

Prerequisites for innovative development of livestock and agriculture through the integration of agricultural production and environmental safety

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Abstract. A multi-year analysis of the state of the livestock sector in the period before the outbreak of war in 2022 is important for the post-war recovery of Ukraine's regions. The purpose of the research was to identify the factors of losses in the production of livestock products, methods and means of integrated development. The generally accepted methods in zootechnology were followed, the study was conducted over a thirty-year period (1991-2021) in accordance with the stages of research work number: 0121U113933 of 18.11.2021. It was found that the number of cattle decreased by 8.4 times, and cows – by 5.2 times. Gross milk production decreased by 2.7 times, and beef and veal production – by 4.5 times. Improving the genetic potential of livestock, feeding, and housing contributed to an increase in cow productivity by 2,842 kg on average in the region and by 4,693 kg at the enterprises. As of 01.01.2021, 5 stud farms of the Ukrainian Black-and-White dairy breed were established with a population of 12,369 heads, including 4,647 cows, with a milk yield of 9,749 kg in 2020. The profitability of milk production in 2019 was 20.6%, while cattle breeding for meat was unprofitable (-27.1%). Many farms turn manure into compost and apply it to the soil for ploughing. Between 1991 and 2021, the Kharkiv region lost the potential of the dairy industry, the number of cattle decreased, with the largest decline in 1991-2001 (6.54 times). Milk production decreased by 2.7 times and beef and veal production by 4.5 times, with the main “drop” occurring between 1990 and 2010 (by 2.7 and 4.5 times respectively). The average annual milk yield per cow in the region from 1990 to 2020 increased by 2,840 kg and in 2020 amounted to 5,821 kg. Practical value: the article is the first to provide a long-term analysis of the state of the cattle breeding industry before the outbreak of hostilities in Ukraine, taking into account technological, organisational and economic aspects

Keywords: organic fertilisers; humus; soil; restoration of fertility; milk; beef

Article's History:

Received: 08.05.2024

Revised: 22.07.2024

Accepted: 27.08.2024

Suggested Citation:

Mamenko, O., Portiannyk, S., & Prusova, G. (2024). Prerequisites for innovative development of livestock and agriculture through the integration of agricultural production and environmental safety. *Ukrainian Black Sea Region Agrarian Science*, 28(3), 19-31. doi: 10.56407/bs.agrarian/3.2024.19.

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INTRODUCTION

The successful functioning and development of each individual production and social unit of society depends on its ability to provide itself with food, first and foremost. One of the most challenging issues in ensuring a high standard of living is the production and supply of milk and meat. At the same time, it is important to preserve the environment and maintain soil fertility. Restoring the number of cattle in the post-war period is important in terms of increasing the production of high-quality milk and beef meat, taking into account modern technologies for breeding, feeding and housing animals.

Increasing cows' milk production helps to solve environmental problems. US scientist J.K. O'Hara (2023) investigates the intensity of greenhouse gas emissions from milk production. The higher the productivity of animals, the less greenhouse gases are produced in the intestines and the less they are released into the environment. The researchers D.V. da Silva *et al.* (2024) tried to propose and determine the net environmental performance of different milk production systems. A case study of a closed composting farm located in South-Eastern Brazil was chosen as a baseline scenario. The results and benefits of the ecosystem were aggregated and converted into monetary units per kg of milk. The semi-closed systems had the worst environmental performance compared to milk production on the farm where composting was applied.

The intensive development of each individual branch of the agricultural sector of the economy and balanced entrepreneurship, as well as in the complex of a large region, should be based on the principles of preserving, improving and strengthening production resources. It is on these principles that land and its agricultural land should be used, because it is not only a platform for living beings, but from the point of view of the economic category, land is the main means of production and requires rational use. Scientists from China, J. Chang *et al.* (2018), point out that rational land use in karst areas can increase the productivity of water and fertiliser use. They propose that agricultural land on sloping areas should be converted to forested areas with moderate grazing, while agricultural land on flat areas should adopt a grain-forage and grain-soybean rotation to meet the needs of a growing population and ensure economic development.

Selection and breeding work plays an important role in increasing animal productivity. Scientists L. Khmelnychi & B. Karpenko (2023) note that the use of linear classification in the breeding process of dairy cattle to determine the breeding value of cows is a fairly effective means of objectively determining the breed characteristics of the exterior type. The presence of a correlation between the final score and the level of milk

production will contribute to the efficiency of selection in the indirect selection of animals for these traits.

An important factor in animal productivity is well-balanced feeding and the use of effective innovative techniques. Researchers M.M. Wright *et al.* (2024) show that adding rapeseed cake to grain mixtures can improve milk production and increase milk fat and protein yields. In addition, there are no milk yield benefits when some barley is replaced with maize in a wheat-barley mix fed to cows grazing on.

L. Cesarini *et al.* (2024) analysed and forecast changes in agriculture at a national scale, which is essential for developing strategies to ensure food security and stability of the entire agri-food chain. This is often challenging as data is usually sparse and long detailed reports are rarely available, but researchers have tried to develop some models to forecast monthly milk production in France, Germany and Italy using climatic and economic variables from open datasets as inputs.

