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Reproductive Ability of Doe-Rabbits and Growth and Preservation of the Offspring by Feeding Sulfur Compounds

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Abstract. The use of organic minerals in the form of nanocompounds as a substitute for mineral inorganic salts is promising, but insufficiently studied. Therefore, the purpose of the search was to determine the influence of drinking sulfur citrate and sodium sulfate 14 days before insemination and up to 20th day of lactation on the reproductive capacity of rabbits and the preservation of the offspring up to 40th day of life. The research was carried out on rabbits of the second breed of *Hyla* breed in "Horlytsia". Control group were fed without restriction complete ration granular feed with free access to water. 1st experimental group were fed with the ration of the control group and during the day were watered with sulfur citrate, at the rate of 8 μg S/kg of body weight. II experimental group were fed with the ration of the control group and with water was given sodium sulfate in the amount of 40 mg S/kg of body weight. Additives to rabbits were watered 14 days before insemination and for up to 20 days of lactation. It was found that on the first day of life of young rabbits their number in the I and II experimental groups was respectively higher by 8.5 and 4.2% compared to the control. The number of young rabbits at 20 and 40 days of age in the I and II experimental groups was respectively higher by 10.4 and 4.4% and 14.0 and 4.6% compared to the control group. The weight of rabbits in the nest of the II experimental group at 1, 20 and 40 days of life was respectively higher by 2.8; 6.1 and 7.0%, which is based on the average mass of one rabbit for these periods and amounted to 1.1, respectively; 2.7 and 4.3% compared with animals in the control group. The average amount of milk produced by rabbits of I and II experimental groups was respectively higher by 10.2% and 6.6% per day and for 20 days of the lactation period compared to the control. The preservation of rabbits in the I and II experimental groups was respectively higher by 6.4 and 6.4% and 3.6 and 4.4% at 20 and 40 days of life of young rabbits compared to the control group. The results of the research indicate the possibility of additional use in the ration of rabbits of the addition of sulfur citrate in the amount of 8 μg S/kg of body weight to increase metabolism and reproductive capacity during periods of increased physiological load

Keywords: nanotechnologies, lactation, body weight, bioavailability of nutrients

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INTRODUCTION

Nanotechnologies are used in the feeding of farm animals to improve the bioavailability of nutrients in the organism, to ensure higher taste, consistency, duration of storage of their products [1; 2]. Nanoparticles preserve the unique properties, resulting in significantly improved physical and chemical properties of the used materials, including minerals [3; 4]. Nanotechnology is used in veterinary physiology, for reproduction and genetics of animals, molecular and cell biology, allowing researchers to work with biological components such as DNA, proteins or cells in small amounts, usually nanoliters or picoliters [5]. Complex nanoprograms are used in animal nutrition systems using available tools and methods that have not an influence on animal health and welfare. This technology offers the best solutions for the use and production of livestock products, which can help to reduce costs and improve the quality of the final indicators [6]. The use of nanotechnology is promising in agriculture and food industry, for the diagnosis and prevention of diseases, improving the ability of plants to absorb nutrients, etc [7].

The most important use in this field are nanominerals. They are characterised by a particle size of 1 to 100 nm. Some of them are stable at high temperature and pressure, they are easily digested in the digestive system [8]. This leads to better interaction with other biologically active substances, due to the larger surface area [9]. Some surface active nanomineraly and nanocomponents can bind and remove toxins and pathogens [10; 11]. The researches have shown that the use of nanominerals, such as nanoselenium, nanochrome, nanozinc, can improve the body's resistance to non-communicable diseases and the quality of their products, this is especially true when replacing inorganic salts of mineral elements with organic nanocompounds, which is widely used in the diet of industrial animals [12].

Rabbits are characterised by small body size, greater feed use, rapid growth, quality nutritious meat, early puberty, and high genetic selection potential compared to other farm animals [13]. Sperm quality is the key to successful fertilisation in breeding rabbits and an indicator of the reproductive capacity of rabbits [14]. Gastrointestinal absorption of minerals is influenced by a number of factors, including its chemical form: soluble compounds (oxides, hydroxides, citrates and sulfates) are easily absorbed, but water-insoluble compounds (sulfides) are poorly digested. Minerals in organic forms have a more efficient use in the organism to increase their bioavailability, which leads to improved ejaculate volume, sperm motility, and then male fertility and fertility of rabbits [15]. Several methods have been developed to get nanoparticles [16], including thermal reduction, metal vapor evaporation method, microemulsion technique, mechanical grinding and chemical reduction [17]. However, regardless of the technology of getting nanoparticles, their advantage in use for animals has been noted, although there are not many such researches, especially in rabbit breeding. We conducted research to study the influence of nanocompounds on the organism of rabbits, which showed a positive influence on organism parameters and reproductive capacity [18; 19].

The purpose of this experiment was to determine the influence of watering sulfur citrate and sodium sulfate 14 days before insemination and for up to 20 days of lactation on the reproductive capacity of rabbits and the preservation of the offspring up to 40 days of life.

MATERIALS AND METHODS

The research was carried out on rabbits of the second breed of Hyla breed in "Horlytsia" Ltd., v. Dobryany of Gorodok district of Lviv region, who used organic and inorganic sulfur compounds in physiologically justified amounts in young rabbits in previous research. Females were divided into three groups (control and two experimental), 20 animals in each, selected on the principle of analogues. Controlled rabbits of control group (K) were fed without restriction complete ration granular feed containing 18.5% of crude protein, 8.0% of crude fiber, 3.0% of crude fat and 2250 ME kcal/kg with free access to water. Animals of the I experimental group (D–I) were fed the ration of the control group and during the day were fed sulfur citrate, at the rate of 8 μg S/kg of body weight. Sulfur citrate solution (1.0 g/dm^3, pH 1.38) was got from "Nanomaterials and Nanotechnologies" Ltd., Kyiv. Females of experimental group II (D–II) were fed the ration of the control group and with water was given sodium sulfate (Na_2SO_4) in the amount of 40 mg S/kg of body weight. Additives to rabbits were watered 14 days before insemination and for up to 20 days of lactation. The experiment lasted 95 days, including the preparatory period of 10 days, the experimental – 85 days. In the preparatory period for 10 days from the beginning of the research and in the experimental period for 20 days of lactation (65 days of supplements watering) in rabbits was determined by fertility by probing for 12 days after insemination, assessed the number and weight and safety of young rabbits in the nest after birth and up to 40 days of age, determined the milk yield of rabbits by the calculation method: to do this, determine the total weight of the nest on the first day of birth and on the 20th day of life, the difference was multiplied by 2.2 – received the estimated amount of milk consumed by young rabbits. It was found that per 1 g of body weight gain is 2.2 g of milk. These methods are described in the handbook [20]. Mathematical processing of research results was developed statistically using the software package Statistica 7.0 software (Stat Soft, Tulsa, USA). Differences between values in the control and experimental groups were determined using ANOVA, where the differences were considered significant at $P<0.05$ (taking into account the Bonferroni error).

RESULTS AND DISCUSSION

In recent years, the reproductive capacity of rabbits on modern industrial farms has increased due to the use of artificial insemination, hormonal stimulation and selection work. However, there are a number of problems with the supply of minerals and energy during the first and second lactations, which leads to a decrease in the reproductive capacity of rabbits and culling of breeding stock to 80% during the year. Conducting research indicate the importance of providing a complete balanced ration of minerals for young females during lactation, which give a lot of energy to the organism for milk production and embryo development after fertilisation and also continue to increase body weight, which is a physiological process. Therefore, the purpose of our research was to study the influence of drinking sulfur citrate and sodium sulfate on the reproductive capacity and milk yield of rabbits, growth and safety of young rabbits up to 40 days of age. The analysis of table 1 indicates that after insemination of rabbits in all groups, their fertility was the same 100%. The period of pregnancy lasted an average of 31 days, which is within the physiological parameters for this species. Genera in rabbits took place without complications, mainly at night, stillborn rabbits in the nest were not detected. The use of organic and inorganic sulfur compounds in rabbits 14 days before insemination contributed to better fertilisation, which affected the number of offspring in the nest. Thus, on the first day of life of rabbits, their number in the I and II experimental groups was respectively higher by 8.5 and 4.2% compared to the control group. Continuations of research indicate that this feature was noted up to 40 days of life of rabbits. In particular, the number of rabbits at 20 and 40 days of age in the I and II experimental groups was respectively higher by 10.4 and 4.4% and 14.0 (P <0.05) and 4.6% compared to the control group.

***Table 1**. The influence of sulfur citrate and sodium sulfate on the reproductive capacity of rabbits (M±m, n=20)*

Group	Fertility, %	Number of born rabbits, %		Number of rabbits in the nest		
		Living	Dead	1 day	20 day	40 day
K	100	100	–	7.0±0.3	6.7±0.3	6.4±0.1
%				100	100	100
D–I	100	100	–	7.6±0.4	7.4±0.4	7.3±0.2*
%				108.5	110.4	114.0
D–II	100	100	–	7.3±0.6	7.0±0.4	6.7±0.2
%				104.2	104.4	104.6

***Note**: statistically significant differences were taken into account compared with the control group: * – P<0.05, ** – P<0.01, *** – P<0.001; the selections were compared within one line (taking into account Bonferroni correction)*

In the biosphere, the physical, chemical and biological properties of matter are determined by physicochemical phenomena. However, only the size of the substance reduces the action of these variable forces. The size of the substance acquires new physicochemical characteristics. Nanoparticles remain protected from various types of bioactive agents and reactions, such as oxidation, enzymatic or chemical interaction with other molecules. This is due to the active component of nanoparticles, increasing their stability. Therefore, in our opinion, the results got may depend on the used sulfur compound, which has unique properties in the organism that has an influence on the stimulating factors of metabolism.

The analysis was performed on the results of growth and development of rabbits organism showed that the watering of sulfur compounds to rabbits of the second round had an influence on the fetal and postembryonic period of their development (Table 2). In particular, the investigated weight of rabbits that were in the nest of the I experimental group at 1, 20 and 40 days of their lives was respectively higher by 10.0; 20.4% (P<0.05) and 11.9% (P<0.05) compared with the control group. The got results correlated with the indication of average weight of one rabbit in the nest, which on 1, 20 and 40 days exceeded 1.8; 5.2 and 6.4% (P<0.05) of rabbits included in the control. The weight of rabbits in the nest of the II experimental group at 1, 20 and 40 days of life was respectively higher by 2.8; 6.1 and 7.0% (P<0.05), which is justified by the average weight of one rabbit for these periods and amounted to 1.1, respectively; 2.7 and 4.3% compared with animals in the control group.

***Table 2**. The influence of sulfur citrate and sodium sulfate on the growth of rabbits during lactation (M±m, n=30-34)*

Group	Mass of rabbits in the nest, g (age of life)			Average weight of one rabbit, g (age of life)		
	1	20	40	1	20	40
K	418.9±25.0	2072.2±63.2	5519.1±38.8	60.2±0.31	321.1±4.11	903.7±14.8
%	100	100	100	100	100	100
D–I	461.1±28.6	2495.8±143.0*	6180.4±216.0*	61.3±0.29*	338.0±5.29*	962.3±9.04*
%	110.0	120.4	111.9	101.8	105.2	106.4
D–II	431.0±22.4	2199.5±72.1	5909.1±147.8*	60.9±0.15	329.9±3.50	943.2±8.6
%	102.8	106.1	107.0	101.1	102.7	104.3

***Note**: statistically significant differences were taken into account compared with the control group: * – P<0.05, ** – P<0.01, *** – P<0.001; the selections were compared within one line (taking into account Bonferroni correction)*

The got results may indicate that sulfur citrate in the consumed amount, better absorbed in the digestive tract of rabbits and young rabbits up to 40 days of age, which contributed to better bioavailability of nutrients, including sulfur and its positive influence on the growth and development of young rabbits, while the watering of sodium sulfate was marked by less pronounced investigated indicators of their organism compared with the control. Investigations have shown that the young rabbits of the two experimental groups had a higher nest weight and one animal at 1, 20 and 40 days of lactation compared to the control. Suckling rabbits have high energy needs and are characterised by low thermal insulation in the nest, if the temperature is low then the milk consumed is not absorbed by the organism. Therefore, the preservation and development of young rabbits in the nest is completely related to the quantity and quality of breast milk and offspring. The use of organic and inorganic sulfur compounds in rabbits of the experimental groups was marked by a greater amount of produced milk (Table 3).

***Table 3**. Milk yield of rabbits and preservation of the offspring during watering of sulfur citrate and sodium sulfate (M±m, n=20)*

Group	Milk production of rabbits, g		% Preservation of the offspring	
	Per day	For 20 days	20th day	40th day
K %	186.1 ± 8.22 100	3723.9±190.1 100	91.3	88.2
D–I %	205.3 ± 12.5* 110.2	4106.2±276.8* 110.2	97.2 6.4	93.9 6.4
D–II %	198.5 ± 6.14 106.6	3970.1±123.0 106.6	94.6 3.6	92.1 4.4

***Note:** statistically significant differences were taken into account compared with the control group: * – P<0.05, ** – P<0.01, *** – P<0.001; the selections were compared within one line (taking into account Bonferroni correction)*

In particular, the average amount of produced milk by rabbits of experimental group I was higher by 10.2% (P <0.05) per day and for 20 days of the lactation period compared to the control. The got results of the research may indicate a general activating influence of sulfur nan compounds on metabolism in the organism and the process of metabolism in the mammary gland of rabbits, which was more pronounced under the action of sulfur citrate. Slightly different results were got in rabbits of experimental group II, which received sodium sulfate with water, the amount of milk secreted per day and during 20 days of lactation was higher by 6.6% compared with the control group of animals, but these results were unlikely. The results of the preservation of young animals during the search period (40 days of life from birth) in the experimental groups were slightly higher compared to the control. The research by domestic and foreign authors have shown that the quantity and quality of milk from rabbits has an influence on the safety of rabbits during lactation. The results confirming these generalisations were got due to the conducted researches. Thus, the safety of rabbits in the first experimental group was respectively higher by 6.4% at 20 and 40 days of life of rabbits compared with the control group. Watering of the inorganic sulfur compound was marked by less pronounced results of preservation of young animals. In particular, in the second experimental group, the survival of rabbits at 20 and 40 days of life was respectively higher by 3.6 and 4.4% compared with the control. The obtained results of the experiment may indicate more pronounced correlations between milk yield and productivity and preservation of young rabbits in the suckling period under the action of the organic compound sulfur citrate.

CONCLUSIONS

Rabbits watering 14 days before insemination and for up to 20 days of lactation of sulfur citrate in the amount of 8 μg S/g of body weight, was markedly higher (P<0.05) number of rabbits per 40 days of life, greater weight of the nest and one rabbit (P<0.05) for 20 and 40 days from birth, more produced milk per day and 2 days (P<0.05) and higher rates of preservation of 6.4% for 40 days of life compared with the control group. The use of sodium sulfate in the ration of rabbits in the amount of 40 mg S/kg of body weight, contributed to higher nest weight at 40th day of age (P<0.05) and a tendency to more milk from rabbits and retention of offspring up to 40 days of age compared to control.

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Анотація. Застосування органічних мінеральних речовин у вигляді наносполук, як заміни мінеральних неорганічних солей є перспективним, але недостатньо вивченим. Тому метою дослідження було з'ясувати вплив випоювання сульфуру цитрату та сульфату натрію за 14 діб до осіменіння і упродовж до 20 доби лактації на репродуктивну здатність кролематок та збереженість приплоду до 40 доби життя. Дослідження проведені на кролематках другого окролу породи *Hyla* у ТзОВ «Горлиця». Контрольній групі згодовували без обмеження повнораціонний гранульований комбікорм з вільним доступом до води. Тваринам І дослідної групи згодовували корми раціону контрольної групи і впродовж доби випоювали сульфуру цитрат, з розрахунку 8 мкг S/кг маси тіла. ІІ дослідній групі згодовували корми раціону контрольної групи і з водою задавали сульфат натрію в кількості 40 мг S/кг маси тіла. Встановлено, що на першу добу життя кроленят їхня кількість у І і ІІ дослідних групах була відповідно вищою на 8,5 і 4,2 % порівняно до контролю. Кількість кроленят на 20 і 40 доби життя у І і ІІ дослідних групах була відповідно вищою на 10,4 і 4,4 % та 14,0 і 4,6 % порівняно до контрольної групи. Маса кроленят у гнізді ІІ дослідної групи на 1, 20 і 40 доби життя була відповідно вищою на 2,8; 6,1 і 7,0 %, що обґрунтовується середньою масою одного кроленяти за вказаними періодами і становила відповідно 1,1; 2,7 і 4,3 % порівняно з тваринами контрольної групи. Середня кількість продукованого молока кролематок І і ІІ дослідних груп була відповідно вищою на 10,2 і 6,6 % за добу та за 20 діб лактаційного періоду порівняно з контролем. Збереженість кроленят у І і ІІ дослідних групах була відповідно вищою на 6,4 і 6,4 % та 3,6 і 4,4 % на 20 і 40 доби життя кроленят порівняно з контрольною групою. Отримані результати дослідження вказують на перспективу додаткового використання у раціоні кролематок добавки сульфуру цитрату в кількості 8 мкг S/кг маси для підвищення обміну речовин та репродуктивної здатності у період підвищеного фізіологічного навантаження

Ключові слова: нанотехнології, лактація, маса тіла, біодоступність поживних речовин

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The Development of Phyto- and Tissue Origin Medicines for Veterinary Reproductive Issues

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Abstract. Modern conditions of practical veterinary medicine require the use of effective and safe drugs. Along with the already known and common medicines, the search for new drugs which are harmless for the body and have the physiological direction of action is still required. In recent years, the attention to the use of phyto- and tissue-derived drugs increased. However, the problem of their use is insufficiently studied – many aspects of their clinical use require further development, expansion of the spectrum of used medicinal plants, study, and implementation into veterinary practice. Therefore, the purpose of this work was to develop a comprehensive vitamin-hormone drugs based on phyto- and tissue medicines for the treatment and prevention of reproductive abnormalities in animals. Based on the information on the etiopathogenesis of disorders of reproductive function indicators: homeostasis, reducing of the concentration of hormones (estrogen or progesterone), changes in the morphofunctional state of endocrine (pituitary, thyroid, and adrenal gland) and reproductive (ovaries) organs, the application of vitamin-hormone drugs in veterinary medicine is scientifically sound. Drugs in terms of pathogenetic therapy can optimise homeostasis, hormone concentrations, stimulate rehabilitation processes in the regulatory organs of reproductive function (pituitary, adrenal, and thyroid) and reproductive organs (ovaries), which, in turn, contributes to the normalisation of follicles which are a prerequisite for the full reproductive capacity of females. Vitamin-hormonal medicines of herbal and tissue origin were developed, with high efficiency for the treatment and prevention of reproductive pathologies of various species of animals, providing the stimulation of reproductive function (estrus signs) for therapy of females with gonadopathies ("Carafest", "Caplaestrol" and "Caplagonìn") and males (display of sexual reflexes and sperm quality) for reproductive activity dysfunction ("Carafand"), increase in the viability of the newborn (increasing the number of lambs and goatlings with satisfactory clinical condition with a high-growth potential, reduce in their morbidity and lethality), preventing the incidence of ìntra- and postnatal (labor hypofunction, diseases of post-labor period) pathology ("Carafest", and "Caplaestrol")

Keywords: animals, males, females, newborns, reproductive pathologies, treatment, prevention

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INTRODUCTION

Modern conditions of practical veterinary medicine require the use of effective and safe drugs [1-6]. Application of biotechnological methods in reproductive managing has to serve the maximum use of the reproductive potential of the animals, providing in-depth knowledge of and adherence to the biological patterns of reproduction and use of these methods in animals with optimal health and physical condition [7-11]. In particular, such an important technological milestone of the animal industry as reproduction involves the use of hormonal drugs [12-18]. However, using one or another hormonal drug, it should be kept in mind that the action on the female reproductive system can be shown in different ways – depending on the source of the functional state of the reproductive organs and the hormonal status of the body. The wrong use of the drug, regardless of criteria, can have negative effects [19-22]. Although not all scientists share this perspective and didn't find the negative impact even of multiple uses of hormonal drugs on sexual function, that should be associated with the optimisation of the dose of used drugs [23-28].

Along with the already known and common medicines, the search for new drugs, which are harmless for the body and have the physiological direction of action, is still required. In recent years, attention to the use of both human and veterinary phytomedicines increased [29-33]. Many plants contain biologically active substances, among which special attention should be paid to a plant hormone that is relevant and logical for the practice of reproductive veterinary medicine. The range of action of these substances is vast (phytoestrogens, antiestrogens, antigonadotropins), which allows using them to treat animals with different pathological processes [34-37].

Among tissue derivatives, the use of the placenta is of the greatest interest since it is a concentrate of biologically active substances – proteins, lipids, enzymes, hormones, and many others that encourage its wide use, in particular, in the field of reproduction of animals [38-43].

However, the problem of the use of phyto- and tissue-derived drugs is insufficiently studied, many aspects of their clinical use require further research, expansion of the spectrum of used medicinal plants, study, and implementation into veterinary practice.

