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Enhancing the Efficiency of Dairy Farming through Improving the Regional System of Fodder Production



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Abstract. Addressing the issue of increasing the efficiency of dairy cattle breeding, increasing the volume of milk and dairy products is closely linked to the strengthening and development of fodder supplies. The State program of agriculture development and regulation of markets of agricultural products, raw materials and food for 2013–2020 implemented in the Vologda Oblast, as well as other legal documents do not fully promote intensive fodder production. This results in poorly developed meadow and field fodder production, fodder crop breeding and fodder seed production, harvesting, storage, and use of fodder negatively affects the efficiency of dairy cattle breeding in general and determines the range of the existing system problems. In this regard, the purpose for the research is to develop and scientifically substantiate the ways of improving the system of fodder production to increase the efficiency of dairy cattle breeding in the region. In accordance with the intended purpose we have met a set of objectives. Thus, based on materials of the Vologda Oblast, we conducted a brief analysis of the dairy cattle breeding for 2000–2016 which revealed that the overall situation in sub-sectors since 2013–2016 has stabilized: cattle stock is maintained, there is an increase in cow productivity and the total volume of milk produced, etc. We also presented the results of the assessment of fodder production potential and its development in modern conditions. We found that the region possesses quite large reserves for increasing fodder production. It is noted that the increase in crop areas and intensification of regional systems of fodder production, including the improvement of species and variety composition of fodder crops, development of resource-saving technology of their cultivation and harvesting, will increase the total fodder production. The development of efficient fodder production should be based on the maximum use of climatic resources, biological and environmental factors in the region. To develop the ways of improving the system of fodder production in the Vologda Oblast, we analyze the situation in terms of an economic leader – AO Plemzavod Rodina – with the aim of replicating its experience and practice in the farms of the Northwestern Federal district as a whole. It has been revealed that the use of modern scientific research results will help agricultural producers harvest fodder with higher concentration of metabolic energy up to 10–10.5 MJ per 1 kg of dry matter and increase the content of crude protein by more than 14 %, and decrease the consumption of concentrated and protein feeds. In conclusion, it is noted that the implementation of complex measures on the improvement of the system of fodder production development with regard to the above areas, latest scientific achievements, and experience of advanced farms will help increase the total production of high-quality fodder in the Vologda Oblast 1,5–2 times. The theoretical and methodological framework of the research includes fundamental works of domestic scholars and economists, general scientific research methods (abstract-logical, system approaches, generalization, economic and statistical, etc.), statistical (grouping, sampling, comparison, generalization), and graphical and tabular methods of data visualization. The practical significance of the obtained results is determined by their further use by specialists and farm managers, researchers in the field of dairy cattle breeding and fodder production in order to develop areas and measures to overcome the current situation in the sub- industry.

Key words: dairy cattle breeding efficiency, improving the system of fodder production, technology, fodder crops, fodders, efficiency.

In modern economic conditions the most important part of the food security issue is providing the population with affordable milk and dairy products in sufficient amounts. Despite the fact that in recent years Russia has witnessed an increase in the volume of agricultural production, in animal husbandry production growth of rates, particularly in dairy farming, remain quite low. Thus, the volume of milk production in the country in 2016 amounted to 30.8 million tons (below the level of 2015 by 0.1% and the 2000 level by 4.7%). Every year the consumption of milk and dairy products is reduced, which in 2016, according to the Ministry of Agriculture, amounted to 239 kg per capita (71.7% of the recommended consumption¹). By consumption of dairy products² Russia lags behind many European and CIS countries. For example, according to Rosstat, in Azerbaijan, per capita consumption of dairy products (when measured in terms of milk) in 2015 amounted to 272 kg, in Armenia – 258 kg, in Belarus – 254 kg, in Ukraine – 210 kg. In Europe, this figure is about 306 kg per capita, while in Germany it exceeded 349 kg, in the US – about 269 kg, in New Zealand – 601 kg. We believe that the reason for such dynamics is the change in Russians' consumer preferences by reducing the purchasing power of their incomes (with

the remaining nominal wages at higher prices and inflation) and higher prices for dairy products³.

In Russia, the level of profitability in dairy cattle breeding remains low, production costs are increasing, the acute issue of lack of own funds remains, annual reduction in cow population takes place, the volume of milk production is reducing, livestock diet is not balanced, lack of fodder is observed, along with their poor quality, and a number of other negative trends. One of the main reasons for the current situation in the industry is unsatisfactory condition of fodder supplies.

According to experts [11], commercial characteristics (efficiency index, performance, etc.) of cattle approximately 25–35% dependent on genetic characteristics (i.e. on the breed), 10–20% – on welfare, and more than 50% – directly on the quality of fodder and nutrition. It follows that for effective dairy cattle breeding it is necessary to create sustained, balanced fodder supply base to ensure uninterrupted supply of quality fodder for farms. In this regard, the issue most relevant to agricultural science and practice is the development and scientific substantiation of areas of improving the system of fodder production to raise the efficiency of dairy cattle breeding, which determines the purpose for the article.

¹ According to recommendations of the Ministry of Health published in 2016, the standard rate of dairy products consumption in Russia is 325 kg per person per year, including milk, kefir, yogurt, butter, and cheese.

² Consumption of milk in Russia is reducing. Available at: <https://agrovesti.net/news/indst/potreblenie-moloka-v-rossii-snizhaetsya-a-tseny-prodolzhayut-rasti.html>

³ According to the Ministry of Agriculture of Russia, average consumer prices in 2016 were: pasteurized milk – 51.45 rub/kg (+ 8.3% from the beginning of the year), butter – 477.24 rub/kg (+ 19.4), cheese – 460.89 rub/kg (+9.9%).

There are many works devoted to issues of improving economic efficiency of fodder production and the industry as a whole by domestic and foreign economists, including V.R. Boev, N.I. Kovalenko, A.I. Kostjaev, E.N. Krylatykh, A.N. Semin, V.N. Surovtsev, I.G. Usachev, A.A. Shut'kov, J. Bennewitz, A.J. Heinrichs, O. Harel and others [25, 26, 28–33]. Issues related to rational dairy cattle feeding based on significant improvement of fodder supplies, increase in productivity and lowering production costs are reflected in works by A.S. Emel'yanov, N.G. Grigoriev, A.P. Kalashnikov, V.M. Kosolapov, Yu.F. Lachuga, I.S. Popov, L.K. Ernst, and others [8, 12, 13, 17].