Over the last 30 years (1991-2021) covered by the research, the use of mineral fertilisers in soils has decreased tenfold, and organic fertilisers by 5-7 times, while at the same time, humus has been leached from the soil through erosion and nutrient removal with the harvest. According to O. Drebot *et al.* (2024), special attention should be paid to the issues of economic activity to balance environmental and economic factors on the basis of social relations, which necessitates the restructuring of land and the structure of sown areas of major crops, taking into account the regional characteristics of the general phytosanitary state of the census of a particular region, weather and climatic, relief and soil conditions. Scientists I. Shumyhai *et al.* (2023) point to a biogeochemical imbalance of molybdenum in the agricultural landscapes of the Forest-Steppe zone of Ukraine, where a lack of the element in the soil was found. Technogenic migration in the soil cover is manifested by its increased dispersion. O. Mamenko *et al.* (2021) focus on the emergence of biogeochemical endemics. This has been significantly affected by the ruthless ploughing of land in both Ukraine and Kharkiv region, high energy consumption, disruption of ecological balance, reduced soil fertility, and the decline of livestock production. Under such extreme conditions, the number of cattle decreased by 8.4 times, milk production – by 2.2 times, and meat production – by 2.2 times. The authors highlight the attempts to find a way out of the crisis, but restoring soil fertility and raising cows is a long-term endeavour.

The purpose of the research was to identify the causes and factors of losses in the production of livestock products in Kharkiv region, to determine methodological principles and methods, means of integrated

development of livestock and agriculture through mutually necessary sectoral components of agricultural progress.

MATERIALS AND METHODS

This study analyses the state of livestock and agriculture in the Forest-Steppe zone of Ukraine. A 30-year period of time was analysed – from 1991 to 2021, the last three ten-year periods. The dynamics of cattle numbers in general and by categories of farms in Kharkiv region, milk and beef production per capita, along with livestock numbers, gross and average productivity data, were studied, and the contribution of the livestock sector to the development of crop production and soil fertility in Kharkiv region was calculated. Statistical data are taken from the State Statistics Service of Ukraine (n.d.). The authors worked with the data from the annual reports of breeding plants in printed format, so it is not possible to provide an electronic link. When taking average samples of feed, milk, and organic waste, the methods generally accepted in zootechnical practice were followed, the method of ecological monitoring of ecosystems was used, and the study was conducted in accordance with the stages of the research work State Registration Number: 0121U113933 (Fig. 1).

Registration card for research and development work

State Registration Number: 01210113933
Public Date of Registration: 18-11-2021
Status of the performer: 17 Chief Executor



Figure 1. Registration card for research and development work

Source: Ukrainian Institute of Scientific and Technical Expertise and Information (n.d.)

The analysis was based on the scientists' own research and international scientific publications. The scientific and economic experiments were conducted in cattle-breeding enterprises of the Forest-Steppe zone of Ukraine, whose biogeocenoses are subject to

increased anthropogenic pressure near industrial cities, oil and gas production and processing sites, and major motorways. The experiments were conducted on dairy cows of the Ukrainian Black-and-White dairy breed with different types of feeding: silage-silage-concentrate feeding, silage-silage, silage-root crops and silage-hay feeding, respectively. Animals were selected by the method of analogues for live weight and milk production and divided into three groups: the first control group and the second and third experimental groups. To improve the quality, environmental safety of cow's milk and cow productivity, the main feeding ration for the experimental groups was balanced with a specially developed vitamin and mineral premix. An experiment was also conducted on calves in the dairy period. Laboratory analysis of selected samples of plant and animal origin for the content of macro- and microelements, including heavy metals, was carried out by atomic absorption spectrophotometry (AAS-30 spectrophotometer, Germany), which gives a minimum error in sample analysis. The quality and environmental safety of milk was monitored in accordance with DSTU 3662:2018 (2019), as well as the requirements of international quality standards (Regulation of the European Parliament..., 2004). The following data were also used for the analysis: State Enterprise... (n.d.), State Register of Breeding Subjects... (2021). The monographic method, method of analysis and synthesis, empirical and comparative methods were used in writing the paper. The calculation was carried out in the STATISTICA software package version 10.0.

RESULTS

While in 1991 Kharkiv region was ranked 4th in Ukraine by cattle and 5th by cows, in 2021 it was ranked 8th and 11th, respectively. The decline in cattle numbers has been a long-standing problem in Ukraine due to the lack of an effective government support programme. That is, the loss of cows, which is the main means of production, reached 80.9% (Table 1).

