area. Thus, the value of grown fodder crops at the first level of productivity was about EUR 2 billion, directing them to the needs of livestock farming will allow obtaining over EUR 4.1 billion. Upon reaching the second and third levels of productivity, the added value increases by another EUR 1–2 billion. It is much more effective for the development of the agricultural sector of the region compared to the usual export of fodder crops to other countries.

4.4. Results of modelling the optimal industry structure of production in the agricultural sector of the region. According to the results obtained, the share of pork will prevail in the value of livestock products, which will be from 45 to 53 % depending on the optimisation option. It can be explained by the higher economic efficiency of using feed in pig farming compared to other areas of livestock farming (Table 14). The specific weight of the value of milk, beef, lamb, wool, and different types of meat in the above structure will decrease with each subsequent level of productivity in favour of the production of poultry meat and chicken eggs, the shares of which will increase to 21 and 10 %, respectively. The results of modelling the optimal production structure depend on changes in the level of marginal and forecasted prices for each type of livestock product, the capacity of the domestic market, production productivity, and other factors.

Table 14

Structure of the value of livestock products in the Carpathian region of Ukraine according to modelling results

Product type	Performance level		
	1	2	3
	Structure, %		
Milk	21.33	15.33	12.29
Cattle meat	14.65	10.53	8.44
Pork	45.69	52.53	45.79
Lamb	2.50	1.79	1.44
Poultry	8.51	12.24	20.68
Eggs	4.49	5.55	9.73
Other meats	2.56	1.84	1.47
Wool	0.27	0.19	0.16
Total	100.0	100.0	100.0

Source: own research.

Upon reaching the first level of productivity in terms of the value of all produced products, the value structure of agricultural products in the Carpathian region will be close to the balance between crop production and livestock production (Table 15). An increase in productivity to the second and third levels will increase the share of the value of livestock products in the overall structure. However, the final value of

products determines the structure. In that case, there will be an even more significant shift toward increasing the weight of the share of livestock products for the production of which fodder crops will be used. Accordingly, the specific weight of the livestock industry will increase from 63 to 72.3 %, which will affect the sectoral specialisation of the region's agricultural sector. The results of the study show and substantiate the priority areas of development of the agricultural sector of the region in terms of sectors. The main goal is the realisation of its economic potential in terms of maximising the value of the final product produced, depending on the achieved level of productivity and the variability of sales prices for each type of product.

Table 15

Structure of the value of agricultural products in the Carpathian region of Ukraine according to modelling results

Agricultural sectors	Performance level		
	1	2	3
	Structure by value of all products produced, %		
Crop production	51.82	47.63	45.69
Animal production	48.18	52.37	54.31
Total	100.0	100.0	100.0
	Structure by value of final products, %*		
Crop production	36.81	30.64	27.69
Animal production	63.19	69.36	72.31
Total	100.0	100.0	100.0

Note. * Excluding the value of fodder crops used to produce livestock products.
Source: own research.

Thus, summarising the obtained modelling results, it is necessary to note that for the further development of the agricultural sector of the region, it is worth focusing on changing the industry structure in favour of the production of livestock products. Namely, this is pig and poultry farming with the appropriate provision of fodder grain production. It is also essential to diversify the cultivation of crop products in the direction of the development of vegetable growing and the expansion of areas under fruit and berry crops, which make it possible to obtain a relatively higher value of products per 1 hectare of land area. The central resource reserve for the realisation of the economic potential of the agricultural sector of the region is an increase in the level of production productivity and a partial change in the purpose of part of the pasture and hayfield areas not used for fodder production, in favour of the expansion of perennial plantings and arable land. The structure's orientation should ensure the food needs of the region's population with the possible increase in export potential for the most profitable commodity positions.

5. DISCUSSION

We obtained results of modelling the economic potential of the agricultural sector in the Carpathian region according to the criterion of maximising the final value, taking into account various influencing factors, in particular the achieved level of production productivity, price changes, ensuring the food needs of the local population following

the specified restrictions and other influencing factors. The basis of the modelling process of economic potential is the optimisation of the structure of agricultural land use of the studied region with the determination of shares for each type of product. The model focuses on achieving the optimal balance between crop and livestock production, ensuring the products' maximum and final value.