According to the results of analysis of the Russian literature on the subject, in Russia studies on the development of detailed standards of feeding cattle based on qualitative improvement of forage supplies were completed back in 1983. Scientists made a transition to the evaluation of fodder energy power in metabolic energy and proposed “Standards and diets for livestock animals” for its further implementation; they were approved at the meeting of the Bureau of the Department of Animal Husbandry of Lenin All-Union Academy of Agricultural Sciences. In 1985, a handbook “Standards and diet of livestock animals” was published, edited by A.P. Kalashnikov and N.I. Kleimenova. In 1993–1995, it was revised and published in three volumes; in 2003, the revised and expanded third edition was published, edited by A.P. Kalashnikov [17].

In conditions of the Vologda Oblast – the area of risk farming – dairy farming is a

priority sub-sector. Its products historically and geographically have a competitive advantage over products from other Russian regions; the region possesses necessary material and human resources; considerable farming areas sufficient to provide industry with fodders; livestock population consisting of adapted dairy breeds; and modern livestock farms [1, 2].

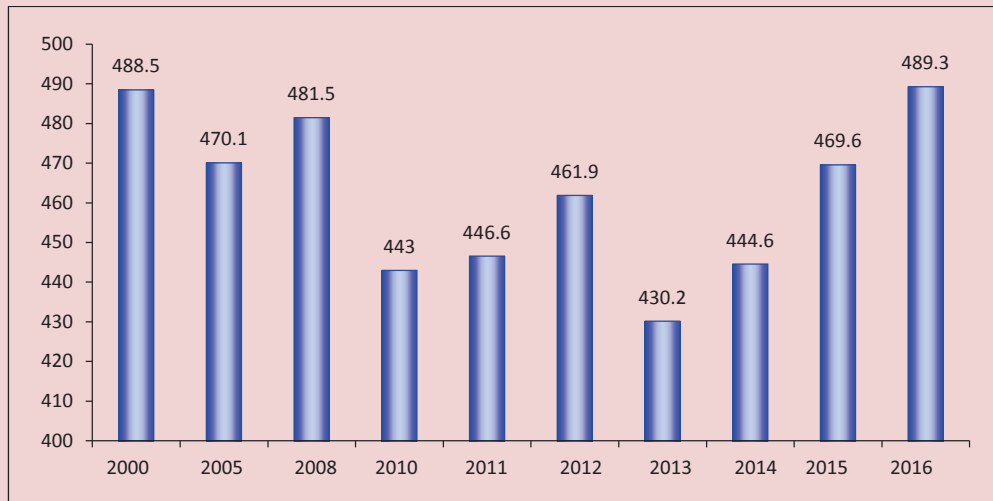
In 2016, the Vologda Oblast ranked second in the list of constituent entities of the Northwestern Federal district in livestock (including cows) population and gross milk yield. The region ranked fourth in dairy flock production (in 2010–2012, 2014 – ninth, 2015 – sixth). Agricultural producers provide the population of the region with milk according to with recommended standards⁴. In addition, more than 200 thousand tons of milk and dairy products are exported annually.

In 2016, all types of households produced 489.3 thousand tons of milk, which is 19.7 thousand tons more than in 2015 and 0.8 thousand tons more than in 2000 (*Fig. 1*).

With regard to livestock population dynamics, it decreased by 151 thousand animals (47.6%) in all types of households in 2000–2016, including cows – 74.7 thousand (49.7%) (*Fig. 2*). However, since 2013 the decline has slowed down. It should be noted that the share of breeding stock in the total livestock population of the region is increasing every year. The share of breeding cows in the total flock in 2016 amounted to about 60%.

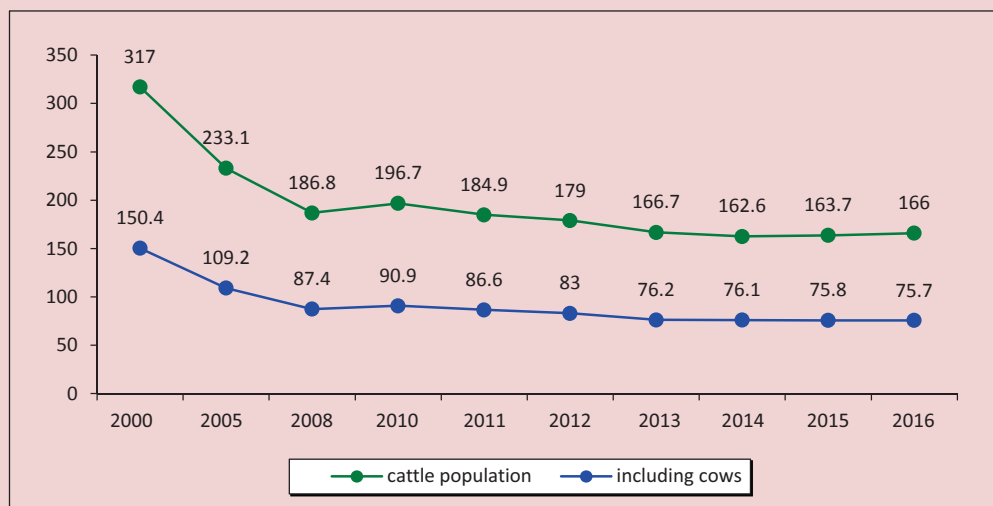
⁴ On Approval of Recommendations for rational standards of food consumption which meet modern requirements of healthy eating: Order of Ministry of Health and Social Development of the Russian Federation No. 614, dated 19.08.2016. Available at: <http://www.garant.ru/products/ipo/prime/doc/71385784/>

Figure 1. Gross milk production in the Vologda Oblast, thousand tons, all types of households