Therefore, *the purpose of this work* was to develop a comprehensive vitamin-hormone drugs based on phyto- and tissue medicines for the treatment and prevention of reproductive abnormalities in animals.

MATERIALS AND METHODS

The research was conducted at the Department of veterinary reproductive medicine and practical complex of the animal industry and crop science of Kharkiv State Zooveterinary Academy, control of medicines was conducted in the State Institution "V. Danilevsky Institute for Endocrine Pathology Problems of the NAMS of Ukraine" (Kharkiv) and in State Scientific-Research Control Institute of Veterinary Medicinal Products and Feed Additives (Lviv), experimental verification and approbation took place in farms of different forms of ownership of the eastern, central and the southern regions of Ukraine.

β-carotene was obtained from crops that contain a significant amount of this substance (grass meadow, green mass of alfalfa, carrot, pumpkin) by extraction.

Total estrogens and chorionic gonadotropin were obtained from the female placenta by extraction.

Phytoestrogens and phytoandrogens were obtained from plants such as oregano (Origanum Vulgare), red clover, hop, millet (bran), acorus (Acorus calamus) [44].

The content of β-carotene in preparations was titrated for calorimetry scale, and estrogen – using Kober's reaction (standard – ampule solution of synoestrol).

Prepared drugs were packed in bottles or vials of dark glass with 10, 20, 50, 100 cm^3 of volume, sealed with rubber or aluminum caps or plastic stoppers or lids, and were autoclaved. They were kept in a dry, protected from light place at a temperature of 5°... 15°C for up to 1 year.

The effectiveness of the program of complex therapy of females for gonadopathy was determined among 339 cows, 77 sheep, and 35 goats.

According to the comprehensive program for the prevention of perinatal pathologies, 393 sheep and 104 goats were treated, as well as 512 lambs and 125 goats were evaluated.

A comprehensive program of therapy for males with reduced reproductive capacity was applied to 17 bulls, 29 boars, and 15 dogs.

Assessing the state of the structure and function of the testes, the manifestations of conditioned and unconditioned reflexes, sperm quality, and its fertilising ability, a conclusion concerning the reproductive capacity of males is made.

RESULTS

Regarding the direction of the research and the concept of continuity and consistency, it was logical to develop an effective, simple, and susceptible to practice veterinary medicine methods of therapy and the prevention of disorders of reproductive function in animals. The mechanisms of origin and development of pathologies and disorders of the reproductive function were obligatory to be encountered. Based on the information of etiopathogenesis of disorders of reproductive function indicators: homeostasis, reducing of the concentration of hormones (estrogen or progesterone), changes in the morphofunctional state of endocrine (pituitary, thyroid, and adrenal gland) and reproductive (ovaries) organs, the application of vitamin-hormone drugs should become scientifically effective. Preparations in terms of pathogenetic therapy can normalise the indices of homeostasis, the concentration of hormones stimulates the rehabilitation processes in organs-regulators of reproductive

function (pituitary, adrenal, and thyroid) and reproductive organs (ovaries), which, in turn, contributes to the normalisation of follicle- and steroidogenesis, which are prerequisite for total reproductive capability in females. For this purpose, vitamin-hormone preparations of phyto- and tissue origin "Cagadin", "Caplaestrol", "Caplagonin" and "Carafest" were developed. The basis of all drugs is "Cagadin", which is a solution of β-carotene in oil (Table 1 and 2).

***Table 1**. The composition of "Cagadìn" (1.0 ml)*

Carotene, mg	10.0±0.75
Refined oil, ml	Up to 1.0

β-carotene contributes to the rehabilitation of the structure and the functional state of the reproductive organs and the regulation of reproductive function, so the preparation "Cagadin" is intended for the prevention and treatment of vitamin deficiency and infertility. In particular, this preparation allows:

– to normalise the status of embryos and fetuses;

– to prevent hidden abortion (embryonal deaths), reduce the loss of embryos in the antenatal period;

– to increase the health of the newborns with high potential of growth;

– to increase the birth activity;

– to prevent pathological families (hypofunction of birth activity, dystocia, litter delay);

– to increase the number of fertilised females and the number of newborns from each female.

The preparation "Caplaestrol" is a solution of carotenoids and total estrogen (Table 3 and 4).

***Table 2**. Organoleptic indexes of "Cagadin"*

Index	Characteristic and norm
Appearance	Transparent oily liquid
Color	From dark-yellow to brown
Smell	No specific smell
Identity	Corresponds

***Table 3**. The composition of "Caplaestrol" (1.0 ml)*

Total estrogens according to RD, mg	1.00±0.05
Carotene according to RD, mg	10.0±0.75
Refined oil according to SSU 4492, cm^3	Up to 1.0

Estrogens optimise the development of the fetus, normalise the course of pregnancy and activate the birth activity, as well as promote the secretion of follicle-stimulating hormone in the pituitary gland that stimulates f folliculogenesis in the ovaries.

***Table 4**. Organoleptic indexes of "Caplaestrol"*

Index	Characteristic and norm
Appearance	Transparent oily liquid
Color	From dark-yellow to brown
Smell	Specific
Mass fraction of carotenoids, mg/cm^3	10.0±0.75
Mass fraction of total estrogens, mg/cm^3	1.0±0.05

"Caplaestrol" is intended for infertility treatment, prevention of obstetric-gynecologic pathology. In particular, the scope of use of this preparation is:

– normalisation of the development of an embryo and a fetus;

– prevention of antenatal pathology;

– prevention of pathological birth (hypofunction, litter delay);

– therapy of females with post-natal gonado- and metropathies;

– improving the viability of newborns, potential of their development.

The preparation "Caplagonìn" is a solution of β-carotene and chorionic gonadotrophin (Table 5 and 6).

***Table 5**. The composition of "Caplagonin" (1.0 ml)*

Chorionic gonadotrophin, mg	15±0.5 mg
Carotene, mg	10.0±0.75
Refined oil, ml	Up to 1.0

Due to the contents of the chorionic gonadotrophin in the composition of the preparation, it is used to enhance the reproductive health of females (normalise ovulation as well as formation and development of yellow body).

***Table 6**. Organoleptic indexes of "Caplagonin"*

Index	Characteristic and norm
Appearance	Transparent oily liquid
Color	From dark-yellow to brown
Smell	No specific smell
Identity	Corresponds

Designed to enhance the fertility of females and the reproductive ability of the males. The preparation "Carafest" is an oil solution of carotenoids and phytoestrogens (Table 7 and 8).

***Table 7**. The composition of "Carafest" (1.0 ml)*

Phytoestrogens according to RD, mg	1.0±0.05
Carotenoids according to RD, mg	10.0±0.75
Refined oil according to NSSU 4492, cm^3	Up to 1.0

"Carafest" is similar to "Caplaestrol", however, unlike the latter, it includes plant estrogens. They include phenol ring, which makes them similar to the spatial structure of the hormone β–estradiol, which allows them to bind to receptors of estradiol, exhibiting hormon-like activity.

***Table 8**. Organoleptic indexes of "Carafest"*

Index	Characteristic and norm
Appearance	Transparent oily liquid
Color	From dark-yellow to brown
Smell	Specific
Mass fraction of carotenoids, mg/cm^3	10.0±0.75
Mass fraction of phytoestrogens, mg/cm^3	1.0±0.05

Designed for infertility treatment and to prevent losses in animal reproduction.

"Carafand" is an oil solution of carotenoids and phytoandrogens (Table 9 and 10).

***Table 9**. The composition of "Carafand" (1.0 ml)*

Phytoandrogens according to RD, mg	1.0±0.05
Carotenoids according to RD, mg	10.0±0.75
Refined oil according to NSSU 4492, cm^3	Up to 1.0

***Table 10**. Organoleptic indexes of "Carafand"*

Index	Characteristic and norm
Appearance	Transparent oily liquid
Color	From dark-yellow to brown
Smell	Specific
Mass fraction of carotenoids, mg/cm^3	10.0±0.75
Mass fraction of phytoandrogens, mg/cm^3	1.0±0.05

It is intended for the treatment and prevention of fertility reduction in males. When applying the preparations, it is necessary to balance animal rations for protein, calcium, phosphorus, magnesium, and microelements.

The application of preparations developed by the authors shows high therapeutic effect, as evidenced by the obtained data (Table 11).

***Table 11**. The results of the preparation use in schemes for prevention and treatment of reproductive pathologies*

Actions (therapeutic or prophylactic)/Reproductive pathology	Drug	Therapeutic effect
The complex therapy program of females with gonadopathies	"Capla-estrol"	Symptoms of estrus from the beginning of the treatment – 30.5±0.4 days for 85% of fertilisation (cows)
	"Cara-fest"	Symptoms of estrus from the beginning of the treatment – 40.5±1.05 days for 75% of fertilisation (cows)
	"Capla-estrol" + "Capla-gonin"	Symptoms of estrus from the beginning of the treatment: – sheep – 62.5%-76.9% for 60.0%-80.0% of fertilisation; – goat – 57.1%-66.7% for 70%-75% of fertilisation
The complex program of prevention of perinatal pathologies	"Capla-estrol"	1.Clinical status and the potential of development: – reducing the number of lambs in unsatisfactory clinical condition with low potential of development by 11.1% and young kids by 5.4%; – increase the number of lambs in satisfactory clinical condition with high potential of development by 10.6% and of young kids by 8.6%. 2. Reducing morbidity: – lambs – by 9.5%; – young kids – by 7.4%. 3. Reducing lethality: – lambs – by 7.5%; – young kids – by 4.2%. 4. Prevention of intranatal pathology (genera hypofunction) – sheep – by 13.5%; – goat – by 14.4%. 5. Prevention of postnatal pathology: – lambs – by 8.2%; – goat – by 8.7%
	"Cara-fest"	1. Clinical status and the potential of development: – reducing the number of lambs of unsatisfactory clinical condition with low potential of development by 12.9% and young kids by 5.9%; – increase the number of lambs with satisfactory clinical condition with high potential of development by 12.2 and young kids by 8.8%. 2. Reducing morbidity: – lambs – by 11.1%; – young kids – by 7.9%. 3. Reducing lethality: – lambs – by 8.2%; – young kids – by 5.9%. 4. Prevention of genera hypofunction: – sheep – by 14.8%; – goat – by 16.1%. 5. Prevention of postnatal pathology: – lambs – by 8.8%; – goat – by 9.7%
The complex therapy program of males with reduced fertile ability	"Cara-fand"	1. Improving the quality of semen: – bitterns: increase the volume of the ejaculate – by 28.2%, mobility of spermatozoa – by 6%, concentration – by 17.1%, moving spermatozoa in the ejaculate – by 56.8%, spermatozoa percentage of morphological anomalies decreased in 2.2 times; – boars: the volume of the ejaculate by 23.1%, mobility – by 16.4%, concentration – by 4.4%, amount of moving spermatozoa in the ejaculate – by 61.3%; spermatozoa percentage of morphological anomalies decreased in 1.2 times; – canines: the volume of the ejaculate increased by 36.1%, mobility – by 22.8%, concentration – by 45.1%, amount of moving spermatozoa in the ejaculate – in 2.1 times, pathological forms of spermatozoa decreased in 1.7 times. 2. Activation of androgenesis: – boars – in 5.5 times; – canines – in 4.9 times

As can be seen, the implementation of a complex therapy program of cows with gonadopathies using "Carafest" provides the display of symptoms of estrus in 30.5 days with 75% of fertilisation and in 40.5 days and 85% of fertilisation using "Caplaestrol" respectively. The scheme of treatment of gonadopathies using "Caplaestrol" and "Caplagonìn" provides the display of symptoms of estrus from the beginning of treatment in 62.5-76.9% of the sheep and 57.1-66.7% of goats by fertilisation of 60.0-80.0% and 70-75% respectively.

A complex program of prevention of perinatal pathologies with the use of "Caplaestrol" allows increasing the number of lambs in satisfactory clinical condition with high potential of growth by 10.6% and young kids – by 8.6% and reduce the number of lambs in unsatisfactory clinical condition with low potential of growth by 11.1% and kids – by 5.4%, decrease in the incidence of the lambs by 9.5% and young kids by 7.4% and lethality respectively by 7.5% and by 4.2%, and the number of animals with intranatal (genera hypofunction) and postnatal pathology 13.5% and 8.2% in sheep, 14.4% and 8.7% in goats.

The use of "Carafest" in the complex program for the prevention of perinatal pathologies allows increasing the number of lambs in satisfactory clinical condition with high growth potential by 12.2% and young kids by 8.8% and reduce the number of lambs in unsatisfactory clinical condition with low growth potential by 12.9% and kids by 5.9%, decrease in the incidence of the lambs by 11.1% and young kids by 7.9% and lethality respectively by 8.2% and 5.9%, and the number of animals with intranatal (genera hypofunction) and postnatal pathology by 14.8% and 8.8% in sheep, by 16.1% and 9.7% in goats.

Complex therapy of males with lower reproduction ability using "Carafand" positively influenced the sexual reflexes and sperm quality, due to the stimulation of Leydig cells by androgen-like substances the androgenesis intensified: in bulls – 4.7 times, in boars in 5.5 times and in dogs – 4.9 times; increased the volume of the ejaculate in bulls by 28.2%, in boars by 23.1% and in dogs by 36.1%; increased spermatozoa mobility: bulls – 6%, boars – 16.4% and dogs by 22.8% and the sperm concentration: bulls – 17.1%, boars – 4.4% and dogs by 45.1%; increased percentage of moving spermatozoa in the ejaculate: bulls – 56.8%, boars – 61.3%, dogs 2.1 times; decreased the number of spermatozoa of morphological anomalies: bulls – 2.2 times, boars – 1.2 times and dogs – 1.72 times.

DISCUSSION

The development of phytodrugs is caused by the search for new drugs, harmless for the body, that have the physiological direction of action. For example, in cattle, in many ways, this is due to requirements that impose the milk quality, limiting the use of antibiotics and hormonal drugs of synthetic origin. A significant amount of phytodrugs are close to the body of animals in their chemical nature, they are easily absorbed and included in biochemical processes. Biologically active food supplements based on natural phytodrugs are most effective for increasing resistance, stabilisation of the metabolic processes, and improvement of the herd. The basis of phytotherapy is regulatory principle – support and mobilisation of various autoprotection systems: endocrine, immune, the implementation of therapeutic action of endogenous metabolites [33].

M. Kamatenesi-Mugisha and H. Oryem-Origa [45] described 33 medicinal plants that belong to 25 families and 30 genera and are used in traditional medicine in Uganda for the treatment of sexual impotence and erectile dysfunction.

C.H. Browner [46] described the medicinal plants and related substances that are used for stimulation of labor, regulation of fertility, and treatment of reproductive disorders in the indigenous communities of Mexico.

A. Riaz et al. [47] found the positive effects of the drug, which is a herbal combination of *Withania somnifera*, *Tribulus terrestris*, *Mucuna Pruriens*, and *Argyreia speciosa* on fertility in rats of both sexes. The results of the research allow using herbal combinations for sexual dysfunctions, and other disorders of fertility in human medicine.

P.R. Dalsenter et al. [48] conducted a study on the evaluation of the influence of water extract of Yarrow on the reproduction ability of rats. The authors detected a significant increase in the percentage of abnormal spermatozoa in males that received the highest dose, without changes of other indicators of the quality of the sperm. The authors of the predicted estrogen/antiestrogen activity of Yarrow extract for the treatment of immature rats–females that are not shown ureotrophic effects.

B. Salgado, R. Paramo, and H. Sumano [49] informed about successful treatment of she-dogs pyometritis using the Chinese herbal drug yun-nan-pai-yao.

P. Amato, S. Christoph, and P.L. Mellon [50] studied the estrogen activity of herbs as drugs for the treatment of menopausal symptoms and found a positive effect of dongquai and ginseng and did not establish this in black coughing and licorice root.

E.K. Nwangwa [51] investigated the effect of ethanol extract of *Xylopia aethiopica* on reproductive status in rats. The results showed a significant and dose-sensitive reduction of morphological characteristics of the testes and sperm parameters (amount, mobility) and a slight decrease in the percentage of spermatozoa with normal morphology. The author concludes that the extract may have some antieffects that can be further investigated for possible use as a male contraceptive.

The task of the research of S. Naser et al. [52] was to determine the effects of alcohol extract of *Physalis alkekengi* on the morphostructure of testes, sperm, and hormone levels in male mice. The extract had an antispermatogenic

action, showning a decrease in the number of sperm, their activity, and the increase in the number of abnormal reproductive cells, but also adversely affected the level of testosterone, raised the level of luteinizing, and did not change the level of follicle-stimulating hormones. The author concluded that alcohol extract of *P. alkekengi* may be helpful in the regulation of spermatogenesis and the fertility of males.

In the work of N. Malviya et al. [53], the scientific substantiation of the traditionally used herbal plants like herbs aphrodisiac for the treatment of erectile dysfunction sexual disorders was considered. All investigated plants showed significant pharmacological activity. The author believes that herbs can be an effective aphrodisiac, moreover, separation and identification of active ingredients from plants can provide dynamic changes in the modern world.

The number of works related to the use of phytodrugs for the treatment and prevention of reproductive pathologies of animals is limited. In particular, N.Ju. Terenteva [54] has improved preventive measures for postpartum pathology in high-producing dairy cows through the use of phytodrugs and scientific justification for their use. The effect of extracts of herbs nettle and pastoral handbags on the contractile function of the uterus was studied. It was found, that phytodrug of nettle provides fast recovery of the tone of nervous-muscular apparatus of the uterus, helps to normalise the metabolism and increase the activity of the immune system of cows and a total propagation completion of involutional processes of reproductive organs, prevents the development of subinvolution of the cervix and acute postpartum endometritis, increases fertilisation, shortens the days of infertility.

D.S.H. Habib [55] conducted an assessment of the effectiveness of the original phytodrugs of wood origin (based on the coniferous paw, the bark of willow, and aspen) to stimulate the metabolism and reproductive function of cows. In the end, an effective method of stimulation of metabolic activity and reproduction ability of cows was designed for use in veterinary practice. The author argues, that drugs created by nature, during a long evolutionary development, are more easily absorbed by the body, have softer physiological action compared to synthetic analogs, and are stripped of their harmful side effects.

There are many more examples of the use of drugs with the placenta. They were used for centuries as a folk medicine, especially in Asian countries [56]. Relative to placenta extract, this method is based on the assumption that the extract contains a significant number of so-called biogenic (natural) stimulants (peptides, amino acids, etc.), which have the properties of growth hormone and the ability to activate the metabolism [57]. Since the 30-ies of the last century, methods of preparation and the suspension of the placenta were introduced [58]. In the 1960s-1970s, the effectiveness of human placental drugs in the treatment of some forms of threatened abortion was studied [59; 60]. The role of the placenta in maintaining pregnancy was shown. In some works, the effectiveness of placental preparations in the treatment of climacteric symptoms was considered.

A number of placental drugs such as PDE, VCP, PAN, "Placentìn", "Horiofag", "Placentol", "Umbilicen", "Horiocen", "Amniocen", "Biostimulgin", "Neogistol" [61] are known in veterinary medicine. It is found, that the placental drugs in the maximum doses for experimental animals (mice, rats, Guinea pigs, rabbits) do not cause toxic effects and do not have side effects on the body of the animal, even during their prolonged use [62].

A.M. Semivolos et al. [63] showed that the use of biologically active tissue drugs is of great importance since they allow increasing the natural resistance of the organism of animals and normalise their reproductive function. It was found, that the tissue drug "Placentin", which is a liquid substrate from the cow placenta, stimulates peptide-forming processes, improves the morphological composition of the blood, causing positive changes in the dynamics of total protein and its fractions.

A.G. Narizhnyj et al. [64] when using biogenic stimulators (PDE preparations (placenta denaturalised emulgated) and "Horiocen") for boars-breeders the improvement of qualitative and quantitative indicators of sperm and increase in fertilisation was found. O.S. Mitjashova, I.V. Gusev, I.Ju. Lebedeva [41] established that the introduction of cattle placenta extract to firstborn cows prior to and during calving detects modulating effects on metabolic processes in the postnatal period. The introduction of the placenta also causes the increase in luteal activity of ovarian, which indicates the stimulation of postnatal anestrus. According to the authors, normalisation of the metabolic and hormonal status of cows, obviously, is associated with increasing the reproductive ability of animals and leads to a reduction in future service periods.

O.B. Djachenko, O.I. Stadnycka, L.V. Ferenc [39] argue, that the introduction of the aloe extract and denaturated and emulgated placenta to cows of highly- and low-productive groups, improves the peptide-synthesis liver function, as well as stimulates the nonspecific resistance of their body, due to the activation of humoral immunity. The content of total protein increases, mainly, due to the albumin and γ-globuline fractions. Application of aloe extract and denaturated and emulgated placenta to cows, in the period prior to calving, provides complete recovery of reproductive cycles, increasing fertilisation and reducing the service period.

In general, it should be noted, that the use of placenta drugs with therapeutic and preventive purposes for reproductive pathologies of animals, is limited. In addition, the placenta is used primarily in the form of a suspension (emulgated), whereas, drugs developed by the authors contain its extract, which provides a specific orientation of actions.