Table 1. Dynamics of the number of cattle and % of the total in Ukraine by categories of farms in the Kharkiv region (as of 1.01, thousand heads – from 1991 to 2021)

Groups of livestock	Unit of measurement	1991	2001	Years 2011	2015	2021	2021 to 1991, %
In farms of all categories							
Total cattle	heads	1,274.6	466.2	194.8	192.1	151.9	11.9
	%	5.18	4.95	4.33	4.95	5.28	
including cows	heads	415.0	217.3	100.5	92.7	79.3	19.1
	%	5.00	4.39	3.82	4.10	4.32	
At enterprises							
Total cattle	heads	1,203.8	338.4	96.8	96.9	79.9	6.6
	%	5.71	6.72	6.34	7.40	7.92	

Table 1, Continued

Groups of livestock	Unit of measurement	Years					2021 to 1991, %
		1991	2001	2011	2015	2021	
including cows	heads	371.9	133.4	39.9	37.3	32.3	8.7
	%	6.01	7.48	6.775	7.05	7.62	
In the farms							
Total cattle	heads	-	3.6	4.0	4.7	3.8	105.6
	%	-	3.51	4.20	4.50	3.46	
including cows	heads	-	1.4	1.6	1.8	1.7	121.4
	%	-	3.91	4.20	4.81	3.90	
In the households							
Total cattle	heads	70.8	127.8	98.0	95.2	82.5	116.5
	%	2.00	2.91	3.30	3.70	3.86	
including cows	heads	43.1	83.9	60.6	55.4	46.8	108.6
	%	1.97	2.70	2.94	3.20	3.19	

Notes: % of total livestock in Ukraine

Source: developed by the authors

It is worth noting that with the outbreak of full-scale aggression, in the first months of the war, the dairy industry suffered the greatest losses (Bal-Prylypko *et al.*, 2024). After the “shock period”, industrial farms in the frontline and near-frontline zones tried to save themselves as best they could. A certain number of animals died. Those who could do something moved their livestock to safer areas in the central and Western regions. That is why in critical regions, including Kharkiv region, dairy farms reduced their livestock by 47.3% (to 17.4 thousand), in Sumy region – by 5.2% (to 25.6 thousand), and in Chernihiv region – by 4.1% (37.9 thousand). The number of cattle increased in Ternopil region, with an increase of 17.5% (16.1 thousand), Odesa region – 14.5% (6.3 thousand), Ivano-Frankivsk region – 12.2% (4.6 thousand). According to the State Register (2021), as of 1 December 2022, the largest number of cattle was concentrated in Poltava (54.1 thousand), Cherkasy (43.1 thousand) and Chernihiv (37.9 thousand) regions. In general, according to the Unified State Register of Animals, there were 1.98 million cattle in Ukraine at the beginning of 2023. The largest number of cattle was in Vinnytsia region (154.6 thousand), Poltava region (151.9 thousand) and Cherkasy region (130.1 thousand). As of 1 July 2024, the number of cattle in the Unified State Register of Identified and Registered Animals was 1,867,858 heads (State Enterprise..., n.d.).

According to preliminary data from the Ministry of Agrarian Policy and Food of Ukraine, as of 1 April 2024, 2 million 330.5 thousand cattle were kept in the household and industrial sector, including 1 million 263.8 thousand cows. Compared to March 2024, the number of cattle increased by 76 thousand heads (+3%), and the number of cows increased by 3.3 thousand heads (+0.3%). Compared to April 2023, the number of cattle decreased by 172.4 thousand heads (-7%), including 91.1 thousand heads (-7%) of cows. About 39% of

animals are kept at industrial enterprises, while 61% are kept in households. Many farmers are keeping cows in wartime conditions and are experiencing a shortage of working capital. The cost of keeping animals is becoming more expensive, as are the costs of feed preparation, diesel fuel and electricity, and profitability is decreasing. Injured animals have to be culled. Production costs are rising much faster than prices for finished products, as people have low purchasing power. The reduction of pasture and agricultural land due to mine and shell contamination remains a challenge. Nevertheless, in 2024, the decline in the number of cattle slowed markedly compared to 2023, and the time for some stabilisation is coming. Moreover, compared to the previous year, the number of cattle in households in Kharkiv region increased by 1% (The number of cattle..., 2024).

In 2020, total milk production in Kharkiv region decreased to 469.9 thousand tonnes, or 2.7 times (-800.7 thousand tonnes compared to 1990). Beef and veal production (in slaughter weight) also decreased, except for households. During the research period, it was found that investments in improving the genotype of dairy herds, more efficient breeding, more intensive milk production technologies, rational feeding, and comfortable housing conditions ensured an increase in milk yield in Kharkiv region to 7,698 kg. The main breed here is the newly created Ukrainian Black-and-White dairy breed, which has a high milk yield potential. There are five breeding plants of this breed in the region, and as of 01.01.2021, there were 12,369 heads, including 4,647 cows, with a milk yield of 9,749 kg each, which is twice as high as the regional average for farms of all categories (State Register of Breeding Subjects..., 2021). However, the loss of a significant number of cows and the lack of regulation in the production sector led to a decrease in gross milk production and a shortage of milk per capita for the population of Kharkiv region (Table 2).