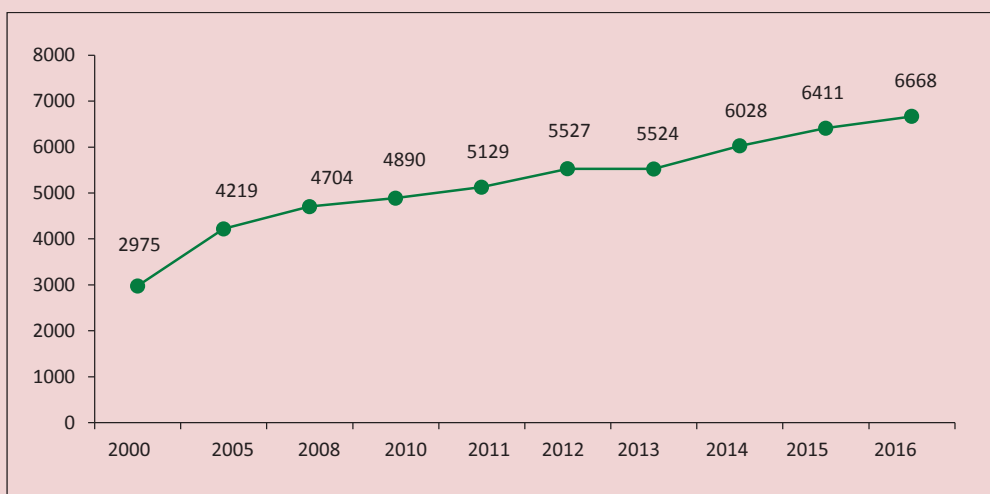
Source: official statistical data of the Unified Interdepartmental Information-Statistics System (EMISS). Available at: <http://fedstat.ru>

Figure 2. Dynamics of livestock population in the Vologda Oblast, thousand animals, all types of households



Source: official statistical data of the Unified Interdepartmental Information-Statistics System (EMISS). Available at: <http://fedstat.ru>

Figure 3. Cow productivity in the Vologda Oblast, kg of milk per cow per year, all types of households



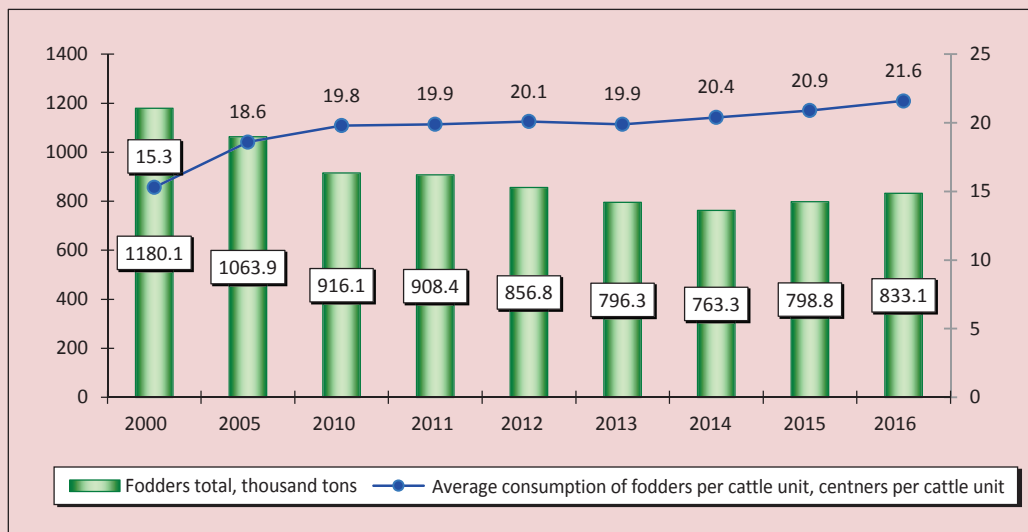
Source: official statistical data of the Unified Interdepartmental Information-Statistics System (EMISS). Available at: <http://fedstat.ru>

It should be noted that the increase in milk production in 2016 compared to 2015 by 4.2% (in 2000 – 1.1%) was achieved due to increased cow productivity (4.0%). Thus, the average milk yield per cow in agricultural organizations of the oblast in 2016 amounted to 6,668 kg, which is 4.0% more than in 2015 and 2.2 times more than in 2000 (*Fig. 3*).

Among region's farms the leading one in cow productivity in the past years has been CKhPK Prisukhonskoe (Prisukhonskoe Agricultural Production Co-Operative) in the Vologodskii District – 10,838 kg/cow (+682 kg compared to 2015), the second one is SPK Vologodskii (Vologodskii Agricultural Production Co-Operative) in the Vologodskii District (8,936 kg, +46 kg), the third – OOO Pokrovskoe in the Gryazovetskii District (8,900 kg +395 kg) [2].

One of the factors in growing productivity in dairy cattle breeding is the improvement of animal diets and fodder supplies as a whole. In 2016, 833.1 thousand tons of fodder (4.3% above the level of 2015) of forage (without grain fodder) were procured – 266.6 thousand fodder units or 21.8 centners of fodder units per 1 livestock unit (4.0 % below the level of 2015), grain fodder – 157 thousand tons (*Fig. 4*) [2]. In 2016, per one livestock unit, 36.0 kg of fodder units (including grain fodder) were procured, in 2015 – 38.9 centners of fodder units. We should note that every year the average consumption of all fodder types is increasing: in 2016 21.6 centners of fodder units of all types were consumed, which is 3.4% above the previous year's level and 41.2% compared to 2000 [2, 4, 17].

Figure 4. Fodder supplies in the Vologda Oblast



Source: Official website of the territorial body of the Federal State Statistics Service in the increasing Vologda Oblast. Available at: www.vologdastat.ru

Thus, according to the results of analysis of a number of indicators of efficiency of dairy farming functioning in the Vologda Oblast, during the research period, the overall situation in sub-sectors has stabilized by 2013–2016, livestock population remained stable; there is an increase in cow productivity and total volume of milk production etc.

We emphasize that to develop and scientifically justify areas of improving the system of fodder production in order to improve dairy cattle breeding efficiency it is necessary to assess the existing capacity and determine the level of its development in modern conditions.

First, it is required to assess the agro-climatic conditions and soil fertility. The territory of the Vologda Oblast is located in the North of the European part of Russia, in the sub-zones of middle and southern taiga, and refers to the zone of risk farming.