CONCLUSIONS

Thus, vitamin-hormone phyto- and tissue drugs developed by the authors are highly effective for the treatment and prevention of reproductive pathologies of various species of animals, providing the stimulation of reproductive functions therapy for gonadopathies of females, increasing vitality, prevention of the incidence of intra- and postnatal and andrological pathology.

In particular, drugs "Carafest", "Caplaestrol" and "Caplagonin" are effective in the program of complex therapy of cows, sheep, and goats with gonadopathies in terms of estrus from the beginning of treatment and fertilisation.

The use of "Caplaestrol" and "Carafest" in a comprehensive program for the prevention of perinatal pathologies can improve the clinical condition and development potential of lambs and kids, reduce their morbidity and mortality, as well as the number of sheep and goats with intranatal and postnatal pathology.

A comprehensive program of therapy for males (bulls, boars, and dogs) to reduce the reproductive capacity with the use of the drug "Carafand" helps to stimulate the display of sexual reflexes and improve sperm quality.

In the future, it is planned to improve the developed drugs to provide antioxidant properties by adding nanobiomaterials, in particular cerium dioxide and orthovanadates of rare-earth elements.

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Розробка препаратів рослинного та тканинного походження для ветеринарної репродуктології

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Анотація. Сучасні умови практичної ветеринарної медицини вимагають застосування ефективних і безпечних препаратів. Поряд з уже відомими і вживаними лікарськими препаратами необхідний пошук нових, що є нешкідливими для організму і мають фізіологічну спрямованість дії. В останні роки зросла увага до використання препаратів рослинного та тканинного походження, однак проблема їх застосування вивчена недостатньо – багато аспектів їх клінічного використання вимагають подальшої розробки, розширення спектра використовуваних лікарських рослин, обґрунтування і впровадження у ветеринарну практику. Тож мета даної роботи полягала у розробці комплексних вітамінно-гормональних препаратів на основі рослинних і тканинних похідних для лікування та профілактики репродуктивних патологій у тварин. На підставі даних етіопатогенезу порушень репродуктивної функції показників: гомеостазу, зниження концентрації гормонів (естрогену або прогестерону), зміни морфофункціонального стану ендокринних (гіпофіз, щитоподібна залоза та наднирники) і репродуктивних (яєчники) органів, науково обґрунтованим є застосування вітамінно-гормональних препаратів у ветеринарній медицині. Препарати в плані патогенетичної терапії дозволяють оптимізувати показники гомеостазу, концентрацію гормонів, стимулювати реабілітаційні процеси в органах-регуляторах репродуктивної функції (гіпофіз, наднирники та щитовидна залоза) та статевих органах (яєчниках), що, в свою чергу, сприяє нормалізації фолікуло- і стероїдогенезу, які є передумовою для повної репродуктивної здатності самок. Розроблено вітамінно-гормональні препарати на рослинній та тканинній основі, що володіють високою ефективністю за лікування та профілактики репродуктивних патологій різних видів тварин, забезпечуючи стимуляцію репродуктивної функції (прояв ознак еструсу) за терапії самок з гонадопатіями («Карафест», «Каплаестрол» та «Каплагонін») і самців (прояв статевих рефлексів і якість сперми) за порушення відтворної здатності («Карафанд»), підвищення життєздатності новонароджених (збільшення кількості ягнят і козенят із задовільним клінічним станом з високим потенціалом розвитку, зниження їх захворюваності та летальності), попередження захворюваності на інтра- та постнатальну (гіпофункція родів, хвороби післяродового періоду) патологію («Карафест» та «Каплаестрол»)

Ключові слова: тварини, самці, самки, новонароджені, репродуктивні патології, лікування, профілактика

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Assessment of the Consequences of Forest Fires in 2020 on the Territory of the Chornobyl Radiation and Ecological Biosphere Reserve

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Abstract. The article presents the consequences of fires that occurred on the territory Chornobyl Radiation and Ecological Biosphere Reserve in April 2020. Research shows that the results of these events characterized as catastrophic. The condition of forests after fires was assessed using satellite data and field trips to review the condition of forests affected by wildfires. The total area affected by the fire in 4 foci was 51,806.5 hectares. The total area of fires in the exclusion zone is 66,222.5 hectares. About 25% of the territories affected by the fires have changed. To preserve the landscape diversity and mosaic of areas covered and not covered with forest vegetation, it is impractical to conduct afforestation (afforestation of fallows) on the territory of the reserve. Among the forests affected by fires, the majority has a high ecological and forestry potential and, accordingly, a high potential for natural recovery (81.6%). In dead forests, the share with a high potential for natural reforestation is slightly lower and amounts to 66.8%. The share of forests with low natural recovery potential is low and amounts to 1.9% and 4.8% in forests affected by fires and dead, respectively. Significantly damaged, and sometimes destroyed, were a number of rare settlements, which are not only important for nature conservation, but also classified by the Standing Committee of the Bern Convention (Resolution 4) as particularly valuable settlements, as well as the "Green Book of Ukraine" (2009). 2 groups were marked as excessively damaged on the territory of the reserve. It should be noted that there is a slight general violation of the protected core of this object of the nature reserve fund, which will allow it to preserve its environmental potential and the functions of protecting and reproducing biodiversity. Most of the areas of the reserve affected by fires have a high forestry potential and are able to recover independently, so they do not require intervention in natural processes for reforestation. The degree of transformation of the ground cover in pine and oak-pine forests of the reserve under the influence of pyrogenic factor is determined by the intensity of the fire. Reforestation in areas with low forest potential should be carried out with clear planning

Keywords: fires, exclusion zone, nature reserve, reproduction, biodiversity

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INTRODUCTION

The exclusion zone has repeatedly suffered from large-scale catastrophic fires, the most dangerous of which were in 1992, 2015 and 2020 [1-4]. In addition to material damage and negative environmental consequences, forest fires in the exclusion zone changed the radioecological situation, causing repeated transfer of radionuclides [4]. Forest fires are one of the determining factors that can increase migration processes. As a result of crown fires, up to 80% of radiocesium can pass to the mineral part of the soil, while normally this indicator does not exceed 40% [5]. In addition, forest fires lead to organic part of the litter being exposed to ashing, which leads to the destruction of the soil organo-mineral complex and the release of mobile forms of radionuclides [6]. The fact that forest fires cause significant changes in the course of migration processes and the accumulation of radionuclides by the phytomass of stands with stable indicators of moisture content and plant composition was also indicated by O. Sungmin, X. Hou, R. Orth [7], S. Stoulos, A. Besis, A. Ioannidou [8] et al. In addition, as noted by P.R. Robichaud and others, fires can enhance the processes of their vertical migration to groundwater and then to rivers, as well as their rise to surface layers of air with wind erosion [9].

Forest fires cause a deep and long-term restructuring of all components of ecosystems and an increase in the variability of the structure of phytocenoses. The spatial distribution of radioactivity and its modelling in space has been addressed by many scientists [10-12]. Burnout of organic soil particles accumulated in the litter and phytomass increases the content of ash elements and mineralised nitrogen, and increases the heating of the soil surface, etc. [13]. As a result, the course of chemical processes in the soil changes and is accompanied by an increase in the sod process of soil formation. This leads to outbreaks of herbaceous vegetation. Gradually, after the restoration of the moss cover, the podzolic cycle begins to resume in the formation of the soil cover [14-17]. With the closure of the grassy tier, the microclimate gradually stabilises, and with the closure of stands, it acquires properties characteristic of forest ecosystems [18].

Statistics show that natural forests of the temperate climate zone are characterised by the repetition of large forest fires every 10-20 years [19]. This leads to the cyclical nature of the processes of renewal of pine stands, and, as a result, to the formation of a mosaic-step character of stands. Mosaic burnout of the soil cover is caused by the features of localization of combustible materials in pre-fire ecosystems, which affects the seed and vegetative renewal of groups of grass cover and trees [20]. Uneven burnout is partially caused by the formation of dead wood foci in the forest, which cause the transition of crawling fires into crown ones. The transition to ground fires is also caused by the accumulation of coniferous daff. Given this, the probability of crown fires in young pine plantations is higher than in natural forests [21]. It is especially large in dense stands that grow without human supervision.

Many modern researchers in Ukraine and abroad point out that high soil humidity, relative humidity and extreme temperature anomalies lead to severe forest fires. These figures were the cause of the largest forest fires in 2020. At the same time, fire hazard conditions at the time of the fire in April 2020 were higher than for other registered major fires [1; 12; 14, 22].

The purpose of this work was an assessment of the consequences of forest fires in 2020 using modern geoinformation systems and space technologies for remote sensing of the Earth's surface on the territory of the Chornobyl Radiation and Ecological Biosphere Reserve and exclusion zone in the context of functional zoning of the territory and the nature of forest vegetation, as well as an assessment of the distribution of plant species listed in the Red Book of Ukraine and damage to their habitats.

MATERIALS AND METHODS

The fire area was estimated using satellite imagery data. In addition, each of the stages of research included: field studies of fires, aerial photography using unmanned aerial vehicles, as well as analysis of the obtained high-resolution satellite images. The study covers the area affected by fires in the exclusion zone and amounts to 66,222.5 hectares, including 51,806.5 hectares in the Reserve. At the same time, ESRI's ArcGis GIS tools were used.

Materials from the Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS) instrument sets installed on the Landsat-8 satellite (Geological Survey (U.S.) were used to solve the problems of applying GIS technologies for landscape safety using remote sensing data from the Earth's surface. The satellite information processing products used in this study are posted on the geological portal of the United States Geological Survey [23; 24], in the fire information for resource management system (FIRMS) [25]. This method has already been used by the authors of the article in several previous publications, where this method of data processing was used to determine the electrical conductivity of soil in the Dniprovsko-Orilskyi Nature Reserve and in monitoring of biodiversity in the Chornobyl Radiation-Ecological Biosphere Reserve [26-28].

Indexes derived from the spectral channels of sensors installed on Landsat-8 or Sentinel-2 (ratio of spectral bands) satellites were used to monitor landscape safety [28]. Overall, the resolution of Sentinel-2 spectral channels is higher than that of Landsat-8. But it should be noted that the Sentinel-2 satellite has been operating in orbit since June 23, 2015. Therefore, if there is a need to obtain retrospective information about ecosystems, it is possible to use information from the Landsat-8 satellite (or earlier Landsat series satellites). For current monitoring, information from the Sentinel-2

satellite has an advantage. In addition, by combining information from both sources, it is possible to receive data with a higher time resolution or get scenes without a high level of cloud cover.

The forests after fires was assessed using satellite data and field trips to survey the condition forests affected by wildfires. By comparing the NDVI vegetation indices of 2019, 2020 and 2021, changes in the state of vegetation cover were revealed. As a result of fire damage, changes occur in natural complexes that affect the passage of vegetation and can be detected using satellite data. After analysing the received satellite images, visits were made to the damaged areas in order to validate the decryption data. These methods made it possible to estimate the approximate area and location of dead forests, significantly damaged swamps and fallows.

Analysis of the temporal dynamics of the normalised fire index was the basis for determining the areas of ecosystems affected by the pyrogenic factor and monitoring the dynamics of ecosystem recovery after fires. Of particular importance is the multidimensional statistical analysis of a set of indices for a single date. For example, an analysis of the main components of the set of indices presented at the date corresponding to the highest vegetation activity of vegetation cover will provide information about the diversity of settlements and the state of biotic potential. Ultimately, tensor analysis of the dynamics of a set of indices over time is a tool for understanding the complex dynamics of ecological and landscape systems.

RESULTS AND DISCUSSION

The largest forest fires in the history of the exclusion zone occurred during April and May 2020. They destroyed and damaged thousands of hectares of natural landscapes. The most dangerous in terms of scale and consequences were 4 foci of forest fires [29]. One of the largest occurred on April 03, 2020, on the territory of the Drevlyansky nature reserve, as a result of arson of dry grass by local residents. From there, the fire spread through the territory of the Kotovske Forestry. As a result of arson of deadwood, the second largest fire broke out near the territory of Dytyatkivske forestry, from where the fire spread to the territory of the Reserve and the exclusion zone. The causes of the third largest fire, which started on the territory of the Paryshivske Forestry, have not yet been determined. The fourth fire in the exclusion zone, which was localised in the immediate vicinity of the radioactive waste disposal zone, spread to the territory of the Reserve as well.

The weather conditions of 2019 – early 2020 were favourable for the occurrence of fires were, namely an unusually warm winter and the lack of snow cover. According to observations by the Ukrainian Hydrometeorological Centre (weather station Chornobyl), about 61% of the annual average rainfall and a 2.6ºC increase in the annual average air temperature were recorded in 2019. Weather conditions in the autumn-winter period also contributed to further dehydration of ground fuel and increased the risk of forest fires.

In all decades from November 2019 to April 2020, higher values of the average air temperature were recorded compared to similar decades of previous years and, especially, compared to the long-term norm. The lack of precipitation also exceeded the norm by 30%. The snowless winter of 2019-2020 additionally contributed to a further decrease in the humidity of the forest litter, grass cover and topsoil. The relative humidity of the air was also low during April 2020, while the value of this parameter varied between 20-40% during daytime hours, with the minimum recorded value of this parameter of 16%. Such weather conditions, further complicated by increased wind speeds, caused the rapid spread of fires and the complexity of their elimination.

The winter-spring period of 2020 was also marked by the excessively low water content of rivers and other aquatic ecosystems of the exclusion zone. Low soil moisture reserves in the catchments of the Pripyat River and its tributaries, as well as a lack of snow and low cementation of the soil (freezing did not exceed 10 cm), led to the absence of spring flooding. Given this, the conditions for ensuring fire prevention measures were extremely unfavourable (low humidity of floodplains and peatlands, drying up of most fire-fighting reservoirs and other water bodies). The low water content of the canals of the Pripyat land reclamation system was also caused by the fire of peatlands of the Kryva Hora-Chapaivka district.

As the authors of the article have already noted in reports and chronicles of nature [29; 30], the largest share of territories affected by fires are forests – 64.3%, fallows – 21.6%, swamps – 5.7%, fires of previous years and dead woods – 5.3% (Table 1, Fig. 1).

***Table 1**. Damage to the ecosystems of the exclusion zone as a result of forest fires (April 2020), ha*

Land category	Total area affected by fires, ha		
	Total for the Reserve	Total for the radioactive waste management zone, ha	Total for exclusion zone, ha
Forests	32413.1	10179.2	42592.3
Fallow lands, meadows	10721.8	3558.8	14280.6
Swamps	3530.5	235.6	3766.1
Burnt, dead forests	3513.6	4.6	3518.2
Free-growing forest plantations	64.9	0	64.9

Table 1, Continued

Land category	Total area affected by fires, ha		
	Total for the Reserve	Total for the radioactive waste management zone, ha	Total for exclusion zone, ha
Clearings, sighting lines	291.2	69.2	360.4
Roads	157.8	27.4	185.2
Firebreak	60	31.6	91.6
Water bodies	738.1	119.8	857.9
Other lands	315.5	189.8	505.3
Total	51806.5	14416	66222.5

***Source**: [30]*

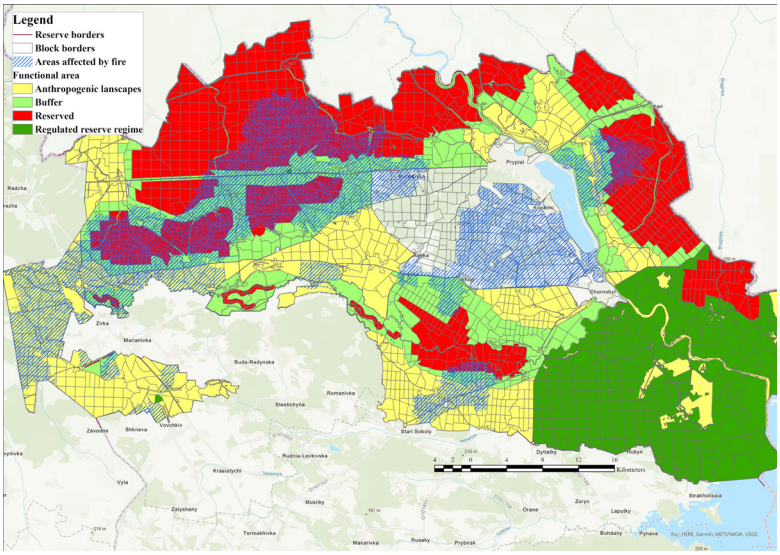


***Figure 1**. Spread of fires in the context of functional zoning of the Reserve*

Fires on the territory of the exclusion zone in the spring of 2020 lasted about a month, as a result of which large areas of forest, meadow and swamp ecosystems were damaged. Most of the damage was caused to the forests. However, it should be noted that the degree of damage and the ability to regenerate in tree species vary. Among the breed composition of forests, the greatest damage was caused to monoculture pine forests, some of which died in the first weeks after the fire, and some will die off in the next 2-3 years. Deciduous tree species have a high ability to regenerate vegetatively and began to actively recover 1-3 months after the fire. The distribution of forests by tree species in the areas affected by the fire is shown in Figure 2. Thus, the share of scotch pine in damaged forests was 52%, silver birch (*Betula pendula*) – 35%, black alder (*Alnus glutinosa*) – 6.4%, common oak (*Quercus robur*) – 6.4% [29; 30]. According to surveys of fires, wetlands are also characterised by the greatest risk of death of pine forests, and in some places birch and alder.

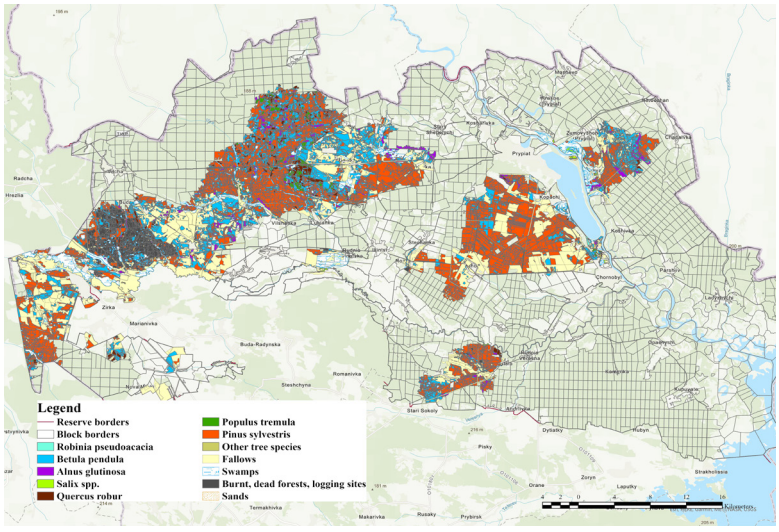


***Figure 2**. Distribution of territories affected by fires by tree species*

For a more detailed analysis of the nature of the spread of fires in this area, a simplex graph was constructed (Fig. 3). The majority of forests affected by fires are young – 37.14% and medium-aged plantings – 52.57%. It graphically shows the ratio of three variables: the age of the stand in years, the height (M), and the quality class of the stand in the area of fire spread. This graph allows assessment of the fire propagation risks in a given area and is a tool for analysing compositional data of planting quality indicators in a three-dimensional format. As these graphs show, under the conditions of high intensity ground fire, young stands with trees whose bark is thin and unable to protect against the effects of high temperatures are most damaged. Coniferous young trees are particularly affected.

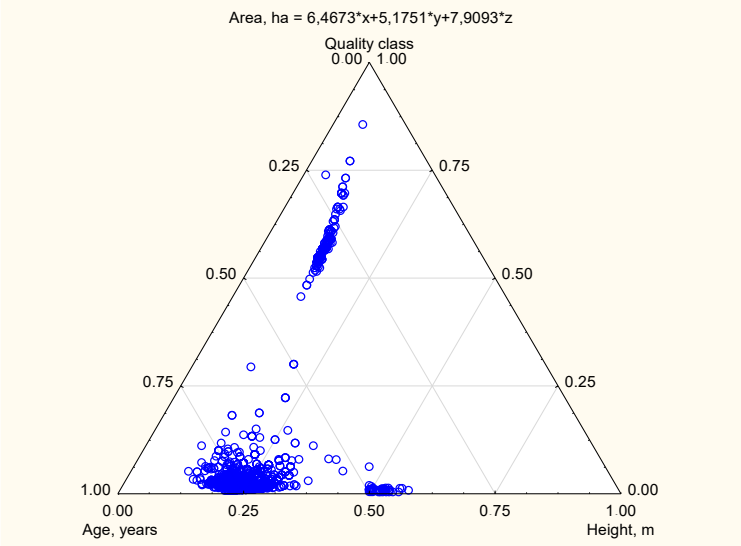


Figure 3. *Ternary Graph of Area, ha against Age, years and Height, m and Quality class*

According to the results of the previous survey, the area of fires consist of forests – 63%, fallows – 21%, meadows and wetlands – 7%, burnt areas of previous years – 7%, as well as other lands – 2%. These territory is characterised by the presence of particularly valuable oak-hornbeam forests, West Palearctic Scots pine forests, continental deciduous and mixed forests of pine-oak, oak swampy forests, birch and coniferous swampy forests, coastal willow formations, Central European tributary ash-black alder groves, mixed oak-elm-ash forests near large rivers, high-grass meadows, eutrophic and oligotrophic upland bogs.