Table 2. Dynamics of milk and meat production per capita in Ukraine and Kharkiv region, kg

Region	Unit of measurement	Years					2020 to 1990, %
		1990	2000	2010	2015	2020	
Production of all types of milk, kg							
Ukraine	kg	472.3	257.4	245.2	247.8	221.9	47.0
	%	100	54.5	95.3	101.1	89.5	
Kharkiv region	kg	397.6	182.8	169.1	192.5	177.6	44.7
	%	100	46.0	92.5	113.8	92.2	
Production of all types of meat (in slaughter weight, kg)							
Ukraine	kg	84.0	33.8	44.9	54.2	59.3	70.6
	%	100	40.2	103.0	120.7	109.4	
Kharkiv region	kg	71.3	28.6	30.1	34.6	33.1	46.4
	%	100	40.1	105.2	115.0	95.7	
Beef and veal production (in slaughter weight, kg)							
Ukraine	kg	38.7	15.3	9.3	8.9	8.2	21.2
	%	100	39.5	60.8	95.7	92.1	
Kharkiv region	kg	31.7	11.6	8.2	8.5	8.6	27.1
	%	100	36.6	70.7	103.7	101.2	

Notes: % to the previous period

Source: developed by the authors

Feed costs for the production of 1 tonne of live weight gain of cattle, 1 tonne of milk and one head of cattle in enterprises were within the traditional range

and only in recent years (2018-2020) have increased significantly, with the main reason being feed quality (Table 3).

Table 3. Feed costs for the production of 1 centner of cattle growth in enterprises, centner of feed per unit

Region	Feed of all kinds					of which are concentrated					2020 to 2015 (all types / of them concentrated), %
	2010	2015	2018	2019	2020	2010	2015	2018	2019	2020	
Ukraine	15.69	14.80	12.06	13.95	12.84	4.47	4.93	5.79	6.65	6.12	81.8 / 136.9
Kharkiv region	14.68	15.36	13.73	14.19	13.37	4.20	5.23	6.51	6.51	6.52	
Region to Ukraine, %	93.6	103.8	113.8	101.7	104.1	94.0	106.1	112.4	98.0	101.0	
Feed costs per cent of milk production in enterprises, centner of feed per unit											
Ukraine	1.18	1.00	0.86	0.89	0.84	0.37	0.41	0.48	0.49	0.46	71.2 / 124.3
Kharkiv region	0.98	1.02	0.87	0.87	0.83	0.35	0.44	0.49	0.49	0.47	
Region to Ukraine, %	83.0	102.0	101.2	97.8	98.8	94.6	107.3	102.1	100.0	102.2	
Feed consumption per 1 head of cattle in enterprises, centner of feed per unit											
Ukraine	26.73	26.46	29.19	29.59	28.78	17.95	19.41	24.37	24.89	24.20	107.7 / 134.8
Kharkiv region	28.94	31.88	36.16	36.35	36.24	18.16	19.36	24.94	25.53	25.44	
Region to Ukraine, %	119.2	120.5	123.9	122.8	125.9	101.2	99.7	102.3	102.8	105.1	

Source: developed by the authors

The period of the last 10 years (2010-2020 in the dynamics by years) was chosen for the analysis of feed costs (Table 3). The costs per 1 centner of cattle growth in the region's enterprises were lower than in Ukraine only in 2010, and then they grew and in 2020 increased to 4.1% of the average for Ukraine. There was no significant difference between the figures for Ukraine and Kharkiv region and between the years of the study period in terms of feed costs per 1 cent of milk production

at milk production enterprises. However, the cost of feed per head of animals in the region was higher (the difference reached 25.9%, 5.1 in 2020), and feed costs have increased significantly over the past three years (2018-2020) (Ukraine = +34.8, Kharkiv region = +40.2 for feed).

The share of cattle in the Kharkiv region kept in farms of all categories in the national total varied from 5.18 (1991) to 5.28% (2021), including the number of cows – from 5.00 to 4.32%. In 2021, according to the State

Statistics Service of Ukraine (n.d.), Ukraine produced 8.72 million tonnes of milk, which is 5.9% less than in the previous year. At the same time, agricultural enterprises produced 2.75 million tonnes (0.4% less), and households produced 5.97 million tonnes (-8.2%). Poltava, Vinnytsia and Khmelnytsky regions became the leaders in milk production, although milk production in these regions also decreased compared to the previous year. Luhansk, Donetsk and Zaporizhzhia regions produced

the least amount of milk. The productivity of the dairy herd in all categories of farms increased by 1.7 times on average in Ukraine and by 2.1 times in Kharkiv region. The most significant increase in cow productivity was in enterprises – by 2.5 and 2.6 times, respectively. Of all the categories of farms in the Kharkiv region, enterprises produce the most milk. In 2020, 52.1% of total gross milk production was produced by enterprises, which is 8.87% of the national production (Table 4).

Table 4. Dynamics and share of milk and meat production of cattle in the total production in Ukraine by categories of farms in Kharkiv region from 1990 to 2020

Types of enterprises	Unit of measurement	Years					2020 to 1990, ±
		1990	2000	2010	2015	2020	
Milk production							
Farms of all categories	ths. tonnes	1,270.6	539.6	467.2	524.5	469.9	-800.7
	%	5.18	4.26	4.15	4.94	5.07	
Enterprises	ths. tonnes	1,133.0	279.4	175.2	232.6	244.8	-888.2
	%	6.08	7.62	7.90	8.71	8.87	
Private households	ths. tonnes	137.6	260.2	292.0	291.9	225.1	+87.5
	%	2.34	3.72	3.23	3.67	3.46	
Farms	ths. tonnes	-	2.3	6.5	10.6	9.0	+389
	%	-	3.39	5.80	5.98	4.02	
Beef and veal production (in slaughter weight, thousand tonnes)							
Farms of all categories	ths. tonnes	101.5	34.4	22.7	23.2	22.7	-78.8
	%	5.11	4.56	5.31	6.04	6.57	
Enterprises	ths. tonnes	94.6	14.6	5.5	5.4	6.1	-88.5
	%	5.23	4.78	5.25	5.76	7.19	
Private households	ths. tonnes	6.9	19.8	17.2	17.8	16.6	+9.7