The climate of the region is characterized as moderate continental with short springs, short relatively warm and humid summers, damp autumns and long, cold, snowy winters with stable snow covering. The vegetation period lasts 145 days in the northern regions, up to 160 days – in the north. The duration of a frost-free period – from 95 days in the south-east to 125 days in the south of the central part of the oblast.

The oblast is located in the zone of over-wetting: annual precipitation is 500–650 mm. The highest precipitation in summer is in July (8–74 mm) with 13–14 days with precipitation. The sum of active temperatures (over 10°C) in most of the oblast's territory is in average 1550°–1650°, and in the west it increases to 1700°–1800°.

According to the conducted agro-climatic assessment, in the oblast's territory heat is

provided to crops such as rye, barley, early oat, wheat and peas varieties, potatoes, many cultures and varieties of perennial grasses.

The soil covering of the territory of the Vologda Oblast is quite varied: the northern part is dominated by podzolic soils, the south – by sod-podzolic soil, bog soils are present in some places. Bog-podzolic soils in the agronomic context are the most low-fertile and require liming, fertilizing and control of the air and water regime. They are prevalent in the western part of the oblast. In general, soil fertility in the oblast is low. The average content of humus in the soil is 2.5 %. More than half of the cultivated (arable) soils have a high degree of acidity, many are subject to erosion and waterlogged.

Currently, low- and mezo-podzolic soils (87%) are mostly cultivated. Light loams and light loamy sand are cultivated for field crops, with the most favorable air and water regime; soils of heavier mechanical texture are used for hayfields and pastures.

Second, an important step is the state analysis of fodder production in the region. In general, the cultivated area of agricultural crops in all types of households in 2016 was 373.1 thousand hectares (45.6% less than in 2000 and 0.2% more than in 2015). Among constituent entities of the Northwestern Federal district, the Vologda Oblast had the highest share of farmland usage – 29 %, the second was the Pskov Oblast (18%) and the third – the Leningrad Oblast (16%; *Tab. 1*).

Table 1. Cultivated agricultural lands in all types of households in the Vologda Oblast, thousand ha

Constituent entities of the NWFD	Year									2016 to 2015, %	2016 to 2000, %
	2000	2005	2010	2011	2012	2013	2014	2015	2016		
Republic of Karelia	64.8	46.9	38.4	34.4	31.5	32.1	32.3	32.5	33.5	103.1	51.7
Komi Republic	80.0	52.7	40.5	39.5	38.8	38.5	41.1	40.7	39.4	96.8	49.3
Arkhangelsk Oblast	206.8	134.5	104.4	97.1	97.0	89.8	87.0	77.0	73.6	95.6	35.6
Vologda Oblast	686.1	541.6	451.8	445.9	428.8	395.2	376.5	372.4	373.1	100.2	54.4
Kaliningrad Oblast	257.9	217.9	148.1	143.6	166.7	183.7	222.2	245.6	261.9	106.6	101.6
Leningrad Oblast	373.2	293.3	250.5	246.2	237.8	231.4	226.8	229.9	240.3	104.5	64.4
Murmansk Oblast	11.5	7.8	7.1	7.4	7.3	7.3	7.3	7.7	7.2	93.5	62.6
Novgorod Oblast	270.3	180.6	181.4	191.0	191.0	175.3	177.0	178.5	181.5	101.7	67.1
Pskov Oblast	539.2	365.3	275.5	257.3	238.3	244.9	244.7	245.3	244.0	99.5	45.3
<i>Northwestern Federal district, total</i>	<i>2490</i>	<i>1841</i>	<i>1498</i>	<i>1462</i>	<i>1438</i>	<i>1398</i>	<i>1415</i>	<i>1430</i>	<i>1455</i>	<i>101,7</i>	<i>58,4</i>
<i>Share of the Vologda Oblast in the Northwestern Federal district, %</i>	<i>27.6</i>	<i>29.4</i>	<i>30.2</i>	<i>30.5</i>	<i>29.8</i>	<i>28.3</i>	<i>26.6</i>	<i>26.0</i>	<i>25.6</i>	<i>98.5</i>	<i>92.8</i>
<i>Position of the Vologda Oblast among constituent entities in NWFD</i>	<i>1</i>	<i>1</i>	<i>1</i>	<i>1</i>	<i>1</i>	<i>1</i>	<i>1</i>	<i>1</i>	<i>1</i>	<i>-</i>	<i>-</i>

Source: compiled by the author based on official statistics from the Unified Interdepartmental Information and Statistics System (EMISS). Available at: <http://fedstat.ru>

In the structure of cultivated lands in the Vologda Oblast, the highest share is traditionally occupied by fodder crops (in 2016 – more than 60%) since there is the need to provide livestock farming with own-produced fodder; the share of grain crops amounted to 31.2% (Fig. 5). Among constituent entities of the Northwestern Federal district the Vologda Oblast in 2016, as well as in the previous year, ranked second in the area of grain crops in all types of households.

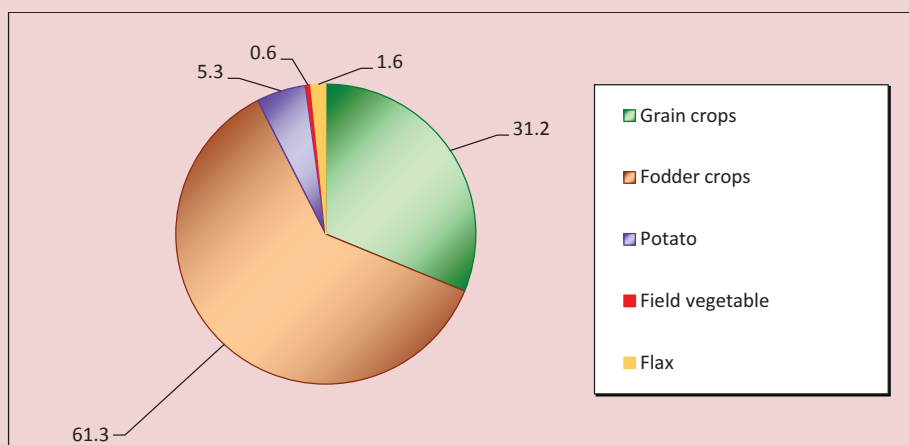
In region’s agricultural enterprises in 2016, the structure of cultivated grasses by ripeness was as follows: early ripening– 6.0%, mid-ripening – 38.0%, late-ripening – 56%. Early ripening grasses are represented by eastern galega, orchard grass and phalaris; mid-ripening include double-crop red clover, alfalfa, Lotus corniculatus, meadow fescue, awnless brome, festulolium, oat-grass and mixtures; late-maturing crops consist of a mixture of single-crop red clover and Timothy-grass, Timothy-grass and wild grasses (Tab. 2). Just

like in previous years, the structure of grasses by ripeness is dominated by late-ripening grasses with lack of early-ripening herbage [5, 7, 9, 12].