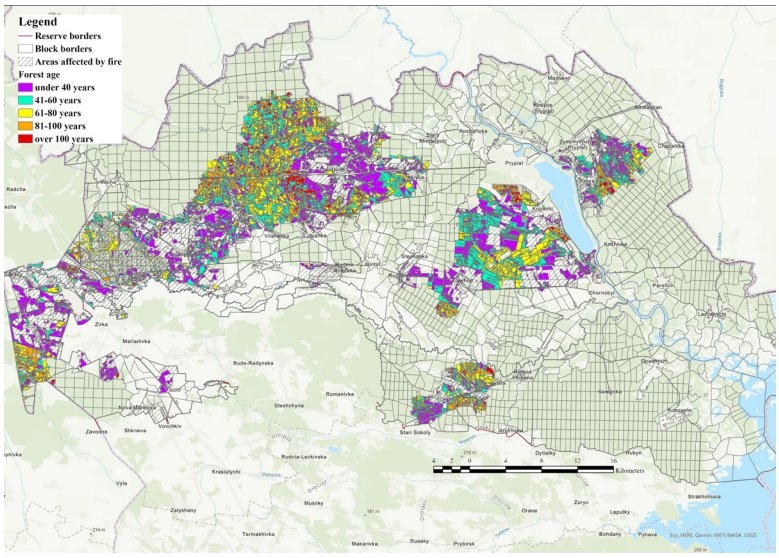
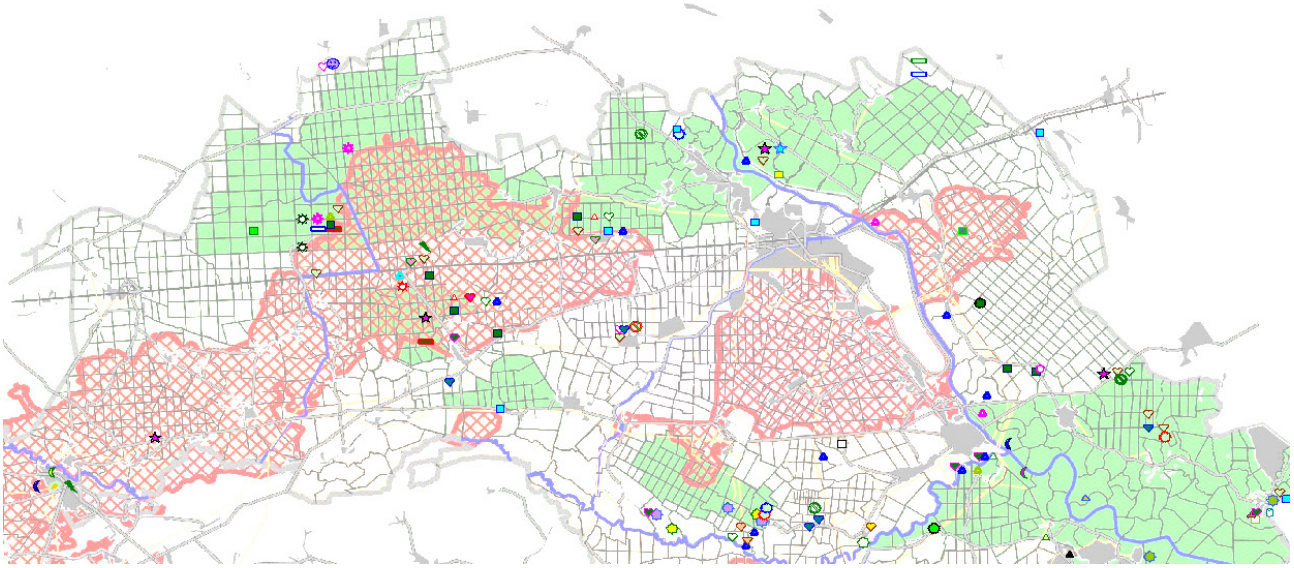


Figure 4. *Distribution of territories affected by fires by forest age*

As the authors of the article previously noted in the Chronicle of nature [30], largely damaged, as well as partially lost, a number of rare biotopes have been identified within the Reserve, which are of great environmental importance and are listed in the settlements from Resolution 4 of the Standing Committee of the Bern Convention (14 biotopes) [31], in the "Green Book of Ukraine" (2009) [32]. 2 groups are significantly and moderately damaged within the Reserve. At the same time, the protected core of the Reserve has not been strongly affected and has been preserved, which will ensure further conservation of biodiversity and other conservation functions.



Symbols:

- *Aldrovanda vesiculosa*
- *Pedicularis palustris*
- *Salix lapponum* (approximate point)
- *Salix myrtiloides*
- *Salix starkeana* (approximate point)
- *Viola uliginosa*
- *Drosera rotundifolia*
- *Huperzia selago*
- *Lycopodium annotinum* (approximate point)
- *Salvinia natans*
- *Polypodium vulgare*
- *Matteuccia struthiopteris* (approximate point)
- *Botrychium multifidum* (approximate point)
- *Ophyoglossum vulgatum*
- *Picea abies* (approximate point)
- *Juniperus communis*
- *Alisma gramineum* (approximate point)
- *Allium ursinum*
- *Sparganium minimum* (approximate point)
- *Zannichellia palustris* (approximate point)
- *Leucanthemella serotina* (approximate point)
- *Dianthus stenocalyx*
- *Silene lithuanica*
- *Gentiana pneumonanthe*
- *Chenopodium acerifolium* (approximate point)
- *Lythrum hyssopifolia* (approximate point)
- *Polemonium caeruleum*
- *Trapa natans*
- *Chimaphila umbellata*
- *Moneses uniflora*
- *Pyrola chlorantha* (approximate point)
- *Batrachium aquatile* (approximate point)
- *Calla palustris*
- *Stipa borysthenica*
- *Carex paniculata* (approximate point)
- *Carex umbrosa*
- *Juncus bulbosus* (approximate point)
- *Iris sibirica*
- *Lilium martagon*
- *Veratrum lobelianum* (approximate point)
- *Caulinia minor* (approximate point)
- *Najas major* (approximate point)
- *Cephalanthera rubra* (near Dytiatky point is approximate)
- *Dactylorhiza incarnata* (approximate point)
- *Dactylorhiza fuchsii*
- *Epipactis helleborine* (approximate point)
- *Epipactis palustris*
- *Goodyera repens*
- *Gymnadenia conopsea* (approximate point)
- *Hammarbya paludosa* (approximate point)
- *Neottia nidus-avis*
- *Platanthera bifolia*
- *Platanthera chlorantha*
- *Bromopsis benekenii* (approximate point)
- *Potamogeton rutilus* (approximate point)
- *Jovibarba globifera* (approximate point)
- *Sempervivum ruthenicum*
- *Andromeda polifolia* (approximate point)
- *Oxycoccus palustris*
- *Ledum palustre*
- *Clematis recta*
- *Trollius europaeus* (approximate point)

***Figure 5**. Distribution of plant species listed in the Red Book of Ukraine and damage to their habitats as a result of forest fires in 2020*

Among the rare and endangered species of flora and fauna, the following were recorded here: *Lilium martagon, Platanthera chlorantha, Leucanthemella serotina, Succisella inflexa, Carex umbrosa, Lycopodium annotinum L., Silene lithuanica, Pulsatilla patens, Pulsatilla pratensis,* etc. [29; 30].

The authors of this article noted in our previous reports and publications that some valuable and rare habitats of particular conservation importance and included in the list of habitats of Resolution 4 of the Standing Committee of the Bern Convention have been damaged and sometimes lost. In particular, it includes [29-31]:

- D2. 3 – transition swamps and floodplains – more than 5 ha;
- D5.2 – swamps dominated by large sedges – more than 50 ha;

• E 1.9 – open dry acidophilic and neutrophilic grass groups – more than 100 ha;
• E2.2 – plain hay meadows – more than 10 ha;
• E3.4 – wet and moist eutrophic meadows – more than 10 ha;
• E5.4 – moist high-grass meadows and fern edges – more than 1 ha;
• G1.11 – riparian willow forests – more than 10 ha;
• G1.21 – floodplain periodically wet forests dominated by alder (Alnus) or ash (Fraxinus) – more than 50 ha;
• G1.22 – floodplain forests dominated by oak (Quercus), elm (Ulmus) and ash (Fraxinus) – more than 10 ha;
• G1. 51 – sphagnum birch forests – more than 5 ha;
• G1.7 – thermophilic deciduous forests – more than 50 ha;
• G1. 8 – acidophilic oak forests – more than 10 ha;
• X04 – complexes of upper swamps – more than 0.5 ha;
• X35 – continental sand dunes – more than 10 ha.

From plant communities that are listed in the "Green Book of Ukraine" (2009) significantly and moderately damaged within the Reserve are: *Pineta (sylvestris) juniperosa (communis)* (more than 1 ha), Scheuchzeria-Sphagnum swamps (more than 1 ha) [32].

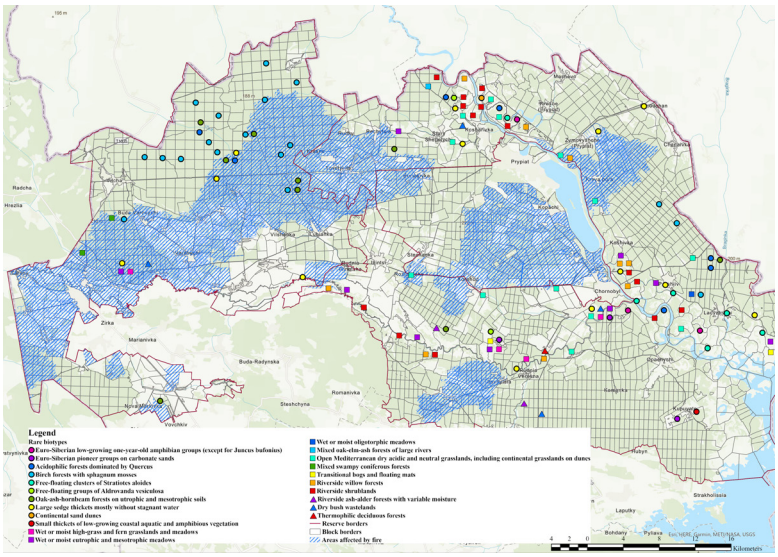


Figure 6. *Habitats protected by Resolution No. 4 of the Berne Convention, which are in danger of destruction due to forest fires in 2020, and require special protection measures*

The condition of forests after fires was assessed using satellite data and field trips to observe the condition of forests affected by wildfires. These methods made it possible to estimate the ap-proximate area and location of dead forests, significantly damaged swamps and fallows (Fig. 7).

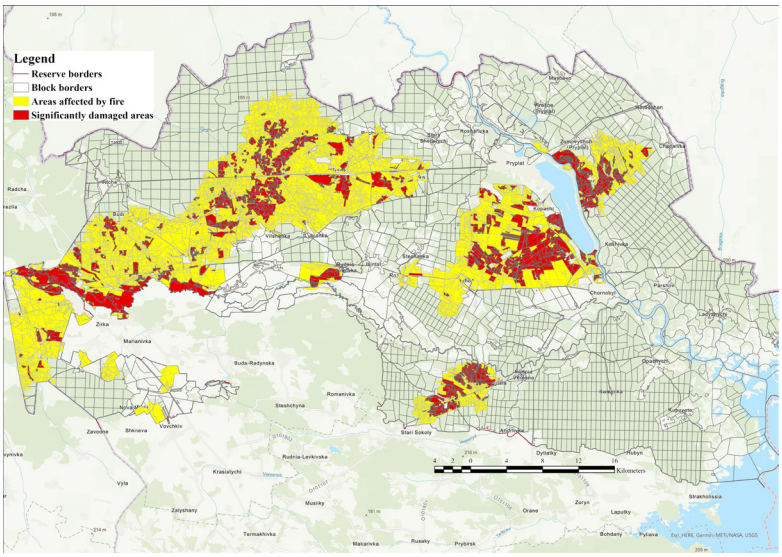


Figure 7. *Location of natural complexes significantly damaged by fires in 2020*

According to the data obtained as a result of fires in 2020 about 25% of the territories affected by fires have been changed. Among them, 62.2% are forests, 20.3% are fallows, 11.5% are swamps, 2.5% are burnt and dead plantings. In addition, the fires affected grassy and woody-shrub vegetation overgrowing roads, areas under power lines, floodplains, reclamation canals, which was also reflected as a result of analysis of satellite data.

Among the areas affected by fires and significantly damaged, forests, swamps and fallow areas can be considered valuable for preserving biodiversity. Burnt and dead plantings were valuable as possible testing sites for ecosystem restoration research and monitoring the course of natural regener-ation processes in ecosystems. The largest losses due to fires were among pine forests (82.17%) and birch (13.6%). The distribution of damaged forests by main species and their location is shown in Figure 8.

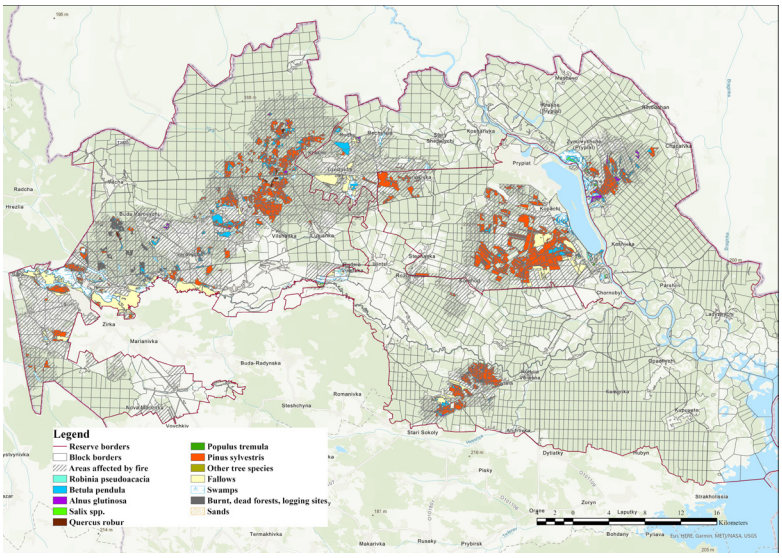


Figure 8. *Location of forests destroyed by fires and their division by main species*

Young and middle-aged stands are predominant among the dead forests (Fig. 9). The death of stands in these forests is caused both by the influence of high temperatures on the crown and trunk and by the burning of root systems in the upper layers of the soil (Figs. 10-11). In particular, in humid, damp and wet conditions on the territory of the Reserve, the above-ground cover is often formed with a predominance of sphagnum mosses and sedges (especially in deciduous forests). Due to the high levels of moisture in such areas of the forest, they form a surface root system, which is significantly damaged in the event of fires. This leads to the death of stands and windthrow in them in the coming months after the fire.

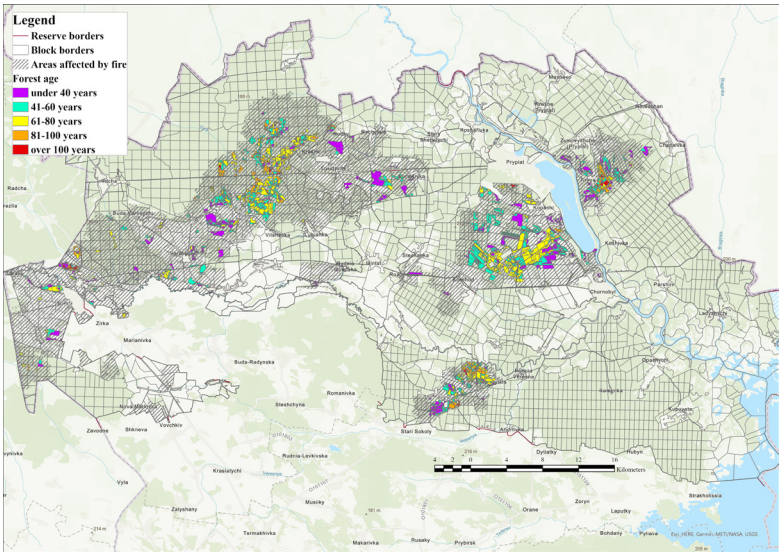


Figure 9. *Location and distribution of forests destroyed by fires by age*

The degree of transformation of the ground cover in the pine and oak-pine forests of the Reserve under the influence of pyrogenic factor is determined by the intensity of the fire. After a ground medium-intense fire

in pine and other forests of the reserve, there is a decrease (up to 90%) in the species diversity of moss-lichen cover. High-intensity and low-intensity fires lead to the complete death of the moss-lichen cover. Biotic diversity in areas affected by high-and low-intensity fires is differ than in the control area, in particular, there is a larger number of species and genera belonging to certain communities. As example, in the areas affected by the large fire in 2015, forest species – indicators of living above-ground cover – are being replaced by ruderal ones.

***Figure 10**. Burning of living above-ground cover and litter in the black alder forest in the TFC C_4. Photo from 29.04.2020*

***Figure 11**. Windthrow in a pine forest after burning root systems in the TFC B_3. Photo from 21.07.2020*

In dry and fresh conditions in coniferous plantations on the territory of the exclusion zone high reserves of forest litter are formed, which causes high combustion temperatures and thermal damage to tree trunks and crowns. Deciduous forests in these conditions are most often young stands up to 0.6 relative density with an admixture of Scots pine, formed naturally on former agricultural lands. Such forests are characterised by high reserves of herbaceous plants, which leads to the rapid passage of fires in them. However, in such stands, young trees have thin bark that is not able to protect them from fires.

CONCLUSIONS

Forest fires that occurred in April 2020 on the territory of the Chornobyl Radiation and Ecological Biosphere Reserve and the exclusion zone had catastrophic consequences. More than 51,806.5 hectares of protected land within the Chornobyl Radiation and Ecological Biosphere Reserve and 66,222.5 hectares within the exclusion zone were damaged by forest fires. More than 25% of the damaged territories were significantly changed. The causes of fires in most cases were the ignition of dry grass as a result of arson by residents of the nearest settlements.

Many forest ecosystems affected by fires in April 2020 have a high ecological and forestry potential and, accordingly, a high potential for natural recovery (81.6%). In dead forests, the share with a high potential for natural reforestation is slightly lower and amounts to 66.8%. The share of forests with low natural recovery potential is low and amounts to 1.9% and 4.8% in forests affected by fires and dead, respectively. To preserve the landscape diversity and mosaic of areas covered and not covered with forest vegetation, it is impractical to conduct afforestation (afforestation of fal-lows) on the territory of the reserve. In addition, fallows are an important food base for ungulates, in particular, Przewalski's horse, deer, and bison.

In the pine and oak-pine forests of the reserve, the transformation of the ground cover is determined by the intensity of fires. Crawling medium-intensity fires of pine and other forests cause a decrease in the species diversity of mosses and lichens by up to 90%, while crown and high intensity ground fires lead to its complete loss. Most of the territory damaged by fires in 2020 on the territory of the Reserve has a high forestry potential, and its ecosystems are capable of self-healing, so they do not require any forestry activities.

The losses within the reserve of rare biotopes, which have an important environmental function and are included in the list of settlements of Resolution 4 of the Standing Committee of the Bern Convention (14 biotopes), were significant. In general, the protected core of the Reserve has not undergone a strong transformation and has been preserved, which will allow it to continue to perform the functions of preserving and reproducing biodiversity and other environmental functions.