Notes: % of total production in Ukraine

Source: developed by the authors

Beef and veal production (in slaughter weight) in 2020 was almost 4.5 times lower in all categories of farms in the region compared to 1990. By category of farms, the share of gross production produced

by enterprises is 7.19% and by households – 6.37%. The most objective and economically justified indicator of cattle productivity is the milk yield of cows (Table 5).

Table 5. Average annual milk yield per cow, kg

Region	Index	Years					2020 to 1990, %
		1990	2000	2010	2015	2020	
Farms of all categories							
Ukraine	kg	2,863	2,359	4,082	4,644	5,129	179.1
	%	100	82.4	173.0	113.8	110.4	
Kharkiv region	kg	2,979	2,137	4,560	5,483	5,821	195.4
	%	100	71.7	213.7	120.2	106.2	
At enterprises							
Ukraine	kg	2,941	1,588	3,975	5,352	6,634	225.6
	%	100	54.0	250.3	134.6	124.0	
Kharkiv region	kg	2,975	1,689	4,413	6,302	7,698	258.8
	%	100	56.8	261.3	142.8	122.2	
At private households							
Ukraine	kg	2,637	2,960	4,110	4,497	4,666	105.2
	%	100	139.9	108.0	108.0	105.2	
Kharkiv region	kg	3,017	3,059	4,660	4,937	4,545	150.6
	%	100	101.4	152.3	105.9	92.1	

Notes: % to the previous period

Source: developed by the authors

Investments in the development of the dairy industry in enterprises over the past decade (2010-2021) have created more opportunities to improve genetic potential, apply intensive production technologies, improve feeding, and create more comfortable conditions. As a result, the average annual milk yield per cow in Ukrainian enterprises increased to 6,634 kg, and in the region – to 7,698 kg, which is more than in households by 1,968 and 3,153 kg. However, as of 01.01.2021, the number of cows kept in Ukrainian enterprises has significantly decreased and amounts to only 25.3%, and to 40.7% of the total in the region. A new Ukrainian Black-and-

White dairy breed is being introduced in Kharkiv region. There are five breeding plants in the region that are engaged in the improvement of cattle of this breed with a total number of 12,369 heads of breeding cattle as of 1 January 2021, including 4,647 heads of cows. According to the annual reports of breeding plants for 2020, the milk yield per cow is 9,749 kg, which is almost twice as high as the average for farms of all categories in the region (190.1%). Gradually, from year to year, the livestock sector (especially meat production) in the country is not profitable, as evidenced by the level of profitability of production at the enterprises of the region (Table 6).

Table 6. The level of profitability of milk and meat production at enterprises

Types of products	Years							
	1990	2000	2012	2015	2016	2017	2018	2019
Milk	32.2	-6	1.8	12.7	18.6	26.9	16.1	20.6
Cattle for meat	20.6	42.3	-28.3	-16.9	-23.2	3.4	-17.7	-27.1

Source: developed by the authors

The production of cattle meat has led to a critical state of the industry due to a decrease in the number of livestock and production volumes (Kopytets & Voloshyn, 2020). Volatility in purchase prices for livestock products, low purchasing power of the population, imperfect import regulation and financial and credit policy in the agricultural sector, as well as unregulated

relations in the areas of production, harvesting, processing and trade have led to the decline of the industry. In Ukraine and in Kharkiv region, due to the decline in gross livestock production, milk and meat production per capita lags far behind physiological standards (380 kg of milk and 80 kg of meat) and continues to decline (Table 7).

Table 7. Dynamics of milk and meat production per capita in Ukraine and Kharkiv region, kg

Region	Unit of measurement	Years					2020 to 1990, ±
		1990	2000	2010	2015	2020	
Production of all types of milk, kg							
Ukraine	kg	472.3	257.4	245.2	247.8	221.9	-250.4
	%	100	54.5	95.3	101.1	89.5	
Kharkiv region	kg	397.6	182.8	169.1	192.5	177.6	-220.0
	%	100	46.0	92.5	113.8	92.2	
Production of all types of meat (in slaughter weight, kg)							
Ukraine	kg	84.0	33.8	44.9	54.2	59.3	-24.7
	%	100	40.2	103.0	120.7	109.4	
Kharkiv region	kg	71.3	28.6	30.1	34.6	33.1	-38.2
	%	100	40.1	105.2	115.0	95.7	
Beef and veal production (in slaughter weight, kg)							
Ukraine	kg	38.7	15.3	9.3	8.9	8.2	-30.5
	%	100	39.5	60.8	95.7	92.1	
Kharkiv region	kg	31.7	11.6	8.2	8.5	8.6	-29.1
	%	100	36.6	70.7	103.7	101.2	

Notes: % to the previous period

Source: developed by the authors

While from 1990 to 2010, the production of milk and meat of all kinds per capita continued to decline, from 2010 to 2015, milk production per capita increased by 2.6 kg on average in Ukraine and by 23.4 kg in the region, in 2020, compared to 2015, milk production

decreased by 10.5% on average in Ukraine and by 9.2% in the region, and is 58.4 and 46.7% of the physiological norm, respectively.