As far as the cultivation of crops is concerned, pea crops in single-crop sowing and in the mixture with barley (oats, wheat) on grains remains an important element in fodder production. They are much superior to other grains by yield (1.5–2.0 times) and more valuable for balanced livestock feeding [5, 6, 14, 19, 21]. All in all in 2016, the yield of grain crops in the Vologda Oblast amounted to 19.8 centners per ha, which is 10% below the level of 2015 and 45.6% above the level of 2000 (Tab. 3). The yield of perennial grasses during the research period did not change significantly, of annual grasses – decreased by 53.8% compared to 2000.

One of the factors reducing crop yields in the region is low land fertility. To overcome the current situation the households annually apply organic and mineral fertilizers. However, in

Figure 5. Structure of cultivated areas of major crops in the Vologda Oblast, all types of households, 2016, %



Source: official statistics of the Unified Interdepartmental Information-Statistics System (EMISS). Available at: <http://fedstat.ru>

Table 2. Composition of grasses in the agricultural enterprises of the Vologda oblast, %

Structure	Year						
	2010	2011	2012	2013	2014	2015	2016
<i>Culture</i>							
Perennial grasses, total	100	100	100	100	100	100	100
- legume and legume-grass	42.5	39.3	37.8	42.6	39.7	42.0	44.6
- grain crops	57.5	60.7	62.7	57.3	60.3	58	55.5
<i>Ripeness</i>							
Perennial grasses, total	100	100	100	100	100	100	100
Including early-ripening:	7.9	7.7	8	7.6	7.0	7.0	6
- mid-ripening	31.7	31.7	31	27.7	31.0	36.0	38
- late- ripening	60.6	60.6	62	64.7	62.0	53.0	56
<i>Years of usage</i>							
Perennial grasses, total	100	100	100	100	100	100	100
- 1st–3rd year of usage	40.0	40.9	40.0	39.9	44.4	43.6	48.8
- 4th year of usage and older	60.0	59.1	60.0	61.1	55.6	56.4	51.2
Source: compiled by the author based on departmental statistics of the Department for Agriculture and Food Supplies of the Vologda Oblast.							

Table 3. Crop yields in the Vologda Oblast in all types of households (per harvested area), kg/ha

Culture	Year									2016 to 2015, %	2016 to 2000, %
	2000	2005	2010	2011	2012	2013	2014	2015	2016		
Legume and legume-grass	13.6	16.4	15.9	19	18.6	15.7	22.1	22.0	19.8	90.0	145.6
Oats	15	16.7	13.4	19.5	20.3	15.8	19.1	20.3	16.6	81.8	110.7
Barley and wild barley	no data	no data	17.6	19	18.3	15.6	23.6	23	21.2	92.2	-
Peas	23.1	25.1	32.7	30.3	31	27.4	35.6	32.9	25.5	77.5	110.4
Perennial grasses (total for hay)	no data	19.7	19.1	19.3	19.3	18	15.4	17.2	17.2	100.0	-
Annual grasses (total for hay)	18.6	7.8	28.4	53.1	6.5	no data	11.4	13	8.6	66.2	46.2
Corn for silage, green fodder and haylage	no data	no data	243.2	310.2	204.2	no data	no data	264.8	350.1	132.2	-
Source: compiled by the author based on official statistics from the Unified Interdepartmental Information and Statistics System (EMISS). Available at: http://fedstat.ru											

recent years, the removal of nutrients from the soil is not compensated for by applying mineral and organic fertilizers as their amounts significantly decreased in 2016 compared to 2000 (*Tab. 4*).

In general, in 2016 mineral fertilizers were applied in 53.3% of the cultivated area of agricultural crops, organic – only in 4.2% of the entire area under cultivation. The share of mineral and organic fertilizers applied to 1 hectare of agricultural crops amounted to 38.4 kg and 3.7 t of application rate respectively. Fodder crops were applied 18.0 kg of application rate of mineral fertilizers and 1.6 t of organic fertilizers, which is 5 or more times below the necessary amount [3, 9, 11, 14, 15].

Despite the difficulties in fodder production, a number of leading households in the Vologda Oblast are still making progress. One of such leading households in the region is AO Plemzavod Rodina⁵. The household possesses 9,224 ha of agricultural land, including 6,681 ha of arable land, 1,685 ha of hayfields, and 861 hectares of pastures. Due to the fact that cattle are not grazed, part of pastures and grasslands are ploughed and used for sowing.

The structure of sown areas of the household in 2016 included 60% of grains, 33% of perennial grasses, and 7% of annual grasses (*Tab. 5*). Grain crops mostly include barley varieties such as “Sonet”, “Zazerskii 85”,

Table 4. Fertilizer application for crops in agricultural organizations of the Vologda region