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Оцінка наслідків лісових пожеж 2020 року на території Чорнобильського радіаційно-екологічного біосферного заповідника

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Анотація. У статті представлені наслідки пожеж, які сталися на території Чорнобильського радіаційно-екологічного біосферного заповідника у квітні 2020 року. Дослідження показують, що наслідки цих подій мали катастрофічний характер. Стан лісів після пожеж оцінювався з використанням супутникових даних та виїздів з метою огляду стану лісів пройдених пожежами в натурі. Загальна площа, пройдена вогнем у 4 осередках, становила 51 806,5 га. Загальна площа пожеж на території зони відчуження складає 66 222,5 га. Серед пройдених пожежами територій зазнали змін близько 25 %. Для збереження ландшафтного різноманіття, мозаїчності вкритих і не вкритих лісовою рослинністю ділянок – проведення лісорозведення (заліснення перелогів) на території Заповідника є недоцільним. Серед лісів пройдених пожежами більшість має високий еколого лісівничий потенціал та, відповідно, високий потенціал природного відновлення (81,6 %). У загиблих лісах частка з високим потенціалом природного лісовідновлення дещо менша і складає 66,8 %. Частка лісів з низьким потенціалом природного відновлення є невисокою і становить 1,9 % та 4,8 % у лісах пройдених пожежами та загиблих відповідно. Значною мірою пошкодженими, а подекуди зруйнованими, виявилися низка рідкісних оселищ, що володіють не лише важливим природоохоронним значенням, але й віднесені Постійним комітетом Бернської конвенції (Резолюція 4) до особливо цінних оселищ, а також «Зеленої книги України» (2009). Надмірно пошкодженими на території Заповідника відмічені 2 угрупування. Варто відзначити незначне загальне порушення заповідного ядра даного об'єкту природозаповідного фонду, що дозволить йому зберегли свій природоохоронний потенціал і функції охорони та відтворення біорізноманіття. Більшість територій Заповідника, пройдених пожежами, мають високий лісівничий потенціал та здатні самостійно відновитися, тому не потребують втручання у природні процеси з метою лісовідновлення. Ступінь трансформації надґрунтового покриву у соснових і дубово-соснових лісах заповідника під дією пірогенного фактора визначається за інтенсивністю пожежі. Лісовідновлення на ділянках з низьким лісівничим потенціалом необхідно здійснювати з чітким плануванням

Ключові слова: пожежі, зона відчуження, заповідник, відтворення, біорізноманіття

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Current State of Pineries in Zhytomyr Polissia Under the Influence of Environmental Factors

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Abstract. Recently, there has been a massive drying of conifers all over the world. In North America and Siberia, there are millions of hectares of shrunken plantings; in Europe, pines and firs have been drying up over the past two decades. Furthermore, considerable damage is caused to woody plants by phyto-pest and phyto-diseases, since mass reproduction of *Ips typographus* Linnaeus, *Ips acuminatus* Gyllenhal has been observed in Europe in recent years, *Dendroctonus micans* Kud – in North America, *Polygraphus proximus* Blandford – in East Asia. Nematodes also cause significant damage to pine forests. Among phyto-diseases, *Heterobasidion annosum* (Fr.) Bref. harmfully affects *Pinus sylvestris* L. The appearance of foci of shrunken trees in different parts of the globe indicates the global nature of processes associated with cyclical planetary processes and climate change. This study describes climate changes in the research region for 1961-2020. According to the analysis, it was found that for 2009-2020, considerable damage to pine plantations in Zhytomyr Polissia is caused among needle-eating insects — *Panolis flammea* Denis & Schiffermuller, *Diprion pini* L., *Neodiprion sertifer* Geoffroy; among other pests – *Aradus cinnamomeus* Panz, *Dendrolimus pini* L., *Bupalus piniarius* L. The greatest harmful effect that pineries have recently sustained has been caused by *Diprion pini* L. It was also found out that among phyto-diseases suffered by the pine forests, significant damage has been done by *Heterobasidion annosum* (Fr.) Bref., with the damaged area of 13.0-14.2 thousand hectares. Hydrothermal analysis was performed for 2009-2020. The influence of solar activity on the number of phyto-pest and diseases is analysed. This paper provides the estimate of the amount of CO_2 emissions is given for 2009-2020. It was found that since 2014, the amount of carbon dioxide emissions has decreased from 1.5 million tonnes to 0.6 million tonnes. Correlation analysis of all indicators indicated a high mutual influence between the area of trees damaged by insect pest, root sponge, the Wolf number, and CO_2 emissions to the environment. Mathematical dependences are obtained to predict the influence of the W number on damage to pineries by forest pests and diseases in the conditions of Zhytomyr Polissia

Keywords: climate change, Phyto-pests and diseases, CO_2 emissions, solar activity, hydrothermal coefficient, correlation, mathematical modelling

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INTRODUCTION

Climate changes in Ukraine are more intense than global changes in the world. According to scientific research of the Institute of Irrigated Agriculture of the National Academy of Agrarian Sciences (NAAS) [1], the Institute of Plant Protection of the NAAS [2] and the Institute of Agroecology and Nature Management of the NAAS [3] in Ukraine for 1973-2016, the average annual air temperature increased by 2°C, an increase in precipitation, which had the nature of heavy rains, as well as an increase in the wind regime. Such changes adversely affect both agricultural crops and woody plants. According to literature sources, mass drying of coniferous woody plants is observed in forest biocenoses. The causes of death of pineries include increased anthropogenic impact on the environment, climate changes, namely an increase in air temperature, a decrease in precipitation [4-6]. Apart from the weakening of woody plants, there is an increase in foci of insect pests [7-9] and phyto-diseases [10-12].

Forest conservation is an important task because in comparison with other natural ecosystems, forest ecosystems are of great climate-stabilising importance and constitute a natural framework for natural landscapes and preserve forest biodiversity under their tent. Even though among the main forest-forming species in Ukraine, Scots pine is the predominant tree species and occupies 33% of the land area of the Forest Fund of Ukraine, pine forests require conservation. Diverse scientific research to identify the causes of forest death will contribute to solving the issues of their restoration and multiplication [13; 14].

Since 2010, Ukraine has seen a massive withering of numerous main forest-forming tree species – Pine (*Pinus*), Oak (*Quercus*), spruce (*Picea*), Birch (*Betula*) and ash (*Fraxinus*). A similar situation is observed on all continents in the forest biocoenoses of the temperate zone of the Northern Hemisphere [7-9]. The situation is particularly catastrophic in coniferous forests. Thus, the withering of coniferous species in North America and Siberia totals millions of hectares. The situation is no better in Europe, where over the past two decades there has been a massive withering of Scots pine (*Pinus sylvestris* L.) and European spruce (*Picea abies* (L.) H. Karst). Withering of the main forest-forming tree species in the forests of the Northern Hemisphere in most cases have similar signs of the process and are caused by outbreaks of mass reproduction, similar in biology to stem pests. For example, North America has recently witnessed a massive reproduction of dendrocton (*Dendroctonus micans* Kud), East Asia – the Ussuri polygraph (*Polygraphus proximus* Blandford), a spruce bark beetle in Europe (*Ips typographus* Linnaeus) and sharp-dentated bark beetle (*Ips acuminatus* Gyllenhal) [15-17]. Nematodes also cause significant damage to pine forests [14]. Among phyto-diseases, harmful effect is caused by a fungus from the class of Basidiomycetes – *Heterobasidion annosum* (Fr.) Bref. to the Scots Pine (*Pinus sylvestris* L.) [10-12]. The simultaneous emergence of foci of shrunken tree species in many countries and an increase in their area indicates the global nature of the processes. It is most probable that this is connected with cyclical planetary processes enhanced by anthropogenic impact and expressed in an increase in air temperature and a decrease in precipitation in recent decades in most of the globe [6; 18; 19].

The purpose of this study is to analyse the influence of environmental (air temperature, humidity, precipitation, CO_2 emissions, hydrothermal regime) and planetary (solar activity) factors on the occurrence of foci of insect pests and phyto-diseases in the Zhytomyr Polissia zone.

LITERATURE REVIEW

Various climate changes that occur in the world are planetary in nature. In his study Earth Echo of Solar Storms, which was published in 1976, Professor A.L. Chizhevsky drew attention to the fact that there is a certain correlation between the activity of the sun and the periods of outbreaks of pandemics, epidemics, epiphytic epizootics on Earth [20]. Italian-born microbiologist P. Faraone (1995) drew attention to the pattern of growth of bacterial colonies during years of minimal solar activity [21]. Later, Ukrainian researchers V.S. Martynyuk, N.A. Temuryants, B.M. Vladimirsky [22] in their monograph Nature Does Not Have Bad Weather: Space Weather in Our Lives addressed the change in biological, social, and technological processes impacted by solar activity. In their scientific study The Influence of Solar Activity on the Temperature of the Troposphere and Ocean Surface H.O. Zherebtsov, V.A. Kovalenko, S.I. Molodykh, K.E. Kirichenko [23] noted that the ambient temperature affects the concentration of CO_2 and geomagnetic activity. P.P. Melnyk [24] in his monograph Ecological and Economic Foundations of Nature Management in Agroecosystems pointed out that wheat yield depends on the number of sunspots. In his scientific paper, V.B. Chernyshev drew attention to the fact that the activity of the sun affects the vital activity of insects [25]. Scientific publications of foreign authors note that the activity of the sun has a direct impact on forest fires in Southern Europe [26]. More detailed information about this correlation was published in their papers by researchers M.M. Radovanović, T.A.M. Pavlović et al. [26].

When conducting statistical analysis, scientists V.V. Lavniy and V.H. Mazepa [27] found a direct correlation between such indicators as solar activity and annual winds. In their research, I. Dorotovič, J. Louzada, J. Rodrigues, V. Karlovský analysed the effect of solar activity on pine growth [28].

To date, over fifty forecasts of the 24th cycle of solar activity have been published, which indicate the value of the maximum Wolf number from 42 to 190 [29-31]. The change in the hydrological regime is directly related to the average annual air temperature, which has recently increased in Ukraine by 2°C. Lately, the level of subsurface water and the water level in reservoirs has considerably decreased. One of the causes of climate

change is human activity, since 67% of greenhouse gases are released into the environment through the burning of fossil fuels and energy. To assess changes in the hydrological regime, the Selyaninov hydrothermal coefficient (HTC) is applied [19]. The hydrothermal humidification coefficient allows identifying the humidity of the territory and is determined by the amount of precipitation for the period when the average daily air temperature was above 10°C, which is the period of active vegetation of plants. After all, moisture availability has a direct impact on the sanitary condition of forest stands [5; 19; 32].

Apart from anthropogenic human activity, natural factors, such as volcanic eruptions, also have an adverse environmental impact, and 3-4 gigatonnes per year are released into the environment under their influence. In natural conditions, carbon dioxide constitutes a limiting factor in photosynthesis and not all plants can withstand high concentrations of CO_2 (ten times or more). Increased CO_2 concentration in the environment slows down the growth and development of the plant and a state of suspended animation occurs. More sensitive plants are damaged by phyto-diseases. Furthermore, according to scientists P.G. Guerenstein, and J.G. Hildebrand [33], V.P. Akatov [34], A. Fangmeier [35], R.M. Srinivasa [36], an increase in the concentration of carbon dioxide promotes the reproduction of insect pests [37; 38].

MATERIALS AND METHODS

To achieve the purpose of this study, the necessary statistical information was collected, which included the data from the Main Statistics Department of the Zhytomyrska Oblast, indicators of Ukrainian hydrometeorological centre and the State Agency for Forest Resources of Ukraine (Form No. 12-F), as well as the materials provided by the S.I. Subbotin Institute of geophysics of the National Academy of Sciences of Ukraine (NAS of Ukraine).

According to the obtained data of the Ukrainian hydrometeorological centre, the study analysed the dynamics of climate change for 1961-2020, namely the average annual air temperature, average annual relative humidity, and average annual precipitation.

According to the provided statistical indicators of the State Agency for Forest Resources of Ukraine, the author of this paper analysed the dynamics of the occurrence of insect pests and Heterobasidion annosum in pineries of Zhytomyr Polissia for 2009-2020. The years of increase in forest areas covered with forest vegetation damaged by harmful entomofauna and phyto-diseases were determined.

According to the materials provided by the S.I. Subotin Institute of Geophysics of the NAS of Ukraine, the study established periods of growth and decline of solar activity (W number) for 2009-2020.

To establish the quantitative indicator of aridity of the studied area, the formula of H.T. Selyaninov was used [11]:

$$HTC = \frac{\sum \mathrm{P}}{0.1 \times \sum t_{rel>10}} \quad (1)$$

where $\sum$ P is the sum of precipitation for the month, in mm; $\sum$ t is the sum of the average daily temperature above 10°C.

According to Eq. (1), if HTC<0.4 is a very severe drought, HTC 0.4-0.5 is a severe drought, HTC 0.6-0.7 is an average drought, HTC 0.8-0.9 is a weak drought, HTC 1.0-1.5 is sufficiently humid, HTC 1.5 is excessively humid.

The author of this paper established the years of drought and humidity in the region under study for 2009-2020, and the calculated the amount of greenhouse gas emissions (CO_2) to the environment (according to statistical indicators of the State Statistics Service of Ukraine).

Mathematical and statistical processing of the conducted research results was conducted using the data analysis package programme *Microsoft Excel*.

RESULTS AND DISCUSSION

According to the data from the Ukrainian hydrometeorological centre, a detailed analysis of air temperature changes, precipitation, and relative humidity in Zhytomyr Polissia was conducted for 1961-2020. Lately, the region under study has seen an increase in the average annual air temperature by 3.0°C (Fig. 1).

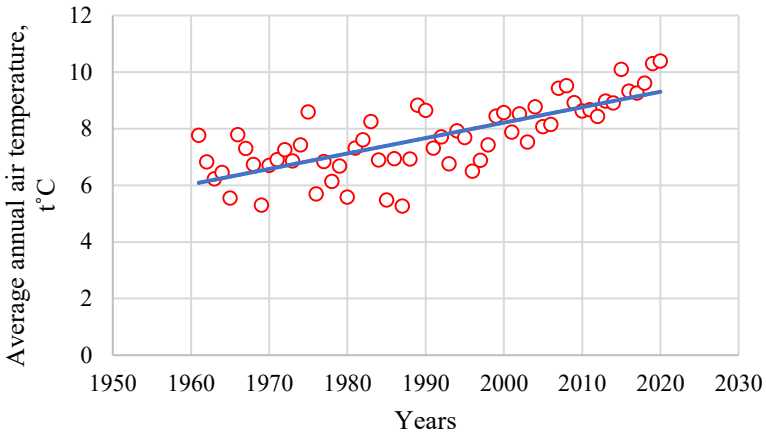

Figure 1. *Changes in the average annual air temperature in Zhytomyr Polissia for 1961-2020*

This warming directly affected the relative humidity of the air (Fig. 2), so over the past fifty-nine years, the relative humidity of the air has decreased by 3%.

There is also an increase in the average annual precipitation by 2 mm (Fig. 3).

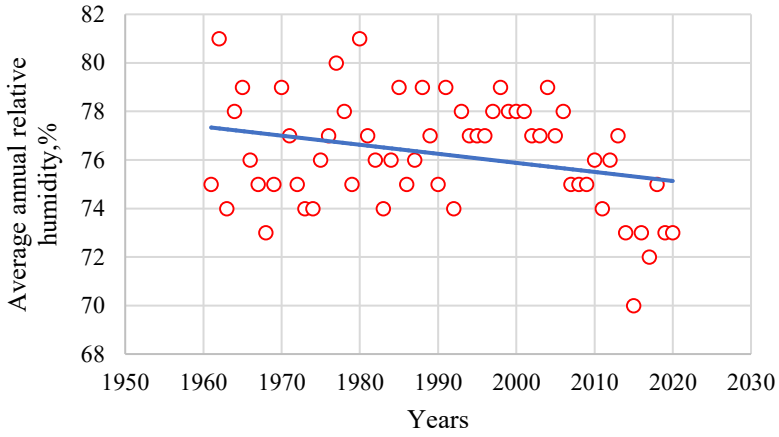

***Figure 2**. Average annual relative humidity in Zhytomyr Polissia for 1961-2020*

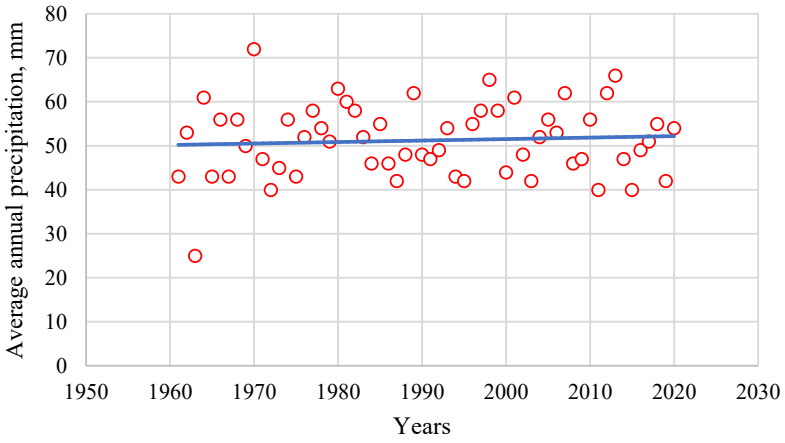

***Figure 3**. Average annual precipitation in Zhytomyr Polissia for 1961-2020*

Thus, the analysis of climate indicators demonstrated substantial climate changes in the region under study, such climate changes have an impact on biodiversity.

Since 2009, the State Agency for Forest Resources in Ukraine has carefully kept records of the occurrence of insect pest foci. According to the submitted reports of 2009-2020: Report on Forest Protection Works (Form No. 7 F), during research, the analysis revealed that the greatest harmful effect to pine woods in Zhytomyr Polissia is caused by:

– needle-eating pest – pine noctuid (*Panolis flammea* Denis & Schiffermuller), pine sawfly (*Diprion pini* L.), European pine sawfly (*Neodiprion sertifer* Geoffroy);

– other pest – pine bark bug (*Aradus cinnamomeus* Panz), pine lappet (*Dendrolimus pini* L.), pine looper (*Bupalus piniarius* L.) (Fig. 4).

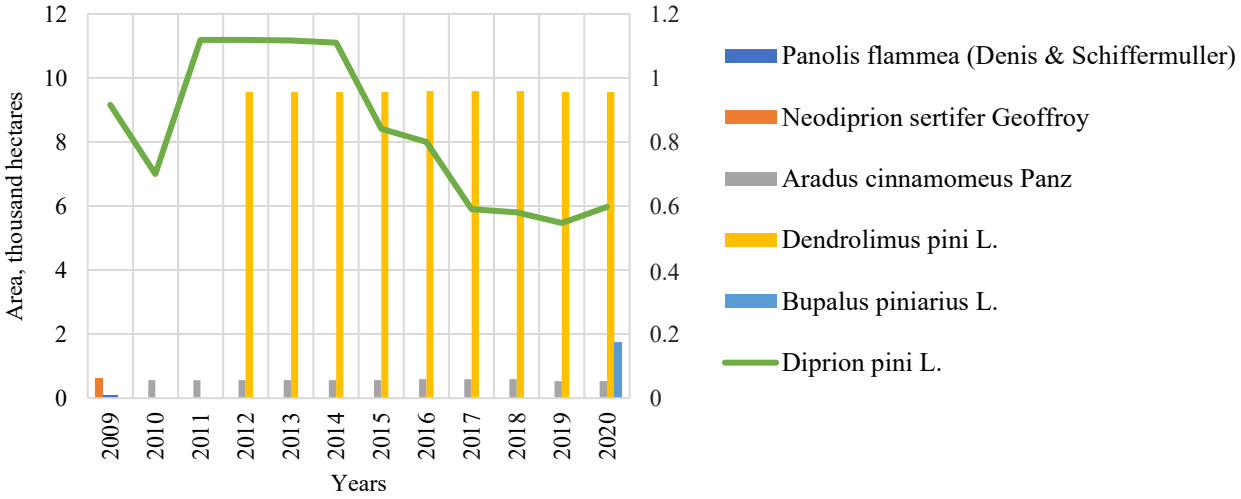

***Figure 4**. Dynamics of the emergence of insect pests in pineries for 2009-2020*

According to Figure 4, the greatest harmful effect is caused to pineries by a needle-eating pest – pine sawfly (*Diprion pini* L.) its largest foci were observed in 2011-2014 and amounted to 11.1 thousand hectares. Over the past four years, this number has decreased by almost 2 times. Pineries of Zhytomyr Polissia occupy 59% (Fig. 5) from other tree species, over 12 years, 20% of their area was damaged by insect pests.

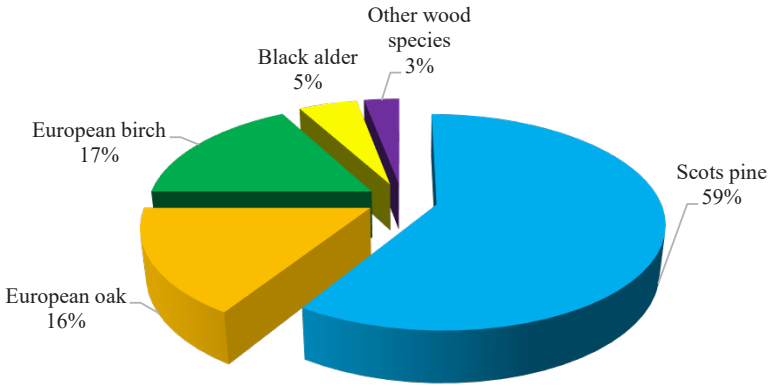

Figure 5. *Share of forest areas covered with forest vegetation by tree species in Zhytomyr Polissia*

Studying the dynamics of solar activity, the Wolf number (W number) for 2009-2020 indicated that the greatest solar activity was observed in 2011-2014; starting from 2015, there is a decrease in the W number (Fig. 6).

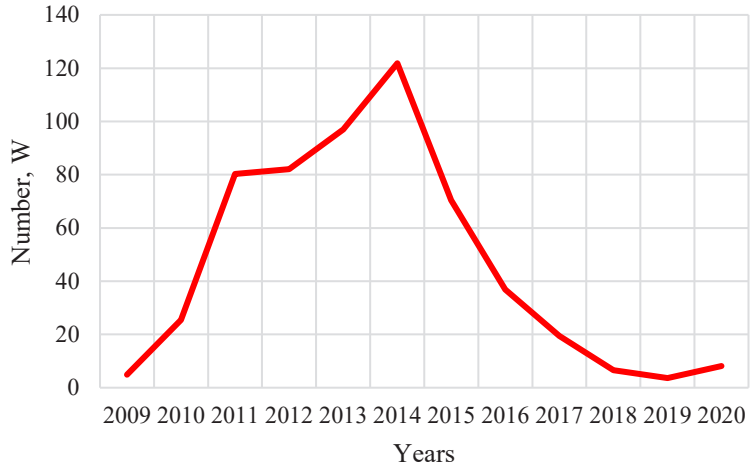

Figure 6. *Values of the average annual W numbers for 2010-2020*

Analysis of the dynamics of the W number (Fig. 6) and the area of trees damaged by insect pests (Fig. 4), reveals a certain pattern: during the solar activity increase in 2011-2014, the number of damaged pineries also increased, and in years of decreasing solar activity – vice versa. The same situation is observed upon analysing the impact of *Heterobasidion annosum* (Fr.) Bref. on pineries; since 2015, the area of plantings damaged by the root sponge has decreased with a decrease in solar activity (Fig. 7).