As for the production per capita of all types of meat, from 2015 to 2020, it increased by 5.1 kg in Ukraine and

decreased by one and a half kilograms in the region, and in 2020 it was 67.8% of the normative indicators on average in Ukraine and 41.4% in the region. Of all the types of meat, beef and veal are the least produced per person in the country (8.2 kg), which is only 21.2% of the 1990 figure, and in Kharkiv region (8.6 kg and 27.1%, respectively). A particular threat to livestock farming is posed by the government's attempt to meet domestic demand for meat and dairy products through imports. This actually brings the country closer to the critical point of national food security, but the loss of soil fertility is very dangerous.

Over 30 years, the gross production of bedding manure has decreased by 8.4 times, while the area of agricultural land has remained virtually unchanged. Cows processed feed into milk, and the production of organic fertilisers from them has also decreased significantly (by 5.2 times) over such a long period, but this is much less than the total number of cattle. However, in enterprises, organic production decreased by 15 times (including 12.1 times from cows). In 2020, households and farms produced organic matter steadily and returned 60% of the total volume of bedding manure production

to land. A decrease in cattle numbers and a decrease in animal consumption of bulk (hay, haylage) and an increase in concentrates in the diet resulted in a loss of organic fertiliser production as soil fertility deteriorated.

During the stall period (210 days), the manure output per cow is 7 tonnes, but during the so-called grazing period (155 days), cows in Kharkiv region are kept tied up, and the average annual manure production reaches 12 tonnes per cow (5 tonnes on average for young cattle). Of the total feed fed to cattle, 60% is absorbed, 5% is lost, and 35% is excreted as excrement, which, together with the remains of uneaten feed and bedding material, forms manure. Manure contains nutrients that are essential for plant life, and it contains 50-70% of nitrogen, which is absorbed by plants after mineralisation in the first year of application to the soil and is the starting material for humus formation. Manure is divided into bedding, semi-liquid, liquid and slurry based on its moisture content. Only cow bedding manure (winter wheat straw), which is the most suitable for obtaining 20% of humus organic matter, was used in the calculations of manure yield and the following results were obtained (Table 8).

Table 8. Dynamics of bedding manure production in farms of Kharkiv region for the period 1991-2021 (thousand tonnes)

Groups of livestock	Years					2021 to 1991	
	1991	2001	2011	2015	2021	%	times
Beef and veal production (in slaughter weight, kg)							
Total from cattle	10,834	3,963	1,656	1,633	1,292	11.9	8.4
including cows	4,980	2,604	1,206	1,112	952	19.1	5.2
In enterprises							
Total from cattle	10,232	2,876	823	825	680	6.6	15.0
including cows	4,464	1,601	480	448	388	8.7	12.1
In farms							
Total from cattle	-	31	34	40	32	5.6	
including cows	-	16.8	19.2	21.6	20.4	21.4	
In households							
Total from cattle	637	1,150	882	857	743	+16.6	
including cows	560	1,092	788	720	608	+8.8	

Source: developed by the authors

Between 1991 and 2021, the production of manure from cattle in all categories of farms decreased by 8.8 times, including 5.2 times from cows. The main reason is a significant decrease in the number of livestock. This was most noticeable in enterprises, while in farms and households it increased, but their total percentage was only 7.4%. In other words, the decrease in organic fertiliser production in Kharkiv region was influenced by a decrease in the number of producers, a trend that coincided with changes in Ukraine as a whole. And this most basic of the most powerful production assets has

different quality indicators even within individual areas of one settlement, let alone an entire farm, a separate district, region, or country. This happens depending on how the land is managed. Long-term barbaric use of land for high yields leads to its depletion, impoverishing it of nutrients, especially its most valuable component – humus. The land is not capable of synthesising this fertiliser on its own; this function is performed by soil biota based on specific raw materials – organic and mineral substances, mostly secondary livestock products, and primarily ruminant manure.

DISCUSSION

For various reasons, it is quite difficult for agricultural producers in Ukraine to maintain, let alone increase, the number of cattle and ensure the production of milk and meat. Between 1991 and 2021, scientists and practitioners were looking for effective ways to not only increase animal productivity but also improve the quality and environmental safety of milk, and much was achieved. Much attention was paid to animal feeding, breeding and selection, improving cattle keeping conditions, and environmental safety. In 2022, the hostilities caused significant losses to the agricultural sector throughout Ukraine, with cattle farms in the frontline regions of the Forest-Steppe zone of Ukraine and the regions that were occupied, including Kharkiv region, suffering the most. In 2023-2024, the situation stabilised somewhat, but the number of cattle in the region decreased by almost 50%. In the second half of 2024, hostilities continued in the Kharkiv region, so there is no hope for a rapid improvement in the livestock sector. Mine contamination of agricultural land complicates the situation with field work, production of high-quality crops and animal feed, and the reduction in cattle numbers has led to a decrease in the application of organic fertilisers to the soil.