Indicator	Year										2016 to 2015, %	2016 to 2000, %
	2000	2005	2010	2011	2012	2013	2014	2015	2016			
Mineral fertilizers applied (per 100 % of nutrients) total, thousand tons	26.3	14.2	13.7	15.8	12.5	9.5	10.9	11.7	11.1		94.9	42.2
Per 1 ha, kg of application rate	42.0	28.5	34.0	41.5	34.3	28.9	36.9	36.7	38.4		104.6	91.4
Including for cultivation:												
- grains	75.0	67.5	71.3	79.4	66.9	64.3	71.2	69.1	70.8		102.5	94.4
- fodders	26.0	11.8	11.6	19.1	17.2	11.5	18.6	17.3	18.0		104.0	69.2
Share of fertilized area in the total cultivated land, %	55.8	37.4	47.7	58.3	53.4	40.1	51.4	52.2	53.3		-	-
Total organic fertilizers applied, thousand tons	1653	1238	922	936	857	856	920	1008	1055		104.7	63.8
per 1 ha, tons	2.6	2.5	2.3	2.5	2.4	2.7	3.1	3.4	3.7		108.8	142.3
Including for cultivation:												
- grains	6.1	6.4	5.6	6.1	5.6	6.3	6.8	7.2	7.4		102.8	121.3
- fodders	1.2	1.1	0.7	0.7	1.0	1.0	1.4	1.4	1.6		114.3	133.3
Share of fertilized area in the total cultivated land, %	3.4	3.1	3.1	3.4	2.7	3.3	3.7	3.8	4.2		-	-

Source: compiled by the author based on official statistics from the Unified Interdepartmental Information and Statistics System (EMISS). Available at: <http://fedstat.ru>

⁵ Since 1987, the household is headed by General Director AO Kolkhoz Rodina, an Honored worker of Agriculture of the USSR, G.K. Shilovskii.

Table 5. Cultivated lands of AO Plemzavod Rodina, ha

Year	Cultivated land (total)	Including			
		grains	perennial grasses	annual grasses	open sowing
2010	6883	2848	3338	-	697
2011	6703	3700	2810	-	193
2012	6638	3700	2738	-	200
2013	6678	3800	2738	100	-
2014	7076	3900	2917	-	256
2015	6681	3950	2731	-	-
2016	6681	4000	2191	490	-

Source: compiled by the author based on monographic study of AO Plemzavod Rodina.

“Nur” and spring wheat “Torridon”, with no crops of oats. The mown area of perennial grasses amounted to 2,191 ha, including 290 ha of hay, 2,341 ha of green mass and 50 ha of seeds.

Perennial grasses are represented mainly by double-crop red clover mixed with Timothy-grass. In the structure of grasses by species composition, 63% are legumes and legume-grass mixtures, 37% – grain and grass-legume mixtures. Herbage belong to mid- (63%) and late-ripening (37%) by time of ripeness. In 2016, 1,177 of herbs of the first year of usage were harvested in the household (54% of the total cultivated area); of the second year of usage – 949 ha (43%); third year – 65 ha (3%); there is no old-aged herbage. Overgrassing is performed annually in the range of 20–25% of the available herbage.

The yield of fodder crops in 2011–2016, compared to 2006–2010 declined, including perennial grasses harvested for hay – 7%, green mass – 10%; however, it is higher than the average yield in household of the Vologda Oblast (*Tab. 6*).

As already noted, the growth of productivity of grain and forage crops to a certain extent depends on sufficient application of mineral and organic fertilizers. However, over the past 10 years the volume of organic and mineral fertilizers in agriculture has declined by more than 30% (*Tab. 7*). Higher amounts of fertilizers are applied to grain crops: in 2016, 93.5 kg/ha of mineral fertilizers were applied, including nitrogen – 38.7 kg/ha, phosphorus – 27.4 kg/ha, and potash – 27.4 kg/ha. 28 kg/ha of mineral fertilizers were applied for fodder grasses, including 28 kg/ha of nitrogen. This suggests that that applied doses of fertilizers and the ratio of nutrients do not provide heavy stable yields. For example, 121–137 kg of nutrients were inhibited per 1 ha of grain crops in the household in recent years, considering application of fertilizers and bio-nitrogen, which is almost 1.5 times lower than their depletion with the harvest.

Harvesting of hay and silage is important in creating sustained fodder supplies. In 2016, the household harvested 1,941 tons of hay (2.4 times more than in 2010), 41,645 tons of silage (101.5 %), and provided 10,249 tons of grain fodder animals (173.7 %; *Tab. 8*).

Table 6. Yield of crops in AO Plemzavod Rodina compared to households in the Vologodskii District, kg/ha

Year							Average	
2010	2011	2012	2013	2014	2015	2016	2011–2016	2006–2010
<i>1. Grains</i>								
23.8	24.2	23.2	22.0	32.2	30.8	31.6	27.4	27.9
21.1	23.9	22.8	19.3	27.7	27.1	25.0	24.3	24.5
<i>2. Perennial grasses for green mass</i>								
165.6	116.8	202.0	189.4	108.6	271.8	226	185.8	199.7
148.3	118.2	145.0	135.3	96.2	150.9	151	132.8	143.9
<i>3. Perennial grasses for hay</i>								
41.0	30.2	31.4	52.4	36.7	58.7	59	44.8	50
25.6	21.9	41.0	24.4	27.7	23.8	24	27.2	24.7

Source: compiled by the author based on monographic study of AO Plemzavod Rodina.

Table 7. Application of fertilizers in AO Plemzavod Rodina

Year	Organic fertilizers, t/ha	Mineral fertilizers, kg/ha rate of application			
		nitrogen	phosphorus	potassium	total
2006	6.6	70.1	24.3	24.3	118.7
2008	6.2	59.6	30.1	30.1	119.8
2010	2.5	27.9	14.5	14.5	56.9
2011	4.0	25.3	20.3	20.3	65.9
2012	4.5	33.3	17.6	17.6	68.5
2013	4.5	29.4	15.6	25.3	70.3
2014	2.7	29.2	28.4	21.6	79.2
2015	3.6	49.2	16.4	16.4	82.0
2016	3.0	55.7	18.4	18.4	92.5

Source: compiled by the author based on monographic study of AO Plemzavod Rodina.

Table 8. Amount of harvested fodders in AO Plemzavod Rodina, tons

Name	Year							2016 to 2015, %	2016 to 2010, %
	2010	2011	2012	2013	2014	2015	2016		
Silage	41019	33300	41350	41005	33135	51823	41645	80.4	101.5
Haylage	-	875	-	-	-	-	-	-	-
Hay	800	1422	1097	1485	1487	2359	1941	82.3	2.4 times
Grain forage	5900	8938	7272	6035	10339	10000	10249	102.5	173.7
Total, tons of fodder units	14095	15977	16091	14978	17709	20895	19500	93.3	138.3

Source: compiled by the author based on monographic study of AO Plemzavod Rodina.