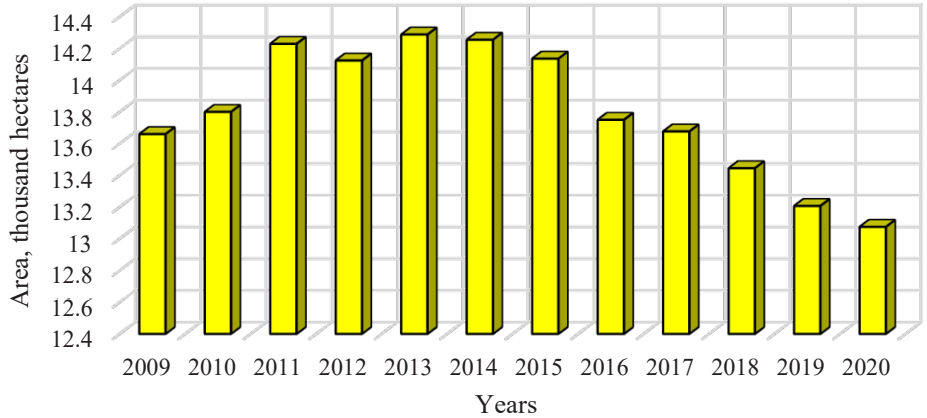

Figure 7. *Dynamics of Heterobasidion annosum occurrence for 2009-2020*

Applying the Eq. (1) by G.T. Selyaninov, the author of this study established the change in climate humidity in the conditions of Zhytomyr Polissia for 2009-2020 (Fig. 8).

According to the analysis results, 2015 was described by a year of average drought; 2009 and 2016 – years of mild drought; 2010-2012, 2018-2020 – years of adequate humidity; and 2013 – excessively humid year.

To find out if there is a correlation between the W number and CO_2 emissions, the study analysed the carbon dioxide emissions into the environment for 2009-2020 (Fig. 9).

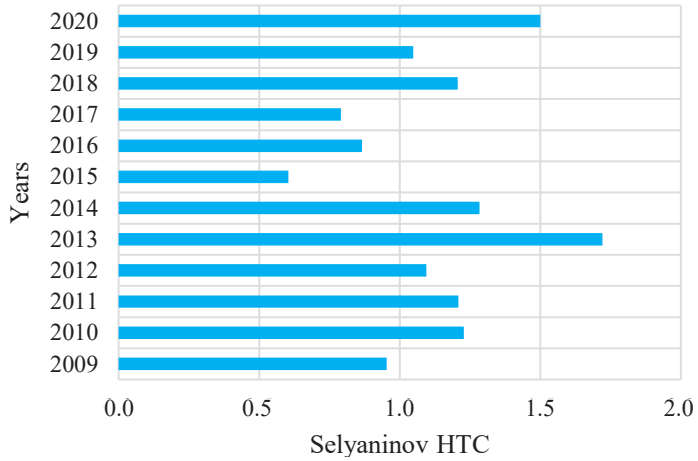

Figure 8. *G.T. Selyaninov Hydrothermal Coefficient Selyaninov*

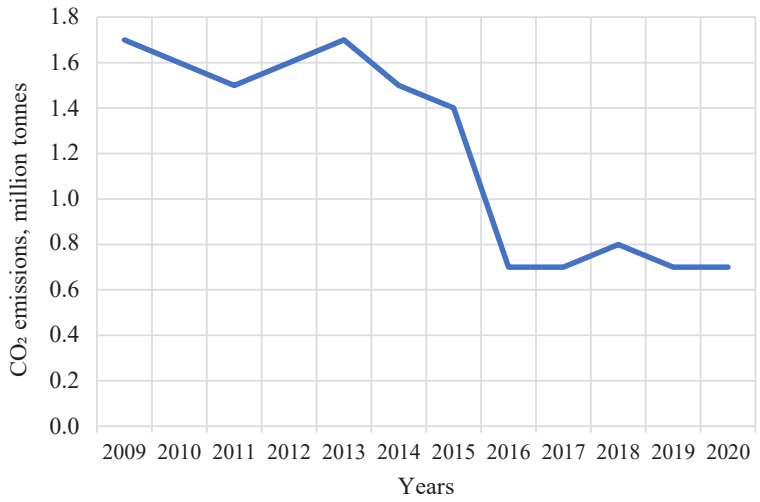

Figure 9. *CO_2 emissions in the natural environment for 2009-2020 (According to the Main Statistics Department of Zhytomyrska Oblast)*

According to the data presented in Figure 9, since 2014, the amount of CO_2 emissions has decreased almost three times. To establish correlations between the area of occurrence of insect pests and Heterobasidion annosum, CO_2 emissions, the W number, the Selyaninov HTC and the average annual air temperature, the average annual relative humidity, and the average annual precipitation sum, the author of this paper applied the data analysis package *Microsoft Excel* and constructed the correlation matrix (Table 1).

Table 1. *Correlation matrix of paired coefficients*

Indicators	Area of trees damaged by insect pests, thousand hectares	Area of trees damaged by Heterobasidion annosum, thousand hectares	W number	Average annual air temperature, °C	Average annual relative humidity, %	Average annual precipitation, mm	Selyaninov HTC coefficient Selyaninov	CO_2 emissions, million tonnes
Area of trees damaged by insect pests, thousand hectares	1.000							

Table 1, Continued

Indicators	Area of trees damaged by insect pests, thousand hectares	Area of trees damaged by Heterobasidion annosum, thousand hectares	W number	Average annual air temperature, °C	Average annual relative humidity, %	Average annual precipitation, mm	Selyaninov HTC coefficient Selyaninov	CO_2 emissions, million tonnes
Area of trees damaged by Heterobasidion annosum, thousand hectares	0.849	1.000						
W number	0.899	0.895	1.000					
Average annual air temperature, °C	-0.567	-0.539	-0.424	1.000				
Average annual relative humidity, %	0.220	0.131	0.005	-0.643	1.000			
Average annual precipitation, mm	0.200	0.092	0.113	-0.461	0.789	1.000		
Selyaninov HTC coefficient	0.292	0.026	0.238	-0.343	0.563	0.586	1.000	
CO_2 emissions, million tonnes	0.746	0.748	0.599	-0.642	0.354	0.193	0.216	1.000

The results of the analysis of indicators suggest that the correlation is quite high (0.899; 0.895) between the following indicators: area of trees damaged by insect pests, area of trees damaged by Heterobasidion annosum and Wolf number. There is also a sufficient correlation between CO_2 emissions in the environment and the area of pineries damaged by insect pests and Heterobasidion annosum (0.746, 0.748). High paired correlation coefficients between solar activity and the area of damaged pineries by biotic factors contributed to the construction of cross-plots (Figs. 10, 11).

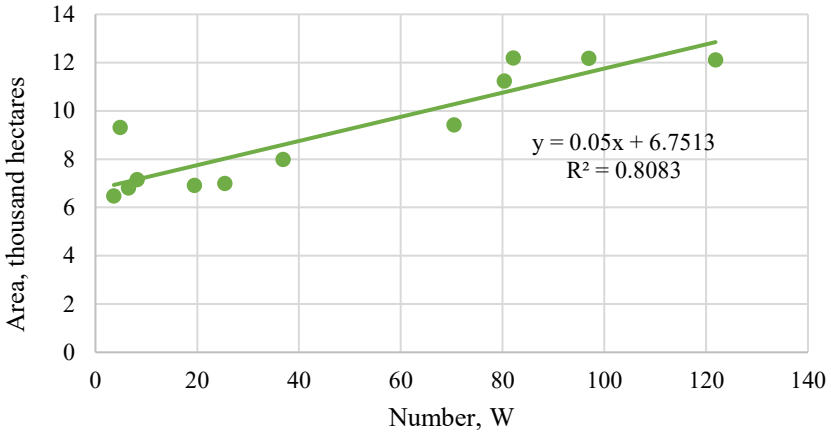

Figure 10. *Influence of the Wolf number on the area of woods damaged by insect pests*

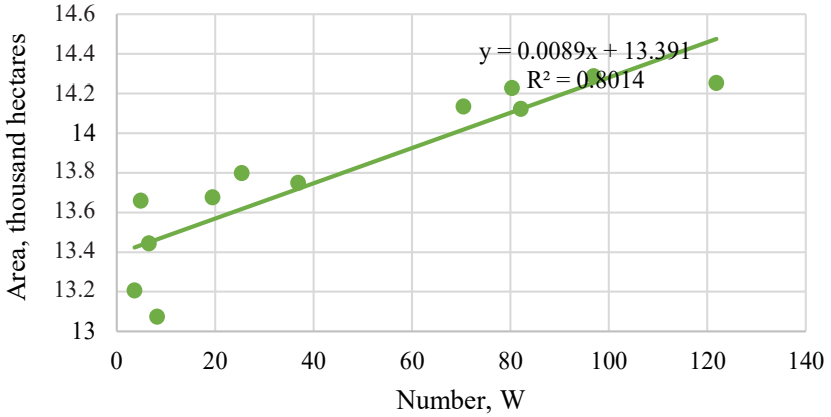

Figure 11. *Influence of the Wolf number on the area of woods damaged by Heterobasidion annosum*

The obtained mathematical dependences are 80% approximated with indicators and have a sufficiently high correlation coefficient, which allows applying empirical equations to predict the influence of the W number on damage to pineries by pests and forest diseases in the conditions of Zhytomyr Polissia.

CONCLUSIONS

In the conditions of Zhytomyr Polissia, climatic changes are observed, namely an increase in the average annual air temperature by 3.0°C, a decrease in the average annual relative humidity by 3%, and an increase in the average annual precipitation by 2 mm. It was found out that the greatest harmful effect of pine woods in Zhytomyr polissia is caused by pine noctuid (*Panolis flammea* Denis & Schiffermuller), pine sawfly (*Diprion pini* L.), European pine sawfly (*Neodiprion sertifer* Geoffroy), pine bark bug (*Aradus cinnamomeus* Panz), pine lappet (*Dendrolimus pini* L.), pine looper (*Bupalus piniarius* L.), and among phyto-diseases, *Heterobasidion annosum* (Fr.) Bref. causes significant harm.

A comprehensive analysis of various indicators for 2010-2020 confirmed the researchers' claims concerning the influence of the Wolf number and carbon dioxide emissions on the spread of insect pests and phyto-disease damage to pineries in Zhytomyr Polissia. It was established that the increase and decrease in solar activity directly affects the growth and decrease in the number of insect pests and phyto-diseases, respectively. The obtained mathematical dependencies can be of practical importance; they can be applied to predict outbreaks of insect pests and phyto-diseases to prevent their occurrence and predict measures to combat them.

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Сучасний стан соснових насаджень Житомирського Полісся за впливу екологічних чинників

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Анотація. В останні роки по цілому світі спостерігається масове всихання хвойних порід. У Північній Америці та Сибіру нараховується мільйони гектар всохлих насаджень, у Європі, за останні 20 років всихають сосни і ялини. Крім того, значних пошкоджень завдають деревним рослинам фітошкідники та фітохвороби, оскільки в Європі останніми роками спостерігається масове розмноження *Ips typographus* Linnaeus, *Ips acuminatus* Gyllenhal, у Північній Америці *Dendroctonus micans* Kud, в Східній Азії *Polygraphus proximus* Blandford. Також значної шкоди сосновим лісам завдають нематоди. Серед фітохвороб шкодочинну дію *Pinus sylvestris* L. завдає *Heterobasidion annosum* (Fr.) Bref. Виникнення осередків всохлих дерев у різних частинах земної кулі, вказує на глобальність процесів, що пов'язано з циклічними планетарними процесами та кліматичними змінами. У статті надано характеристику кліматичних змін у регіоні досліджень за період 1961–2020 рр. Відповідно до проведеного аналізу визначено, що за період 2009–2020 рр. значної шкоди сосновим насадженням Житомирського Полісся завдають серед хвоєгризучих – *Panolis flammea* Denis & Schiffermuller, *Diprion pini* L., *Neodiprion sertifer* Geoffroy; серед інших шкідників – *Aradus cinnamomeus* Panz, *Dendrolimus pini* L., *Bupalus piniarius* L. Найбільшу шкодочинну дію за останні роки завдає сосновим насадженням – *Diprion pini* L. Також з'ясовано, що серед фітохвороб сосновим лісам значної шкоди завдає *Heterobasidion annosum* (Fr.) Bref., пошкоджена площа становить від 13,0–14,2 тис. га. Проведено гідротермічний аналіз за період 2009–2020 рр. Проаналізовано вплив сонячної активності на чисельність фітошкідників та хвороб. Надано оцінку кількості викидів CO_2 у навколишнє природне середовище за період 2009–2020 рр. і з'ясовано що з 2014 р. кількість викидів діоксиду вуглецю зменшилася з 1,5 млн т на 0,6 млн т. Кореляційний аналіз всіх показників вказав на високий взаємовплив між площею пошкоджених дерев ентомошкідниками, кореневою губкою, числом Вольфа та викидами CO_2 в довкілля. Одержано математичні залежності з метою прогнозування впливу числа W на пошкодження соснових насаджень шкідниками та хворобами лісу в умовах Житомирського Полісся

Ключові слова: зміни клімату, фітошкідники та хвороби, викиди CO_2, сонячна активність, гідротермічний коефіцієнт, кореляція, математичне моделювання

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Optimisation of Nutrition of Early-Maturing Potato Varieties on Drip Irrigation in the South of Ukraine

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Abstract. Potatoes are an extremely important crop for the nutrition of the population in Ukraine. Its potential is high-up to 100 t/ha of tubers, but the average yield reaches 14-16 t/ha. To obtain significantly higher productivity, it is necessary to improve the main elements of cultivation technology. The main factor of potato production on drip irrigation is the optimisation of plant nutrition, which the authors have taken to study with three varieties of early maturing potatoes. Studies have established that providing plants with nutrients with the selection of varieties can increase the productivity of tubers up to 37-39 t/ha, or increase its level compared to the control to 64.7%. It was determined that the maximum yield is provided by the main application from autumn $N_{32}P_{32}K_{32}$, before planting $N_{48}P_{48}K_{48}$ and carrying out three top dressings during the growing season simultaneously with watering with a total rate of N_{33} and Plantafol 6 kg/ha, starting from the beginning of budding with an interval of 8-10 days. At the same time, tubers are formed with high-quality indicators as they contain a sufficient number of dry substances, ascorbic acid (vitamin C), and starch. It should be noted that when optimising nutrition, the intake of all the main indicators of potato tubers compared to the control slightly decreased, namely dry substances and starch. On the contrary, the amount of ascorbic acid increased, especially with top dressing with Plantafol. Varietal features regarding the impact on the quality of tubers are also determined. Significantly more dry substances were found in tubers of the Riviera and Prada varieties, and more starch content was found in Prada and Minerva varieties. Slightly less dry matter and ascorbic acid were detected in Minerva potato tubers compared to other varieties. From the grown crop of tubers of the studied potato varieties, it is possible to obtain up to 4.0 t/ha of bioethanol or alcohol if they are processed

Keywords: yield, quality of potato tubers, fertiliser system, Plantafol, bioethanol, alcohol

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INTRODUCTION

As of November 1, 2020, potato production in Ukraine amounted to 21.7 million tons with an average yield of tubers at the level of 10-14 t/ha. In some countries and in some advanced farms, due to the introduction of scientific and technological progress into production, the productivity of this crop reaches 30-40 t/ha. Its potential yield exceeds 100 t/ha, and the collection of dry matter is up to 25 t/ha [1; 2]. That is, now in Ukraine, the potential of biological and economic productivity of potatoes is used only by 10-12%. The difference in these data is because industrial production occupies only a small part of the potato market of Ukraine. Almost 95% of the total potato volume is grown by the population in the private sector.

According to the Ukrainian Association of potato producers, about 3 million tons of potatoes are sold through supermarkets per year, and the population needs twice as much to feed – at least 6 million tons (120-128 kg per person), part of the crop is used for animal feed and processing. Therefore, potato cultivation is an urgent problem aimed at expanding planting areas, increasing yields due to properly selected varieties, and applying mineral fertilisers.

Potatoes are a valuable food, technical, and fodder crop. The main food component of potatoes is carbohydrates in the form of starch. Different varieties of potatoes contain from 17 up to 30% of dry substances in tubers, of which 70-80% is starch and up to 3% is protein substances. Tubers contain vitamins A, B1, B2, PP, etc. Potatoes are an essential raw material for the starch and alcohol industries. Tubers are used for livestock feed both in fresh and processed form, as well as for the production of bioethanol [3-6]. Recently, on the irrigated lands of the south of Ukraine, the technology of growing potatoes improved by the Institute of irrigated agriculture of the National Academy of Sciences, in which tubers are planted in pre-cut ridges, is increasingly used. This, of course, with other elements and measures, contributes to improving the physical condition of the soil, warming it up faster [7].

When applying mineral fertilisers in the optimal amount for plant nutrition, the irrigation regime becomes particularly important in the conditions of the steppe zone of Ukraine. Due to the insufficient amount of moisture for plants, an increase in potato productivity during watering is associated with optimising the moisture supply during the growing season of the crop, which contributes to an intensive increase in aboveground biomass and tubers. In recent years, the area of use of drip irrigation has been constantly growing.

The relevance of the topic of this study is determined by the fact that an important direction for accelerating scientific and technological progress in potato growing is the creation and introduction into production of highly productive varieties and hybrids adapted to the appropriate soil and climatic conditions of the growing zone. For them, it is necessary to develop conditions for the most complete disclosure of genetic potential based on improved seed production, the development of zonal intensive technologies, in particular fertiliser systems.

Therefore, as a result of the study, it was planned to determine the influence of the background of nutrition on the yield and quality of tubers of three varieties of early ripening potatoes when grown on drip irrigation in the conditions of the Southern steppe of Ukraine.

LITERATURE REVIEW

Each agricultural crop, and even its individual varieties or hybrids, have certain features and requirements for the level of nutrition, differ in the removal of nutrients from the soil and their optimal ratio. Potatoes are quite picky about providing the soil with nutrients. So, at the average yield level (18.0 t/ha of tubers and 8.0 t/ha of tops), it removes nitrogen from the soil – 95-105 kg, phosphorus – 40-50 kg, potassium – 110-120 kg/ha. Regarding 1 ton of tubers, this use is 5.6, 2.2, and 6.4 kg, respectively. Potatoes absorb the maximum amount of phosphorus during budding and flowering, and they absorb nitrogen and potassium in the second half of the growing season during the increased growth of tubers and tops [8].

Potatoes also show a significant need for nutrition relating to trace elements, their lack from the very first periods of vegetation disrupts growth processes and normal metabolism. After all, to obtain stable potato yields with high-quality tubers, plants require not only nitrogen, phosphorus, and potassium, but also calcium, magnesium, iron, boron, sulfur, manganese, and other elements. Therefore, the rate of mineral fertilisers should be such as to ensure sufficient nutrition of potato plants throughout the growing season [9].

In particular, to combat scab, it is advisable to replace part of mineral fertilisers with physiologically acidic forms (superphosphate, ammonium sulfate). In fields where scab is very common, it is advisable to feed potatoes with manganese sulfate or ammonium sulfate as 60 kg/ha during mass tying of tubers [10].

The authors recommend applying 30-50 kg/ha of magnesium and 30-60 kg/ha of sulfur to potatoes in addition to the main fertiliser before planting or during the growing season applying micro fertilisers by foliar top dressing. The absorption of nutrients by plants depends on the stage of crop development. So, during the period of early spring growth, there is a need for a significant amount of trace elements, and to achieve high yields, it is essential to have all the nutrients available to plants in an accessible form. Both potassium and nitrogen are necessary for potatoes during vegetative growth, the ovary of tubers and during tuber formation [8].

To obtain high yields of tubers, potato plants need enhanced potassium nutrition, potassium is also vital for the starchiness of tubers. Therefore, its consumption in

significant quantities is typical for potato culture. For the growth of leaves, above-ground biomass, and tubers, nitrogen application is crucial. In general, in the conditions of irrigation in the south of Ukraine, nitrogen nutrition is at the first minimum for most agricultural crops. It is the availability of plants with this element of nutrition that affects the level of yield and product quality. Like potassium, a significant amount of nitrogen is distributed from the leaves to the tubers during their formation. For better rooting and tuber formation, potatoes use phosphorus in fairly large quantities, especially at the beginning of plant growth, as well as at the end of the growing season, for the intensity of tuber growth. This is established on different types of soils and in many countries [11-15].

Balanced nutrition is vital, despite the significantly lower removal of trace elements. In the nutrition of plants, it is necessary to adhere to their optimal content, since they, like trace elements, are a necessary factor in obtaining high yields. The trace elements, boron, copper, manganese, and zinc are the most important for potatoes. The importance of trace elements in the formation of stable yield levels and their quality is determined on many agricultural crops in the conditions of the southern steppe zone of Ukraine [16]. The authors point out the significant influence of trace elements in increasing the yield of potato tubers and the main indicators of their biochemical composition after conducting a study in Polesie [17]. In general, the use of trace elements for vegetable crops and potatoes significantly improves their quality, products with a balanced diet meet the requirements of environmentally friendly standards [18].