It is important to analyse the current situation in the livestock sector, take into account the accumulated scientific and practical experience and prepare for the post-war recovery of the industry, increase in the number of animals and their productivity, and production of environmentally safe milk and beef meat based on the introduction of innovative technologies and international experience. Manure composting is one of the most effective ways of processing manure, which is used in various countries where cattle are kept. Scientists X. Zheng *et al.* (2022) emphasise that anaerobic digestion and composting of manure are increasingly attracting attention due to the increase in organic fertiliser production and environmental safety. Composting is an ideal way to utilise the nutrients in animal manure. To reduce soil contamination with heavy metals, especially such hazardous metals as cadmium and lead, researchers recommend that agricultural producers take a holistic approach by producing both compost and biogas, which is very important in the context of the energy crisis and environmental protection. Heavy metal pollution from man-made and military impacts threatens animal and human health due to their high bioavailability, cumulative nature and migration in the trophic chain.

Scientists from China, H. Wang *et al.* (2013), examined samples of feed and manure for heavy metals on livestock farms. It was found that zinc and copper in animal feed ranged from 15.9 to 2,041.8 and 392.1 mg/kg,

respectively, while mercury, arsenic, lead, and chromium in all feeds were below 10 mg/kg. The concentration of copper, zinc, arsenic, and chromium in animal feed and manure had a positive correlation, but cadmium, mercury, and lead were not statistically correlated between the content in feed and manure. The highest concentrations were found for copper and zinc in both feed and organic waste from different animal species, including dairy cattle. The authors also emphasise that the content of heavy metals in organic waste from dairy animals has only increased over time, which means that it poses an environmental risk of soil pollution. Researchers M. Xiang *et al.* (2021) note that the increase in the content of heavy metals in the soil is due to a violation of the norms for applying organic fertiliser from livestock waste if animals were fed feed containing hazardous ecotoxicants. Heavy metals pose a significant threat to agricultural production. Soil contamination can pose a potential environmental risk, and crop contamination can already pose a risk to human health.

Y. Xu *et al.* (2019) also note that livestock manure tends to be contaminated with heavy metals, as large amounts of the mineral elements copper and zinc are added to the feed, which are heavy metals but biogenically important for the animal body. A large amount of these elements is released into the soil with organic waste. Elevated concentrations of copper and zinc in cattle manure were found in different regions of the country and varied significantly. Scientists from the United Kingdom, F.A. Nicholson *et al.* (1999), also emphasise the environmental hazards of heavy metal contamination of feed and manure. Other scientists (Tao *et al.*, 2020) took samples of feed and analysed the content of cadmium, chromium, arsenic, and mercury using atomic absorption spectrophotometry. The researchers conclude that systematic environmental monitoring of the concentration of heavy metals in animal feed, implementation of feed management and bioremediation strategies to reduce the impact of heavy metals is important, which should be taken into account in the post-war period on farms not only in Kharkiv region but also in other regions where cattle are kept and milk and meat are produced.

Nutrients from organic fertilisers obtained after composting cattle manure are used by plants in the first, second and third year after application. The increase in livestock numbers in the post-war period will lead to an increase in organic waste, which will lead to an increase in organic matter application to the soil and litter manure will be effective as fertiliser for industrial and fodder crops, including sugar, fodder beet, corn for silage and grain, rapeseed, sunflower, soybeans and other crops. The application of organic fertilisers

for fodder crops to be used as feed in dairy cows' diets should be standardised with due regard to the content of heavy metals. Since the accumulation of pollutants in the soil will eventually lead to increased accumulation in plants grown, feed for dairy cows or animals raised for meat, followed by rapid entry into milk and accumulation in muscle tissue. In the more environmentally stressed regions of Ukraine's Forest-Steppe zone, more organic fertilisers can be used for industrial crops such as sunflower, rapeseed, and sugar beet, but avoiding over-application.

Scientists from India emphasise that milk plays a key role in human nutrition, especially for children, due to its content of protein, vitamins, and calcium, which contribute to cognitive development, but the risk of potential hazards of heavy metals in milk due to environmental exposure and the intake of toxic metals from animal feed has attracted not only their attention but also the attention of scientists around the world (Alam *et al.*, 2024). They studied seasonal fluctuations in the quantitative intake of heavy metals cadmium, chromium, and lead by dairy cows in the South Indian metropolis of Bengaluru. The analyses of the samples revealed the content of pollutants in feed, milk, and organic waste. The study covered thirty-nine dairy farms in urban and suburban areas. Significant concentrations of heavy metals were found in organic cattle waste, while cow's milk was safe. At the same time, there was a risk of re-contamination of the soil by organic fertiliser with high concentrations of toxic metals.