Comparing the results of modelling the optimal production volumes for three options depending on the achieved level of productivity with the actual volumes in 2022–2024 in the Carpathian region (Appendix A), it is worth noting significant differences in the main areas of agricultural production. A substantial increase in production volumes is predicted in the livestock sector. In particular, milk production will increase by more than 2 times compared to the actual production level, beef by 2.5 times, and lamb by 6.2 times. The most noticeable increase in production volumes according to the obtained results of modelling the optimal structure is proposed for pork – from 4.4 to 8.7 times, as well as poultry meat – up to 5.4 times and eggs – up to 7.2 times, when the third level of productivity is achieved. It will naturally affect the structure of feed crop production and will lead to an increase in areas for their cultivation to meet the growing needs of livestock in raw materials. Thus, the need for sunflowers will increase up to 4 times, and barley, the most valuable feed crop for obtaining high-quality pork, will increase from 3.6 to 6 times, depending on the optimisation option.

However, the soybean production volume is proposed to be reduced, since its actual volume is more than sufficient to ensure the development of livestock farming in the region on a particular scale. The basic volumes of wheat and corn production are also enough to meet the needs of livestock farming in feed at the first and second levels of productivity. Still, the further development of livestock farming, mainly pig and poultry farming, will increase the additional demand for these feed crops by 30–40 %.

In vegetable growing, due to the increase in areas and yield levels, it is also predicted that the production volumes of most crops will increase by up to 2 times, and tomatoes and table beets by up to 3 times. Another priority area of development of the agricultural sector of the region, for which it is proposed to allocate additional land areas, is the cultivation of fruit and berry crops. The total their volumes will increase significantly, which will allow increasing the profitability of agricultural land use. It is also worth noting the increase in the volume of sugar beet cultivation by 70 % compared to the base level. However, the cultivation of some crops, in particular winter rapeseed, legumes, buckwheat, mustard, flax, due to their lower profitability per 1 ha of land, in accordance with the obtained results of modelling the optimal production structure, is proposed to be reduced in order to achieve the maximum value of the economic potential according to the selected optimisation criterion, provided that the price level for these crops remains relatively low compared to many other more profitable crops. In general, the optimisation of the sectoral structure of agricultural production in the Carpathian region, depending on the achieved level of productivity, will allow increasing the economic potential of the sector calculated at 2024 prices by 2–3.5 times. It will also contribute to the development of other sectors of the national

economy, in particular the food industry, and will ensure the receipt of higher added value.

When comparing with other studies of the agricultural sector of the Carpathian region conducted by many Ukrainian scientists [1–4], it is advisable to note the study of individual components of the potential of the region with a more pronounced theoretical and analytical direction without modelling possible values of quantitative and qualitative indicators that characterise economic potential. Some scientific works are devoted to the study of individual types of the potential of the agricultural sector of Ukraine, in particular, financial potential [5], innovation [6], investment [7], resource [8], export [11–13], economic [9] and economic-ecological potential [15] without taking into account the features and specifics of agriculture in the Carpathian region. However, it is worth noting that a specialised study [28] concerns the optimisation of production in large agricultural enterprises in Ukraine based on the developed economic-mathematical model with the criterion of achieving maximum profit. Still, it does not consider the variability of the sales price and levels of production productivity, unlike our study, which covers the entire agricultural sector of a separately selected region of Ukraine.

The works of scientists from other countries present studies on general approaches to modelling and forecasting agricultural production [18–21], as well as optimisation of land use in agriculture [23–26], including individual countries and regions [22; 27]. However, these studies are focused on the crop sector and do not take into account the development of the economic potential of livestock farming in individual areas of specialisation, which can be achieved based on grown fodder crops when achieving a certain inter-sectoral balance. Additionally, it should be noted that the study we presented does not consider the ecological orientation of production or the basic principles of the circular economy, which are often important components in other scientists' studies [14; 25; 29].

It is quite difficult to determine the impact of the growth in the cultivation volume of the main types of livestock products on the region's ecology and the tourism potential. It requires additional research. However, it is advisable to pay attention to the number of cattle and pigs in other European countries that are close to the region in area or smaller. Thus, according to the Food and Agriculture Organization, as of 2023, Switzerland has about 1.3 million pigs, compared to 1 million in the Carpathian region, and 1.5 million cattle, which is 6 times more. In Belgium, which is half the area of the studied region, there are about 5.4 million pigs and 2.2 million cattle, more than in Ukraine. Similar examples can be given for Denmark, Austria, and the Netherlands [34]. All of these countries have high environmental requirements. Still, they have achieved a certain balance between the development of livestock farming, which significantly exceeds the region's indicators, and the development of recreational and tourism businesses. Therefore, these countries' experiences will be considered in subsequent studies.