Given grain forage, 19,500 tons of fodder units were harvested, 5.79 of fodder units per cattle unit, which is significantly higher (1.6 times) than in the oblast (Tab. 9).

However, the harvested fodders are of insufficient quality (Tab. 10). In 2016, silage of first and second grade amounted

to 29.2 to 68.7%, hay – 0–41.9%. It should be noted that about 91.7% of harvested hay was off-grade, the harvested silage was mainly first and second grade (68.7%).

The share of harvested off-grade silage is significantly lower than in previous years – 11.8%.

Table 9. Fodder supplies in 2016

	Fodders harvested, thousand tons of fodder units	Cattle population, thousand animals	Per cattle unit, tons of fodder units	%
AO Plemzavod Rodina	19.5	3.37	5.79	160
Vologda Oblast (total)	442.7	123.3	3.59	100

Source: compiled by the author based on monographic study of AO Plemzavod Rodina.

Table 10. Quality of fodders at AO Plemzavod Rodina, %

Name	Year	Verified, thousand tons	Graded, %			
			I	II	III	off-grade
Hay	2010	800	15.8	-	67.5	16.7
	2011	1472	-	7.5	72.1	20.4
	2012	1097	-	-	17	83
	2013	1485	-	11.6	25.2	63.2
	2014	1487	-	41.9	35.2	22.9
	2015	2030	-	-	-	100
	2016	1247	-	-	8.3	91.7
Silage	2010	41015	2	27.2	50.6	20.2
	2011	33300	13.3	31.8	28.9	26
	2012	41350	3.2	59.6	23	14.2
	2013	41050	34	29.6	20.1	16.3
	2014	33135	10.9	39.1	39.6	10.4
	2015	50183	27.6	40.3	23.8	8.3
	2016	28384	24.2	44.5	19.6	11.8
Haylage	2010	787	-	-	-	100
	2011	875	-	14.3	-	85.7
	2012	893	-	-	100	-
	2013	240	-	100	-	-

Source: compiled by the author based on monographic study of AO Plemzavod Rodina.

To improve fodder and fodder production in general AO Plemzavod Rodina carries out a set of operations including:

- purchasing modern agricultural equipment and tractors;
- increasing the volume of mineral fertilizers per 1 ha (in the last 3 years – by 11%);
- production of seeds of grain crops and perennial grasses for own needs;
- timely overgrassing;
- compliance with technology requirements in silage harvesting, which provides high-quality fodder;
- maintenance of hay drying towers to store part of the harvested hay; concrete silage trenches with a capacity of 45,000 tons of silage, etc.

In our opinion, the positive experience of AO Plemzavod Rodina can be used by region's households and the Northwestern Federal district as a whole in order to improve fodder production efficiency.

First of all, the Vologda Oblast requires the development of scientifically justified system of fodder production⁶. It must include:

1. The development and implementation of a rational structure of fodder crops areas taking into account agro-climatic and soil conditions, aimed at meeting animals' need for high-quality fodder [7, 17]. According to the calculations, it is necessary to increase cultivation of most productive cost-efficient crops and meeting animals' needs for nutrients [3, 12]. It should

⁶ The system of dairy cattle farming development based on modern milk production technology taking into account fodder production, feeding and cattle breeding in the European North of Russia, providing the productivity of more than 7 thousand kg of milk per cow per year: research report for 2011–2016. Vologda: SZNIIMLPKh.

be noted that with increased cow productivity the structure of fodder crops areas changes towards significant expansion of areas occupied by crops and reduction of areas under perennial and annual grasses and pastures [13, 19].

2. The development of a rational structure of fodder crops areas conducted according to planned orders of households for fodders, taking into account the level of cow productivity, systems and methods for their maintenance, the achieved or planned level of fodder crops productivity [9, 10].

3. Accounting for logistics, condition of soil fertility, and climatic conditions.

It must be considered that the heaviest yield of fodder units per 1 ha of arable land is provided by grain crops, perennial grasses for green mass. Since production costs of annual grasses are significantly higher than that of perennial grasses and they rank below perennial grasses in productivity, the areas of their cultivation must be optimized to minimum [9, 20, 21].

We note that the species composition of fodder grasses in conditions of the Vologda oblast is mainly represented by a wide range of perennial legumes and grass species, annual legumes, grain and cruciferous crops.

Based on the research results⁷, the sowing pattern of perennial grasses would be appropriate to calculate based on their species composition, ripeness and duration of herbage usage. We need to expand the cultivation of legumes and legume-grasses to 60–70%,

⁷ Development of methodological provisions for dairy farming management taking into account natural adapted systems of fodder production, feeding and breeding in the economic conditions of the European North of Russia: research reports. Vologda: SZNIIMLPKh.

the structure must have up to 30 % of early-ripening, 40% of mid-ripening and 30% of late-ripening herbage. Herbage must be used for not more than three years (not less than 70% of the available lands under herbs).

To produce early-ripening grasses⁸ the following crops may be used: orchard grass, eastern galega, ultra-early ripening varieties of red clover, *Lotus corniculatus*. Mid-ripening herbage⁹ is based on varieties of double-crop red clover, meadow fescue, *festulolium*, awnless brome, early-ripening varieties of alfalfa. Late-ripening crops include single-crop red clover mixed with Timothy-grass. The harvesting of the grass mixture begins from June 25th and continues up to July 10–15th. Most perennial grasses should be mowed twice per season, alfalfa – three times. We note that to develop an optimal structure of grasses annual overgrazing is required at the level of at least 20–25% of available herbage.

The structure of fodder crops areas should include not more than 5–6 % of annual grasses. The most common are peas with oats, vetch with oats, peas, oats and sunflower, peas, oats and rapeseed (oil radish), vetch with oats and annual oat-grass. In well-watered and fertilized plots it is possible to sow annual oat-grass in single-crop sowing; in this case, it gives two full mowings. We note that in households with a high level of agricultural technology it is advisable to sow early-ripening corn hybrids for silage in single-crop and mixed sowing with legumes (yellow lupin or fodder beans).

⁸ Mowing ripeness of early-ripening herbage begins in average of May 25th–June 15th.