Farmers often face the question of how to run their farms: conventional or organic farming. Plant-based production of organobiological products in Ukraine is more developed than animal-based production, which requires significant investment (Pysarenko *et al.*, 2019). The choice can significantly affect the financial performance of the farm and the impact on the environment. Norwegian scientists R. Bang *et al.* (2024) compare the profitability of conventional and organic cattle systems, taking into account the characteristics of farms, feed production, feed quality, milk quotas, livestock housing capacity, etc. and conclude that if feed is of good quality, easily accessible, but livestock production cannot be expanded due to the maximum number of animals kept, milk quota restrictions, organic farming can displace conventional farming. Gross profit is maximised by conventional farming. Researchers emphasise the crucial role of feed production capacity and quality in relation to the available milk quota and infrastructure when considering the transition from conventional to organic farming. In other words, in the future, as a guideline for farmers, the environmentally friendly organic-biological type of farming should be more widely

implemented. The organisation of environmentally safe milk production in terms of heavy metal content on cattle farms in different countries of the world under the influence of natural and anthropogenic factors remains relevant (Özbay *et al.*, 2023).

After the end of the war, the restoration of the livestock sector in Kharkiv region and Ukraine as a whole should be based on innovation, taking into account the integration of crop and livestock production components in combination with the preservation of the environment and its components of atmospheric air, soil, water, and living organisms. High-quality, environmentally friendly crop and livestock products, especially milk and beef meat produced in both conventional and organic farms, will have a competitive advantage in the market.

CONCLUSIONS

Over the past 30 years (1991-2021), the Kharkiv region has lost the potential of the dairy industry and the number of cattle has decreased by 8.4 times, including cows – by 5.2 times, the most significant reduction in the total number of cattle occurred in 1991-2001 (by 6.54 times), including cows (by 4.1 times). Due to the reduction in production resources, there was a decrease in milk production (-800 thousand tonnes or 2.7 times) and beef and veal production (in slaughter weight) (-78.8 thousand tonnes or 4.5 times), with the main “drop” occurring in the period 1990-2010 (2.7 and 4.5 times respectively). Enterprises suffered the most among all categories of farms. Despite the decline in gross milk production, the average annual milk yield per cow in the region increased by 2,840 kg (2.0 times or 195%) from 1990 to 2020 and reached 5,821 kg in 2020. The most significant increase in cow productivity (+4,693 kg) occurred in enterprises (from 2,975 kg to 7,698 kg). Cow productivity increased due to breeding, the use of intensive technologies, improved feeding and housing conditions on farms in the region. The reduction in the number of cattle, and cows in particular, led to a decrease in gross production of organic fertilisers (manure) by 8.8 times, including 5.2 times from cows themselves. Despite a significant increase in milk yields, the downward trend in organic production was similar in Kharkiv region enterprises, as well as in farms of all categories in Ukraine. In developing the dairy farming sector in the post-war period, it is necessary to increase the number of cattle, as there is no more effective measure to obtain organic fertilisers and prevent the crisis of degradation of Ukrainian black soil and produce environmentally friendly products in an integrated agricultural production system. Further research could be aimed at analysing the quality and environmental safety of cow's milk and beef produced.

ACKNOWLEDGEMENTS

None.

CONFLICT OF INTEREST

None.

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Передумови інноваційного розвитку скотарства та землеробства за рахунок інтеграції складових аграрного виробництва і екологічної безпеки

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Анотація. Багаторічний аналіз стану галузі скотарства в період до початку війни 2022 року має важливе значення для післявоєнного відновлення регіонів України. Мета дослідження: встановити чинники втрат під час виробництва продуктів скотарства, методи, засоби інтегрованого розвитку. Було дотримано загальноприйнятих методів в зоотехнії, дослідження проведено за тридцяти річний період (1991-2021 роки) відповідно до етапів виконання науково-дослідної роботи номер: 0121U113933 від 18.11.2021 року. Встановлено, що поголів'я великої рогатої худоби зменшилося у 8,4 раза, корів – у 5,2 раза. Знизилося валове виробництво молока – у 2,7 раза, яловичини і телятини – у 4,5 раза. Поліпшення генетичного потенціалу поголів'я, годівлі, утримання сприяло підвищенню продуктивності корів в середньому по області на 2842 кг, у підприємствах – на 4693 кг. На 01.01.2021 створено 5 племзаводів української чорно-рябої молочної породи з поголів'ям 12369 голів, у тому числі 4647 корів, надоєм за 2020 рік 9749 кг. Рентабельність виробництва молока за 2019 рік становила 20,6 %, вирощування великої рогатої худоби на м'ясо виявилось збитковим (-27,1 %). Багато господарств перетворюють гній на компост, який вносять під оранку ґрунту. З 1991 по 2021 роки у Харківській області відбулася втрата потенціалу молочної галузі, поголів'я великої рогатої худоби зменшилося, найбільше скорочення припало на 1991-2001 роки (у 6,54 раза). Зменшилося виробництво молока у 2,7 раза та яловичини і телятини у 4,5 раза, основне «падіння» відбулося в період 1990-2010 роки (в 2,7 та 4,5 раза відповідно). Середньорічний надій на одну корову в середньому по області з 1990 по 2020 рік зріс на 2840 кг і в 2020 році становив 5821 кг. Практична цінність: у статті вперше зроблено багаторічний аналіз стану галузі скотарства до початку бойових дій в Україні з урахуванням технологічних та організаційно-економічних аспектів

Ключові слова: органічні добрива; гумус; ґрунт; відновлення родючості; молоко; яловичина