6. CONCLUSIONS

This study assessed and forecasted the economic potential of the agricultural sector in the Carpathian region of Ukraine based on economic-and-mathematical modelling of the optimal structure of crop and livestock production using the criterion of maximum final value, taking into account the variability of market prices and the achieved productivity levels under the established restrictions.

The Carpathian region of Ukraine has a significant economic potential of the agricultural sector, the implementation of which is possible based on optimising the production industry structure. According to the obtained results of modelling the economic potential, taking into account different levels of productivity of crop and livestock production, as well as price variability and established resource constraints, it is substantiated that the rational use of 2.7 million hectares of agricultural land will allow increasing the final value of produced products to EUR 6.6 billion upon reaching the first level of productivity with a potential increase to EUR 8.17 and 10 billion with a further increase in the technological efficiency of growing products to the second and third levels. Optimisation of the industry structure involves shifting the balance in favour of the production of livestock products, including pork, poultry meat, and eggs, which form a higher value compared to the cultivation of fodder grains and industrial crops for export. In crop production, preference should be given to expanding areas for growing vegetables, fruits, and berries, mainly based on pastures and hayfields not used for fodder production. Accordingly, the predicted optimal sectoral structure of the agricultural output in the region, determined by the final value of produced products, will provide for the share of livestock farming within 63.2–72.3 %, depending on the achieved level of productivity.

To ensure the growth of the economic potential of the agricultural sector of the Carpathian region of Ukraine, it is necessary at the institutional level to: promote investment in the development of the most promising areas of agricultural production, in accordance with the results of the study, to obtain a higher value of products per 1 hectare of land; guarantee state financial support aimed at reducing interest rates on loans, compensation for part of the value of machinery and equipment; provide information and advisory support through the development of advisory services and the dissemination of the latest technologies for growing agricultural products, taking into account the experience of developed countries; simplify regulatory and legal regulation regarding the change of the purpose of part of the pasture and hayfield areas not used in agricultural production for the development of more promising regions of agribusiness – horticulture or vegetable growing; provide tax benefits for a period of up to 5 years for newly created industries in the industry in order to stimulate their rapid development; assist in the training of professional personnel for the development of the agricultural sector of the region's economy; provide grant support for the creation of family farms based on household farms, which will increase the economic potential of the agricultural sector of the region in the long term.

At the level of individual enterprises of the industry, it is necessary to: introduce innovative resource-saving technologies for growing products to achieve a higher level

of efficiency in the use of the involved material, technical, labour and financial resources, which will ensure competitiveness in the market; carry out constant monitoring of the market environment to form an optimal product, price and distribution strategy; to provide control over the quality of manufactured products by established state and international standards, including those of the EU countries, which will facilitate entry into more promising markets; to attract direct investments in the development of vertical diversification of business with an increase in the production volumes of products with a higher level of added value, which will also contribute to the growth of the economic potential of the agricultural sector of the region.

7. LIMITATIONS AND FUTURE RESEARCH

The results of modelling the economic potential of the agricultural sector depend directly on the values of the input information, which concerns the levels of crop yields and animal productivity, reliable statistical data on the available areas of agricultural land by their various types, as the main factor in the formation of potential, as well as the dependence between the change in sales prices and the supply of products on the market based on elasticity coefficients. Accordingly, a change in any of the above-mentioned influencing factors will lead to a change in the optimal production structure and the ratio of branches of the agricultural output. The published statistical information used in the model regarding the actual supply of products by individual types may not fully correspond to the actual values due to problems with accounting for the results of activities in households, which account for more than half of the production volumes in the Carpathian region by individual categories of agricultural products.

To ensure the realisation of the economic potential of the agricultural sector of the region, it is important to attract additional labour resources in the conditions of the demographic crisis and the departure abroad of millions of Ukrainian citizens, which may pose certain limitations. However, due to constant internal migration flows from the eastern and southern regions to the Carpathian region, there are currently no problems with attracting workers for the development of the agricultural sector. After the end of the war, the return of some citizens who went abroad and war veterans is predicted, which will contribute to the growth of labour supply in the market and ensure future needs in labour resources for the development of the agricultural sector of the region. It is also worth noting that modern high-tech livestock farming, especially poultry and pig farming, unfortunately does not create many jobs. More detailed calculations regarding the quantitative needs for attracting additional workers to develop the sector in the region will be the subject of further research.