Many studies have proved that with the optimisation of humidification conditions, the productivity of any crop increases significantly under the influence of plant nutrition. Fertilisers have the greatest impact, and they are a decisive factor in increasing yields due to their rational use, crop yields increase by an average of 40-50%, and on irrigated land, they increase by 75% or more. In addition, fertilisers significantly affect not only the levels of potato yield but also the biochemical composition, nutritional value, taste qualities of tubers, their shelf life, etc. [19].

Currently, due to a sharp decrease in the number of animals, the use of organic fertilisers has significantly decreased, so it is necessary to search for alternative sources of organic mass in the soil, which is determined by many studies. For example, in the Polesie region, it was found that the use of various crops as green manure for potatoes is equal in efficiency to 30-40 tons of manure per hectare [20].

Mineral fertilisers are highly expensive and should be used with the greatest efficiency and payback. One way may be to apply them locally. With this method of application, it is possible to get significantly higher returns from a significantly (halved) reduced dose of fertilisers. Definitely, the local method of applying mineral fertilisers affects physiological processes from the early stages of plant development and continues until the period of formation of spare substances, that is, it significantly affects the yield and the main indicators of its quality. The high efficiency of mineral fertilisers for potatoes has been determined by many researchers [21-24].

According to the generalised data of researchers, the coefficient of use of nutrients by plants using the local method of fertilisation increases in comparison with the scattered one by 10-15% for nitrogen and potassium, and by 5-10% for phosphorus.

Therefore, according to the generalisation of scientific literature, it can be seen that the use of the correct system of plant nutrition (potatoes in particular) is an extremely important element of the technology of growing agricultural crops. The issue of the nutrient regime optimising has become particularly significant recently when the application of fertilisers is insufficient and soil fertility is deteriorating [25].

MATERIALS AND METHODS

Field experiments were conducted during 2018-2020 in the Educational, Scientific and Practical Center of the Mykolaiv National Agrarian University. The soil of the experimental site – southern chernozem – in the arable layer on average contained 3.02-3.21% humus, 20.7-32.0 mg/kg of soil nitrates, 26-45 mg/kg of mobile phosphorus, and 326-472 mg/kg of exchange potassium, pH of water extract was 7.0-7.2.

The source of irrigation of the experimental site was the central main channel of the Ingulets irrigation system, the water of which was characterised by satisfactory quality and belongs to the 2nd class regarding the level of saltwater hazard. According to irrigation indicators, the water was suitable for irrigation and would not lead to salinisation of the soil.

The experiment scheme included the following variants:

Factor A – Variety: 1 – Minerva; 2 – Riviera; 3 – Prada.

Factor B – nutrition variant:

1. Control - without fertilisers;
2. $N_{32}P_{32}K_{32}$ (autumn) – background;
3. background + $N_{48}P_{48}K_{48}$ (when planting);
4. background + $N_{48}P_{48}K_{48}$ (when planting)+N_{33}+Plantafol, 6 kg/ha (in three top dressing with vegetative irrigation).

The area of the experimental plot was 90 m^2, the accounting plot was 50 m^2. The experiment was repeated three times. The research was carried out in accordance with the requirements of the research methodology [26; 27]. Agrotechnics of growing potatoes on drip irrigation, in addition to the factors taken for study, were recommended for the southern steppe zone of Ukraine [7].

The predecessor of potatoes was winter wheat. In autumn, $N_{32}P_{32}K_{32}$ (2 centners/ha of nitroammofos) was applied for the main tillage. Before planting, $N_{48}P_{48}K_{48}$ (3 centners/ha of nitroammofos) was applied according

to the experiment scheme. The planting material was treated with the growth stimulator Poteitin (5 ml/t) together with the mordant Commander extra (0.2 l/t) for water consumption of 20 l/t.

Tubers were planted in late March – early April in the ridge to a depth of 6-8 cm, the nutrition area was 70×15-20 cm.

During the growing season, starting from the beginning of budding, the top dressing was carried out with a general norm of N_{33} and Plantafol 20:20:20 6 kg/ha. The specified fertiliser and Plantafol were applied three times with an interval of 8-10 days simultaneously with irrigation according to N_{11} and Plantafol 2 kg/ha, respectively.

In a layer of 0-20 cm, before the appearance of sprouts on tubers, soil moisture was maintained at 70-75% HB, and in the subsequent growing season – 80-85% HB by drip irrigation.

The yield of alcohol and bioethanol from potato tubers was determined by the calculation method recommended by the Institute of Potato NAAS of Ukraine 100.4 liters, and the yield of bioethanol from 1 ton of raw materials – 100.4 liters, and the yield of absolute alcohol from 100 kg of raw materials – potato tubers (medium starch) – 11.2 kg.

RESULTS AND DISCUSSIONS

Field germination of tubers of the studied potato varieties was formed at the level of 95.8-97.5%. The beginning of budding in all variants of the experiment and in all varieties began on the 53-59 day after planting. The duration of the interphase budding – flowering period, depending on the variety and background of nutrition, ranged from 5 to 9 days. Fertilisers, regardless of the application period, slightly restrained the onset of budding and flowering phases – on average, for 1-2 days compared to the control in all varieties. The Minerva potato variety ripened by 4-7 days earlier than the Riviera and Prada varieties. Fertilisation slightly affected the overall duration of the growing season.

In 2019, all the studied potato varieties formed the lowest yield of commercial tubers, which was caused by the cold spring. Considering the yield within varieties, Minerva was determined to be less productive, the yield of its tubers on average over the years of research in the control was 17.4 t/ha, while in the Riviera and Prada varieties, respectively, their yields were 21.6 t/ha and 22.2 t/ha.

The yield of potato tubers, depending on weather conditions, the variety, and the current nutrition background, ranged from 15.7-39.0 t/ha. On average, over the years of cultivation, the highest yield of tubers of the studied potato varieties was formed at the level of 30.5-35.5 t/ha when applied in autumn $N_{32}P_{32}K_{32}$, before planting $N_{48}P_{48}K_{48}$ and carrying out three top dressing N_{33} and Plantafol 6 kg/ha simultaneously with fertigation, (respectively for N11 and Plantafol 2 kg/ha), which exceeded the control without fertilisers depending on the varietal characteristics of potatoes by 13.1-13.3 t/ha (Table 1).

***Table 1**. Yield of commercial tubers of potato varieties under the influence of nutrition optimisation in research years, t/ha*

Year	Variety (factor A)	Nutrition background (factor B)			
		Control (without fertilisers)	$N_{32}P_{32}K_{32}$ (in autumn) – background	Background + $N_{48}P_{48}K_{48}$ (when planting)	Background + $N_{48}P_{48}K_{48}$ (when planting) + N_{33} + Plantafol
2018	Minerva	17.9	19.8	26.9	31.2
	Riviera	22.0	26.5	31.9	37.6
	Prada	22.5	27.2	32.4	37.9
2019	Minerva	15.7	18.8	22.8	26.7
	Riviera	20.1	22.5	25.7	28.8
	Prada	21.1	23.4	26.4	29.6
2020	Minerva	18.5	20.0	28.4	33.7
	Riviera	22.7	28.3	33.7	38.2
	Prada	22.9	28.9	34.4	39.0
Average for 3 years	Minerva	17.4	19.5	26.0	30.5
	Riviera	21.6	25.8	30.4	34.9
	Prada	22.2	26.5	31.1	35.5
HIP_{05}			2018 yr.	2019 yr.	2020 yr.
	By factor A		1.3	0.8	1.1
	By factor B		1.6	1.2	1.5
	By factors AB		1.9	1.7	2.3

The importance of nutrition optimisation in potato productivity is clearly illustrated in Figure 1, namely, the increase in yield of tubers from background application of $N_{32}P_{32}K_{32}$ averaged 17.2% for three varieties over the years of research, the use of $N_{48}P_{48}K_{48}$ for planting on this background fertilisers – by 43.1%, and fertilisation with watering during the growing season (general norm N_{33} and Plantafol 6 kg/ha) provided a maximum increase in yield by 64.7%. In general, from foliar fertilisation with Plantafol 2 kg/ha three times during the growing season, the yield of tubers increased by 4.4 t/ha on average during the years of cultivation in all varieties (by 21.6% compared to the control).

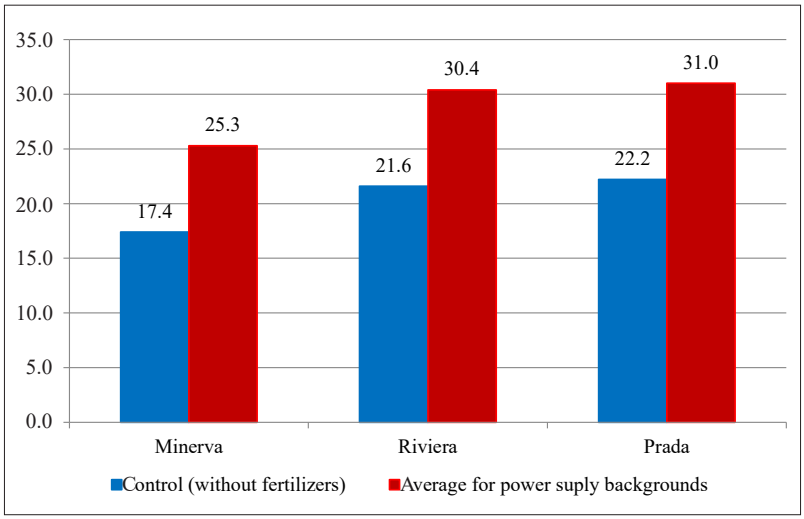

***Figure 1**. Influence of potato varietal characteristics and nutrition optimisation on tuber yield (average for 2018-2020), t/ha*

Of the potato varieties taken for research, the highest level of yield in all the years of cultivation was provided by the Prada variety. The Riviera variety was characterised by similar yield values, and the lowest yield of tubers in this study was provided by the Minerva potato variety. However, all varieties reacted significantly to the optimisation of nutrition by increasing the yield of tubers. On average, for three varieties, the maximum productivity was provided by the cultivation of their use for top dressing with Plantafol on the background of $N_{48}P_{48}K_{48}$ (Fig. 2). The positive effect of growth-regulating substances containing trace elements on the yield of potato tubers was determined in studies conducted at the Institute of irrigated agriculture, that is, in the conditions of the Southern steppe of Ukraine on drip irrigation [28-30]. Note that despite the lowest yield of tubers, which is formed by the potato variety Minerva, this variety significantly increased it with optimisation of nutrition: the increase in all variants of fertilisers to control in this variety was 45.4%, while in the Riviera variety – 40.7%, and Prada – 39.6%.

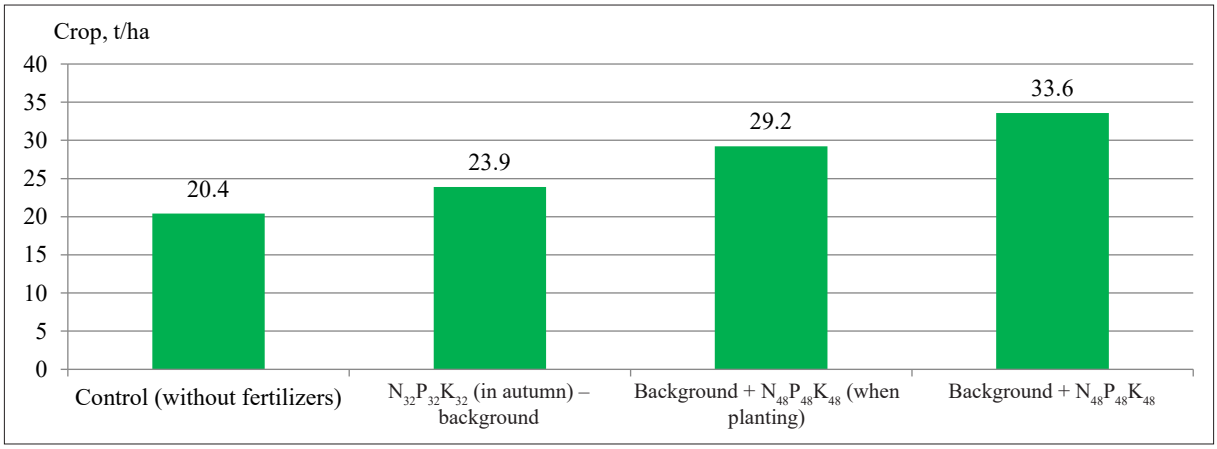

***Figure 2**. The Importance of nutrition optimisation in the productivity of potato tubers (average by varieties for 2018-2020), t/ha*

During this period, potato producers are subject to serious requirements regarding product quality criteria. That is why the cultivation of potatoes, including the quality of tubers, significantly depends on the selection of the variety, the planting scheme, and agricultural technology, the conditions of harvesting, drying, and storage, it is aimed at obtaining not only a high yield but also, accordingly, high quality.

The background of nutrition, as determined by studies, influenced the main indicators of the quality of potato tubers (Table 2).

***Table 2**. Impact of nutrition optimisation on the main quality indicators of potato tubers depending on the variety (average for 2018-2020)*

Nutrition background (factor B)	Variety (factor A)								
	Minerva			Riviera			Prada		
	1	2	3	1	2	3	1	2	3
Control (without fertilisers)	18.5	22.8	14.9	21.5	23.5	13.7	21.0	23.7	14.4
$N_{32}P_{32}K_{32}$ (in autumn)	18.3	23.3	14.5	21.0	24.5	13.4	20.8	24.7	14.2
$N_{32}P_{32}K_{32}$ (in autumn) + $N_{48}P_{48}K_{48}$ (when planting)	18.1	25.5	14.3	20.5	26.2	13.2	20.5	26.2	14.0
$N_{32}P_{32}K_{32}$ (in autumn) + $N_{48}P_{48}K_{48}$ (when planting) + N_{33} and Plantafol, 6 kg/ha	18.0	25.8	14.1	20.3	26.6	12.8	20.2	26.5	13.9

***Note**: 1 – dry matter content, %; 2 – vitamin C (Ascorbic acid) content, mg%/100 g; 3 – starch content, %*

The content of dry matter and starch in potato tubers varied depending on the background of nutrition (application of mineral fertilisers and top dressing with Plantafol) and on varietal characteristics. So, for the period of harvesting in potato tubers of the Minerva Variety, the minimum dry matter content was determined, in the variant without fertilisation it was 18.5%. With an increase in the dose of mineral fertilisers, this indicator decreased. Tubers of the Riviera and Prada varieties contained more dry matter: in the control variants, they contained 21.5 and 21.0%, respectively, and depending on the background of nutrition, from 20.2% to 21.5%. Similar data and their changes were obtained from determining the quality of tubers of different potato varieties by optimising crop nutrition, in particular using biologics [24; 25]. This is also determined by the previous studies conducted with three varieties of summer-planted potatoes for growing on drip irrigation, as was noted [19].

With a similar dependence, the improvement of nutritional conditions also contributed to a decrease in the starch content in the tubers of all the studied potato varieties compared to tubers grown in the control non-fertilised versions. That is, with an increase in the doses of mineral fertilisers, the yield of tubers increases, but in most cases their use leads to a decrease in the content of dry substances and starch in tubers. The starch content is lowest in tubers of the early maturing Riviera variety, and the highest one is in the Minerva variety. It should be noted that in the tubers of potato varieties taken for study, the content of vitamin C or ascorbic acid did not differ significantly. Among the variants of nutrition backgrounds and fertiliser application methods, the most vitamin C in potato tubers was due to the combination of $N_{32}P_{32}K_{32}$ (in autumn) + $N_{48}P_{48}K_{48}$ (when planting) + 1C saltpeter + Plantafol (6 kg/ha) with fertigation. The content of vitamin C in tubers of the Minerva variety on average for three years of cultivation was 25.8 mg%, slightly higher indicators were determined in tubers of the Riviera and Prada varieties – 26.5 mg% and 26.4 mg% respectively, which exceeded the content in tubers grown without fertilisation, by 3.0, 2.9 and 2.8 mg% per raw mass respectively.

By calculation, the authors also determined the possibility of obtaining a conditional yield of bioethanol and alcohol from grown potato tubers in the context of varieties and nutrition variants. For these purposes, tubers are used if they need to be processed, as well as in case of damage or formation of small, non-standard ones, non-commercial tubers and the like.

The highest yield of bioethanol and alcohol from grown potato tubers is provided by the Prada variety, the Riviera variety is close to it in terms of indicators, and the Minerva variety is the smallest because these values are conditional, calculated, and depend on the levels of the formed tuber yield (Table 3).

***Table 3**. Possible conditional yield of alcohol or bioethanol from the potato crop (average for 2018-2020), t/ha*

Nutrition background (factor B)	Possible conditional yield variety (factor A)					
	Minerva		Riviera		Prada	
	Bioethanol	Alcohol	Bioethanol	Alcohol	Bioethanol	Alcohol
Control (without fertilisers)	1.75	1.95	2.17	2.42	2.23	2.49
$N_{32}P_{32}K_{32}$ (in autumn)	1.96	2.18	2.59	2.89	2.66	2.97
$N_{32}P_{32}K_{32}$ (in autumn) + $N_{48}P_{48}K_{48}$ (when planting)	2.61	2.91	3.05	3.40	3.12	3.48
$N_{32}P_{32}K_{32}$ (in autumn) + $N_{48}P_{48}K_{48}$ (when planting) + N_{33} + Plantafol, 6 kg/ha	3.06	3.42	3.50	3.91	3.56	3.98

Under the influence of optimising the nutrition of potato plants, they increase significantly in comparison with the control and background application under the main tillage $N_{32}P_{32}K_{32}$ (autumn). To process tubers into starch is appropriate, and it is widely used by potato growers. Therefore, the production of large volumes of potato tubers and their partial processing to obtain starch, bioethanol, alcohol, chips and other products will significantly increase the profitability of growing this crop and its waste-free production.

CONCLUSIONS

Studies conducted on Southern chernozem with three early maturing potato varieties grown on drip irrigation during 2018-2020 determined that this crop responded significantly to nutrition optimisation. The yield of tubers under the influence of the use of mineral fertilisers in autumn, before planting, and N_{33} and Plantafol 6 kg/ha in top dressing increases to 64.7%. Positively, this element of cultivation technology affects the main indicators of the quality of tubers, the conditional collection of bioethanol and alcohol from the formed crop. The authors have identified Prada as the most productive of the studied varieties, the early maturing Riviera variety forms a slightly lower yield of tubers, and the Minerva variety forms the lowest. However, the latter potato variety is characterised by more favorable indicators for the starch content in tubers.

All potato varieties taken for the study in all years of cultivation reached the maximum yield level with the main background application of $N_{32}P_{32}K_{32}$ in autumn, $N_{48}P_{48}K_{48}$ in spring during planting, and three top dressings with ammonium nitrate (N_{33}) and Plantafol (2 kg/ha) at intervals of 8-10 days simultaneously with watering, starting from the budding phase. In these cultivation variants, with conditional processing of tubers for bioethanol or alcohol, it is possible to get their yield up to 3.0-3.6 and 3.4-4.0 t/ha, respectively.