⁹ Mowing ripeness of mid-ripening herbage begins in average of June 15th–June 25th.

In the composition of grain and leguminous crops by ripeness, in our opinion, should include mid-ripening crops (50%), early-ripening (30%) and late-ripening (20%). To produce high-grade fodder grains, the composition of grain crops must include not less than 60% of barley, 15% – oats, 12% – wheat, 3–4% – winter crops and 8–10% – legumes [7, 10].

It should be noted that optimization of the composition of fodder crops is possible due to the expansion of areas under peas. Field pea is of great economic value in animal feeding as its seeds, leaves and stems are high protein [5, 6, 20, 23]. It does not deplete the soil, enriches it with nitrogen, having an ability to use atmospheric nitrogen through root nodule bacteria. Peas are able to use poorly soluble forms of phosphates, which after necrosis of root residues become available for other plants. Its cultivation in crop rotation provides a 20% reduction in consumption of mineral fertilizers for basic crops without reducing their productivity.

To provide cattle with fodders and ensure seed production of grain crops and perennial grasses, we recommend that the composition of fodder crops areas have about 55% of perennial grasses, at least 40 % of grains and 5–6 % of annual grasses (*Tab. 11*). The yield of grain crops needs to be at the level of 25 kg/ha, perennial grasses for green mass – 200 kg/ha.

Depending on the household's adopted cropping system it is feasible to sow crops in fields appropriate according to a specialized crop rotation system. Species diversity of fodder grasses and their areas must ensure continuous flow of plant raw material.

Table 11. Recommended composition of fodder crops areas, %

Composition	Composition, %
<i>General composition of fodder crops areas</i>	100
- including grains and grain-grasses	40
- fodder grasses	60
- of which perennial grasses	55
- annual grasses and silage	5
<i>Composition of crop patters for grains and grain-grasses</i>	100
of which winter crops	3
spring crops (total), including	97
- barley	60
- oats	15
- wheat	12
- grain legumes	10
<i>Source: compiled by the authors.</i>	

In our opinion, the raw material conveyor for harvesting winter fodder crops has the following features:

- mowing grasses is advisable to start in earlier phases (budding – initial blossom);
- extension of the species composition of grasses at the expense of sowing eastern galega, alfalfa, *Lotus corniculatus*;
- arranging line flow of green mass of clover due to the use of varieties of different ripeness;
- arranging line flow of green mass of annual fodder crops in order to fill the lack of grass from mid-July to the first decade of August;
- achieving the share of early-ripening grasses of up to 30 %, mid-ripening – 30 %, late-ripening – 40 %.

The area of each crop in the system of raw and green forage chains is determined based on the volume of forage, daily needs of animals for

green forage at the farm-and-pasture animal housing, taking into account the planned yields.

The optimal range of forage crops helps obtain full-value feeding ground from late May till first frosts. The expiration date of one crop overlaps the beginning of usage of another, which helps harvest high-grade fodder for livestock.

Raw material lines can be created based on varieties of red clover of different ripeness sown together with other grasses (late-, mid- and early-ripening). Late-ripening varieties of clover include: “Vologodskii”, “Volosovskii”, “Kirovskii 159”, “Falenskii”, “Vityaz”; mid-ripening include: “Falenskii 86”, “Orfei”, “Dymkovskii”; early-ripening include: “Trio”, “Martum”, “Kudesnik” [18, 14, 27].

The Vologda Oblast by its natural and climatic conditions is favorable for developing pasture farms [2, 22]. However, in the past decade zero grazing has been widely practiced.

The share of grazed cows and young cattle has decreased to 13%. This led to the reduction in the total area under pastures. An effective tool for increasing the efficiency of livestock farming production is the use of cultivated pastures, since compared to stable keeping, total costs of produced fodders are reduced 2–3 times. Pasture forage is 2–3 times cheaper than feeding green mass from feeders, and 4 times than the all-year feeding of silage and other stable fodders [15,16].

Due to the fact that soils with low fertility prevent full realization of potential of the cultivated crop varieties, improving soil fertility includes liming and phosphorite application of sour soil, rational use of fertilizers according to the annually compiled balance of nutrients, and maintenance of crop diversification at their optimal structure.

Standard nutrient consumption rate in sod-podzolic soils providing an increase in their content in 1 kg of soil is: phosphorus – 50–60 kg in sandy soil and sandy loam, 70–90 kg in loamy soil and 100–120 kg in clay soils; potassium – respectively, 40–60, 60–80 and 80–120 kg. Doses of nitrogen fertilizers are determined depending on the degree of soil cultivation. The need for organic fertilizers is not less than 8–10 tons per 1 ha of arable land, provided that perennial grasses comprise at least 40 %. This will ensure a positive balance of humus and its increase [5, 9, 18, 20].

The research has revealed that with intensive dairy farming management bulky fodders need to have average energy nutrient value not less than 10 MJ ME (0.82 fodder units) in 1 kg of dry matter with more than 14 % of crude protein. Achieve such results is possibly through application of more advanced and effective

technology of making fodders of perennial grasses, annual legume-grasses and other crops [4, 12].

Thus, analysis of the dynamics of fodder production development in the Vologda Oblast suggests the following conclusions:

1. The economics of agricultural enterprises depends on the quality and amount of harvested forage.

2. The most relevant objective today is improving the quality and energy value of fodders.

3. To solve this problem at the regional level it is necessary to develop a comprehensive program on the principles of public-private partnership, including areas such as:

- rational structuring of the forage crops areas;

- expansion of crops of legume species up to 60–70 %, early-ripening grass – up to 30 %;

- annual regeneration of perennial grasses up to 20–25 % of the area;

- introduction of raw material line based on cultivated grasses, as well as pastures and hayfields;

- increasing the dose of fertilizer application up to 120 kg/ha of mineral fertilizers and up to 7–8 t/ha of organic fertilizers, soil liming;

- improving the machine-tractor fleet to reduce the period of main agricultural activities.

The implementation of complex measures on improving the system of fodder production development in the Vologda Oblast taking into account the above trends and latest scientific advances will increase the total production of high quality fodder 1.5–2.0 times which is confirmed by the experience of advanced economies.

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