In addition, the limiting factor was the lack of specific statistical data on the production of certain types of vegetables and berries in the region due to the peculiarities of Ukrainian legislation on state statistics regarding the confidentiality of information. Accordingly, the calculated indicators for such types of products were approximate. An additional limitation was the difficulty of assessing the approximate

population size of the region in the absence of relevant information at the time of the research. It is necessary to take into account the constant internal and external migration flows caused by the war, which affected the accuracy of the limitations of the needs of the region's food market by main commodity groups. Also, the model does not take into account in crop production the level of losses of grown products during harvesting, transportation, and storage, and in livestock production, the possible level of animal mortality as a result of the spread of dangerous diseases, such as bird flu or African swine fever, which can cause significant losses and reduce the economic potential of the industry.

An important limiting factor in modelling the economic potential of the agricultural sector is climate change and its impact on the yield of various crops, which will be the subject of our subsequent research. It is worth noting that the agri-food market of Ukraine is an integral part of the world market. It depends on global processes to determine demand, supply, and sales prices for various categories of agricultural products. Therefore, in the future, it is advisable to include in the model the influence of the factor of changing conditions on the international market of agricultural products that can be produced in the region for more accurate forecasting of price levels and elasticity coefficients. It is also essential to research the institutional financial and investment mechanisms for realising the economic potential of the Carpathian region of Ukraine, especially in the long term, considering the modelling results obtained.

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Appendix A

Table A1

Comparison of modeling results of estimated production volumes of main types of agricultural products in the Carpathian region of Ukraine under three options with baseline*

Product type	Base volume, thousand tons	Correlation of the results of modeling optimal production volumes depending on the achieved productivity level (1–3) to the base level, times		
		1	2	3
Cattle meat	61.3	2.447	2.447	2.447
Pork	151.2	4.414	7.906	8.767
Lamb	4.8	6.250	6.250	6.250
Poultry	152.3	1.035	2.222	5.381
Other meats	1.3	23.077	23.077	23.077
Wool	0.301	12.458	12.458	12.458
Eggs	1524.8	1.618	2.947	7.374
Milk	1057.5	2.156	2.156	2.156
Rye	103.9	1.944	1.944	1.944
Wheat	1844.5	0.838	1.108	1.434
Maize	2017.7	0.692	0.963	1.309
Barley	378.8	3.611	5.331	5.885
Oat	15.3	26.151	25.597	26.835
Buckwheat	23.3	min	min	min
Legumes	11.9	min	min	min
Soya beans	2498.7	0.373	0.574	0.784
Winter rapeseed	692.4	min	min	min
Sunflower seeds	300.8	2.335	3.268	3.986
Sugar beet	269.5	1.781	1.781	1.781
Potatoes	4018.6	1.582	1.741	2.072
Cucumbers	183.4	1.531	1.547	1.668
Tomatoes	156.9	2.912	2.912	2.912
Cabbage	574.2	1.350	1.390	1.552
Table beet	131.6	2.112	2.205	2.615
Table carrots	147.0	1.806	1.912	2.244
Onion	118.9	3.380	3.755	4.951
Apples	398.3	0.190	2.493	3.192
Pears	40.4	2.498	3.562	4.078
Plums	36.7	3.756	4.729	4.729
Sour cherries	28.9	3.575	4.602	5.824
Cherries	9.0	2.552	3.950	5.856
Apricots	1.9	19.105	19.105	19.105
Peachs	0.5	18.532	18.734	18.734
Strawberry	8.7	3.633	3.633	3.633
Raspberry and blackberry	4.8	3.688	3.909	3.909
Currant	3.8	2.948	3.727	3.727
Nuts	25.0	2.437	2.799	3.744
Grapes	34.3	6.679	6.679	6.679

Note. * Statistical data on the base level of production of livestock products of grain and industrial crops in the region are given for 2024, the base volumes of production of other crops (vegetables, fruits and berries) are given for 2022 due to the lack of up-to-date published statistical information for all categories of farms in the regions of the Carpathian region.

Source: compiled based on our own research and statistical data [33].

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