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Оптимізація живлення ранньостиглих сортів картоплі на краплинному зрошенні Півдня України

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Анотація. Картопля є виключно важливою культурою харчування населення в Україні. Потенційні можливості її високі – до 100 т/га бульб, проте середня врожайність сягає 14–16 т/га. Для отримання значно вищої продуктивності необхідно удосконалювати основні елементи технології вирощування. Головним із факторів виробництва картоплі на краплинному зрошенні є оптимізація живлення рослин, саме цей захід нами взято на вивчення з трьома сортами ранньостиглої картоплі. Дослідженнями встановлено, що забезпечення рослин елементами живлення з добором сортів дозволяє збільшити продуктивність бульб до 37–39 т/га, або підвищити її рівень порівняно з контролем до 64,7 %. Визначено, що максимальну врожайність забезпечує основне внесення з осені $N_{32}P_{32}K_{32}$, перед садінням $N_{48}P_{48}K_{48}$ та проведення трьох підживлень упродовж вегетації одночасно з поливами загальною нормою N_{33} і Плантафолу 6 кг/га, починаючи з початку бутонізації з інтервалом 8–10 днів. При цьому формуються бульби з високими показниками якості – в них міститься достатня кількість сухих речовин, аскорбінової кислоти (вітаміну С) і крохмалю. Зазначимо, що за оптимізації живлення вступ усіх основних показників бульб картоплі порівняно до контролю, дещо знижувався, а саме сухих речовин та крохмалю. Кількість аскорбінової кислоти, навпаки, зростала й особливо за підживлень Плантафолом. Визначено і сортові особливості щодо впливу на якість бульб. Значно більше сухих речовин міститься в бульбах сортів Рів'єра і Прада, а крохмалю – Прада та Мінерва. Дещо менше, порівняно з іншими сортами сухої речовини і аскорбінової кислоти, визначено в бульбах картоплі сорту Мінерва. З вирощеного врожаю бульб досліджуваних сортів картоплі за умови їх переробки можливо отримувати до 4,0 т/га біоетанолу чи спирту

Ключові слова: урожайність, якість бульб картоплі, система удобрення, Плантафол, біоетанол, спирт

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Dynamics of the Species Composition of Phytocenoses of Floodplain Mountain Meadows of the Carpathians Subject to Superficial Improvement

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Abstract. The conducted research of various authors has developed a number of measures for surface improvement of meadowland in various soil and climatic conditions. However, studies on the influence of such surface improvement measures as the use of organic and mineral fertilizers and sowing of perennial grasses and legumes in the sod on the dynamics of the species composition of Floodplain Mountain meadows of the Carpathians have not yet been conducted, which confirms the relevance of this study. The article presents the results of three-year studies conducted during 2017-2019 in the peasant farm of V.F. Martyshchuk (the Verkhovinsky District of the Ivano-Frankivsk region) to study the features of transformation of the species composition of natural phytocenoses of floodplain Meadows of the Black Cheremosh river of the mountain and forest belt of the Carpathians under the influence of their surface improvement with the use of organic and mineral fertilizers and sowing of a cereal mixture for haymaking use and *Tribolium repens* L. for multipurpose use. It was found that floodplain Meadow phytocenoses were mainly cereals and mixed grasses with a share of wild cereals of 57-58% (up to 15 of them % *Festuca rubra* L. s. str. and 5-6% of low-value ones in feed terms *Calamagrostis arundinaceae* (L.) Roth and *Deschampsia caespitosa* (L.) Beauv.), mixed grasses – 35-38% and unseeded *Fabaceae* 5-7%. When applying a set of measures for surface improvement of cereals and mixed grasses, low productive (within 1.95-2.15 t/ha of dry weight) floodplain mountain meadowlands, their species composition improved. For making $P_{30}K_{60}$ the content of wild plants increased by 2-5% *Fabaceae*, and $N_{60}P_{30}K_{60}$ – by 9-10% unseeded *Poaceae*. For haymaking use, *Poaceae* with *Phleum pratense* L. and *Festuca pratensis* Huds. against the background of making $N_{60}P_{30}K_{60}$ for sowing a mixture in the sod in the spring, their share increased to 74%, and for multi-year use and sowing *Trifolium repens* L. against the background of making $P_{30}K_{60}$ the quantity of *Fabaceae* increased to 44% or by 32%. The highest floral saturation (43 species from 19 families and 93-98% from perennials) was observed in variants without fertilization and with the introduction of $P_{30}K_{60}$ for multi-year use, which is 4-14 species more compared to haymaking use, or with the introduction of $N_{60}P_{30}K_{60}$ and or with sowing a mixture of cereals on the background of $N_{60}P_{30}K_{60}$ for haymaking use, or sowing *Trifolium repens* L. against the background of $P_{30}K_{60}$ for multipurpose use

Keywords: legumes, cereals, species composition, meadow phytocenosis, mixed grasses, floral saturation

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INTRODUCTION

One of the most important ways to improve meadowland is to improve its surface. Among the measures of superficial improvement of meadow grass stand, which can dramatically affect its species composition when caring for it, there is fertilization and sowing of herbs. Fertilizers can be used effectively on all types of meadowland. Nevertheless, first, they are highly effective on sufficiently moistened land (floodplain and low-lying Meadows, normal land and irrigated areas of grasslands), where valuable meadow grasses from the mesophyte group predominate [1-2]. Regular use of fertilizers in optimal doses and ratios that correspond to the nature of the herbage and soil characteristics increases the share of valuable forage species in herbage and creates reliable conditions for maintaining high productivity of meadowland for many years [3-5].

Along with mineral fertilizers, organic fertilizers are used in meadows (manure, including liquid, silt from reservoirs, sapropels, bird droppings, peat, wastewater, green mass of green manure, etc.), primarily on poor low-humus soils, as well as for the purpose of their disposal in Mountain Meadows where there is no arable land [2; 6]. The response of meadow plants to mineral fertilizers is higher than that of field crops. However, the effectiveness of fertilizing meadow grass is largely determined by the ratio of nutrients. On *Poaceae* in herbage, a complete mineral fertilizer, then in descending order nitrogen-potash, nitrogen-phosphorus, nitrogen, potassium-phosphorus, potassium and phosphorus [2], provides the greatest return.

Nitrogen fertilizers are more effective in meadows that are better provided with moisture (lowland and floodplain) with a predominance in herbage *Poaceae* herbs. The highest reaction to the application of phosphorous and potash fertilizers is characterized by *Fabaceae* herbs that, with regular fertilization, last longer in herbage [7]. Nitrogen fertilizers on legume and cereal herbage, in contrast to *Poaceae*, little effective [8]. When applying nitrogen fertilizers, as you know, the growth of *Poaceae* at the same time, conditions of potassium and phosphate starvation are created for *Fabaceae* and there is a displacement of them from the herbage. If there is insufficient potassium supply, valuable grass species fall out and species that can absorb it from hard-to-reach forms spread [9].

In recent years, the interest of sowing herbs has significantly increased on meadowlands of industrial workers and scientists due to the emergence of new technical opportunities and an energy and environmental crisis in the national economy of Ukraine [2]. It was found that seeding *Poaceae* in undisturbed Meadow turf, it does not give positive results in conditions of insufficient supply of nitrogen to the soil. Seedlings that are provided with nitrogen due to its fixation by nodule bacteria take root better. Greater positive effect of seeding *Fabaceae* it is manifested when the soil is sufficiently provided with mobile forms of phosphorus and potassium [10]. For successful sowing, it is necessary to weaken the old coenosis and strengthen the ability of seedlings of sown species to grow rapidly. Better results from this measure are observed in wet growing conditions and in wetter years, in particular in low-lying Meadows than in dry ones [11].

Sowing a legume-cereal mixture in a degenerate Meadow stand quickly improves the species composition of agrocoenoses, reducing the proportion of low-value mixed grasses in feed terms and increasing the productivity of meadowland and feed quality [12; 13]. A similar effect on the structure of reducing coenoses is produced by sowing a cereal mixture, but mineral nitrogen fertilizers provide the increased and stable productivity of these coenoses over the years. Improves the species composition and accelerates the process of stabilization of Meadow coenoses and sowing seeds of wild grass species, which are collected in meadows adapted to certain conditions with natural, but productivity remains low [14].

In the practice of onion farming, the most promising method of creating legume-cereal herbage is sowing perennials *Fabaceae* herbs in loosened strips by combined aggregates [15]. It was found that for seed germination and survival of seedlings, appropriate conditions are necessary, which take root better in places with partially disturbed sod, as well as when draining seeds using phosphorous fertilizers and inoculants. The best results are obtained when sowing *Fabaceae* in a grass stand that has no strong competitors, as well as without the use of nitrogen fertilizers.

The analysis of literature sources on the development and improvement of measures for surface improvement of meadowlands shows that the features of transformation of the species composition of phytocenoses of floodplain mountain meadows of the Carpathians with their surface improvement have not yet been studied. This has become the subject of our research, which is covered in this article.

Research purpose it consists in establishing the features of transformation of the species composition of phytocenoses of floodplain Meadows of the mountain and forest belt of the Carpathians with their superficial improvement.

MATERIALS AND METHODS

Experimental studies on the peculiarities of transformation of the species composition of phytocenoses of Floodplain Meadows of the mountain and forest belt of the Carpathians with their surface improvement were carried out during 2017-2019 in the peasant economy of V.F. Martyshchuk (P. Krasnik Verkhovinsky district, Ivano-Frankivsk region) in the floodplain of the Black Cheremosh river. The soil cover of the experimental site consists of sod-brown-earth shallow underdeveloped carbonate light loamy on alluvium calcites, middle-stony

on the modern alluvium, which is covered with pebbles from a depth of 0.5-1.0 m. The 0-20-cm layer of this soil contains humus – 2.6%, alkaline hydrolyzed nitrogen – 8.4 mg/kg, mobile phosphorus – 4.3 mg/kg, exchange potassium – 7.8 mg/kg with PH Sol. – 5.0 and ecological and agrochemical score-16.

The study was conducted according to generally accepted methods in feed production and onion farming [16]. The size of sown plots is 10 m^2, accounting – 8 m^2. The experiment is repeated four times. The experiment scheme included the following options and factors (table. 1): improvement *factor:* 1) no improvement, 2) $P_{30}K_{60}$, 3) $N_{60}P_{30}K_{60}$, 4) 15 t/ha of manure, $P_{30}K_{60}$ + seeding *Trifolium repens* L. 6 kg/ha for multipurpose use and 5) $N_{60}P_{30}K_{60}$ + seeding the mixture of *Poaceae* (*Phleum pratense* L., 6 kg / ha + *Festuca pratensis* Huds., 10 kg/ha). Factor *usage mode*: 1) haymaking with 2 slopes and 2) multi-slope (imitation of pasture use).

Mineral fertilizers, in doses according to the experiment scheme, in particular, nitrogen in the form of ammonium nitrate, phosphorous – granular superphosphate and potash – kalimagnesia, as well as litter manure, in doses according to the experiment scheme, were applied annually in one period in the spring superficially after snowmelt. Sowing of a mixture of cereals and creeping Clover according to the experiment scheme was carried out once in the spring superficially when laying the experiment in 2017. Mowing of grasses for haymaking use in the first mowing was carried out in the flowering phase of the dominant components of the grass stand, and for multi-mowing (imitation of pasture) and after grass for haymaking use – the height of the grass stand is 15-20 cm.

The species composition of the meadow phytocenosis on the experimental site was studied under the influence of measures for its surface improvement by geobotanical description of grass stands before considering the harvest according to DSTU 4687:2007 [17]. The definition of Meadow plant species and their families was carried out in accordance with the modern nomenclature of taxa [18].

RESULTS AND DISCUSSION

Studies conducted by various authors have established that surface improvement, in particular the introduction of organic and mineral fertilizers and sowing of cereals and legumes of perennial grasses in the sod, has a positive effect on the species composition of Meadow phytocenoses, which in turn has a positive effect on the productivity and chemical composition and nutritional value of feed [2; 19; 20]. In particular, with the introduction of nitrogen fertilizers, growth and development improves and the number of long-term fertilizers increases *Poaceae* herbs and the number of perennials decreases *Fabaceae* herbs and mixed grasses in Meadow phytocenoses. At the same time, their floral saturation decreases. The introduction of phosphorous and potash fertilizers, especially in years favorable for precipitation, leads to an increase in the meadow phytocenosis of perennial plants. *Fabaceae* and reducing the number of *Poaceae*.

Sowing of cultivated species adapted to certain ecological conditions of the growing place, perennial *Fabaceae* without applying nitrogen fertilizers or *Poaceae* by applying these fertilizers, it increases the share of sown species in Meadow phytocenoses. Sowing seeds of wild species on degraded Meadow herbage adapted to certain ecological conditions improves the species composition and accelerates the process of its stabilization [2].

The results of our research presented in the article on the influence of surface improvement measures for floodplain meadowlands with natural herbage of the Black Cheremosh River in the Carpathian Mountain and forest belt on their botanical feed composition are described below. The original herbage before laying the experiment was cereal-mixed with the content of wild plants *Poaceae* 53-54%, mixed grasses – 39-42% and unseeded *Fabaceae* 4-8%, which is clearly visible in Figure 1 in the version without fertilizers.

For both haymaking and multi-mowing use in the fertilizer-free version on average for 2017-2019 studies compared to the first year, the ratio between *Poaceae* and mixed grasses did not change much, although there was a tendency to increase *Poaceae* and reduction of mixed grasses (Table 1, Fig. 1). For $P_{30}K_{60}$, there was an increase in the content of wild perennial *Fabaceae* plants for haymaking use by 2%, and for multicut – by 5%.

For $N_{60}P_{30}K_{60}$ compared to $P_{30}K_{60}$ during haymaking use, an increase was observed in unseeded crops of *Poaceae* by 9% while the content was reduced of *Fabaceae* by 5% and of mixed grasses by 6%. In this case, the multi-year use of cereals increased by 10%, and legumes and various grasses decreased by 7 and 8%, respectively.

When applying manure in comparison with the option without fertilizers, the changes between these botanical groups were similar to the changes that were observed under the action of applying $N_{60}P_{30}K_{60}$ compared to making a $P_{30}K_{60}$, but less pronounced (Table 1). When applying manure in comparison with the option without fertilizers for haymaking use, an increase was observed in the share of unseeded crops of *Poaceae* by 7% when the content was reduced of *Fabaceae* by 2% and of mixed grasses by 5%. For multipurpose use, *Poaceae* increased by 5% in this case, and *Fabaceae* and mixed grasses decreased by 1 and 4%, respectively.

Analysis of the results of sowing a mixture of *Poaceae* herbs and *Phleum pratense* L. and *Festuca pratensis* Huds. in the sod in spring against the background of making $N_{60}P_{30}K_{60}$ for haymaking use showed that the greatest changes occurred with the Botanical composition of the herbage in this case, according to the average data. Total share *Poaceae* compared to making $N_{60}P_{30}K_{60}$ it increased from 67 to 74% or by 7%, and compared

to the option without fertilizers – by 17%, and mixed grasses decreased – by 6 and 13%, respectively. As part of the *Poaceae* Botanical group, the total share of sown grasses increased to 43%, including *Phleum pratense* L. – up to 19%, and *Festuca pratensis* Huds. – up to 24%. At the same time, the number of unseeded *Poaceae* crops decreased by 26% compared to the option with the introduction of $N_{60}P_{30}K_{60}$ and by 22% compared to the option without fertilization.

For multi-year use for sowing in the sod in spring against the background of $P_{30}K_{60}$ *Trifolium repens* L. application according to the data averaged over three years, its share increased by 30%, and the total number of *Fabaceae* increased from 12 to 44% or by 32%, and by 37% compared to the option without fertilization. Simultaneously, the share of *Poaceae* decreased by 16 and 20%, respectively, and that one of mixed grasses by 11 and 6%, respectively.

Analysis of the results of studies by year showed that in this case, the patterns of changes that occurred with the ratio of botanical groups of grass stands, both for haymaking and multi-mowing use, were mostly similar to the results obtained on average over three years (Fig. 1). For haymaking use in the direction from the 1st to the 3rd year, there was an increase in the total share of grass stands *Poaceae* and a reduction in the number of mixed grasses by 3-9%. Against the background of making $N_{60}P_{30}K_{60}$ and for sowing the mixture *Poaceae* these changes were more significant. Among the sown herbs in the variant with sowing a mixture of cereals for three years there was an increase in the content *Phleum pratense* L. and reducing the share *Festuca pratensis* Huds. by 8-13%.

For multi-manual use, the largest share of *Poaceae* in most options, except for the option with seeding *Trifolium repens* L., was in the second year of use. At the same time, this year, in these variants, the lowest share of *Fabaceae* in the herbage (at the level of 3-5%) was also due to adverse weather conditions, resulted from the lack of moisture. Meanwhile, as in the option with seeding *Trifolium repens* L. in the sod, its share was stable during all three years of research in the herbage at the level of 37-40%.

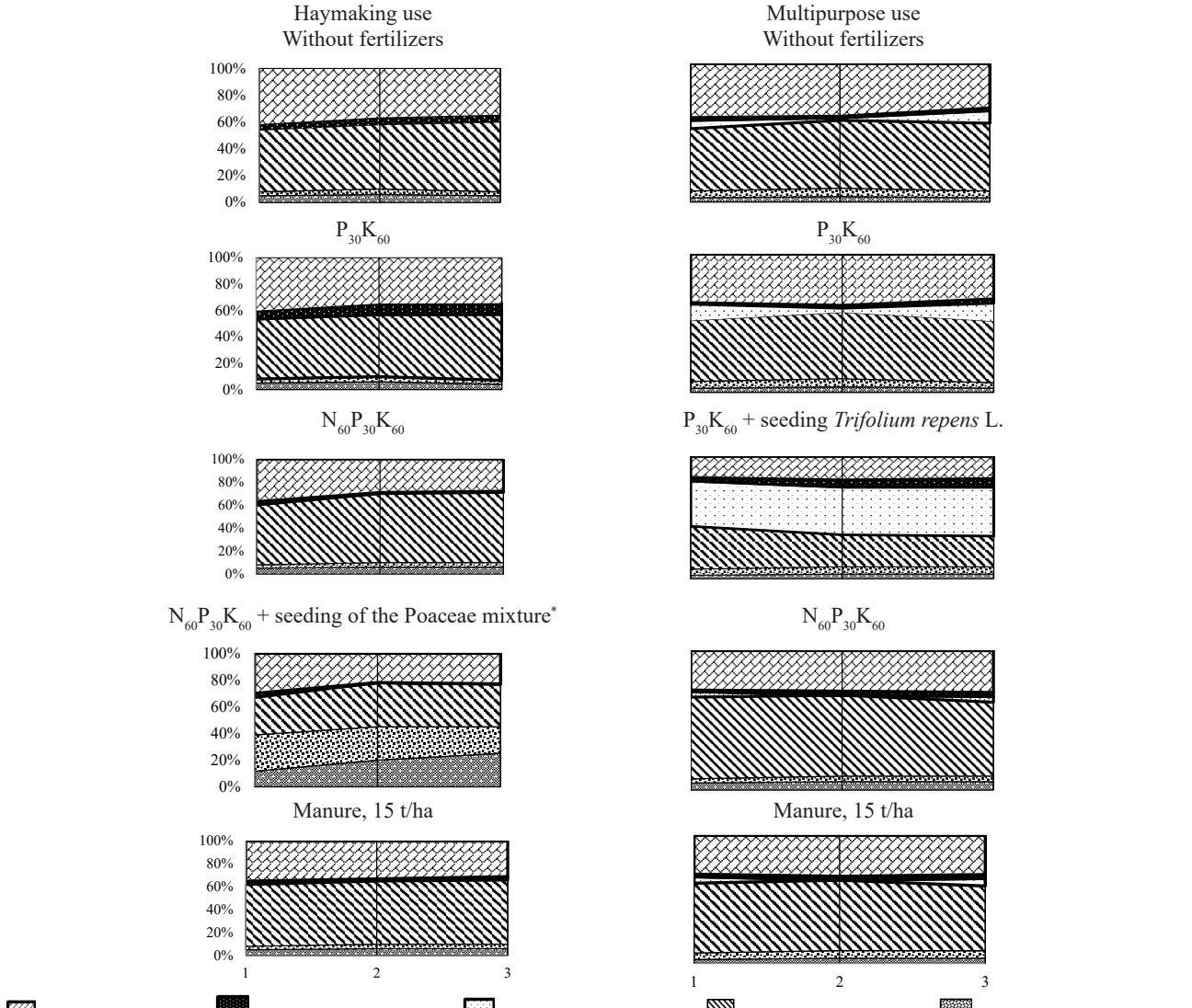

Figure 1. *Botanical composition of the grass stand of floodplain mountain meadows depending on surface improvement measures, 2017-2019, %*

Notes*: 1, 2, 3 – years of use. *Components of the mixture: 1) Phleum pratense L., 6 kg/ha +2) Festuca pratensis Huds., 10 kg/ha*

***Table 1**. Botanical composition of the grass stand of floodplain Meadows depending on surface improvement measures (average for 2017-2019)*

Options for improvement measures	Total *Poaceae*	Including		Unseeded	Total *Fabaceae*	Including *Trifolium repens* L.	Miscellaneous herbs
		By components*					
		First	Second				
Haymaking use							
Without fertilizers	57	5	3	49	5	–	38
$P_{30}K_{60}$	56	5	3	48	7	–	37
$N_{60}P_{30}K_{60}$	67	6	4	57	2	–	31
$N_{60}P_{30}K_{60}$ + seeding of the *Poaceae* mixture*	74	19	24	31	1	–	25
Manure, 15 t/ha	64	6	4	54	3	–	33
HIP_{05}, t/ha							
Multipurpose use							
Without fertilizers	58	3	5	50	7	6	35
$P_{30}K_{60}$	54	3	5	46	12	9	37
$P_{30}K_{60}$ + seeding *Trifolium repens* L.	38	4	6	28	44	39	18
$N_{60}P_{30}K_{60}$	66	6	4	56	5	3	29
Manure, 15 t/ha	63	4	6	53	6	4	31
HIP_{05}, t/ha	3	1	1	3	2	2	2

*Components of the mixture: 1) *Phleum pratense* L., 6 kg/ha +2) *Festuca pratensis* Huds., 10 kg/ha

The results of studies on the study of the floral saturation of the meadow natural grass stand of the floodplain in the third year of use, depending on the measures of surface improvement for haymaking and multi-mowing use are shown in Table 2. Their analysis showed that among the improvement measures in the composition of the meadow phytocenosis of the floodplain, the largest number of species (43) was recorded for multi-peak use in variants without fertilization and against the background of $P_{30}K_{60}$, which is 6 more species than for haymaking use.

***Table 2**. Share of components of meadow grass stand of the floodplain depending on surface improvement measures, % (3rd 2019 year of use)*

Types	Haymaking use				Multipurpose use			
	Without fertilizers	$P_{30}K_{60}$	$N_{60}P_{30}K_{60}$	$N_{60}P_{30}K_{60}$ + seeding of the *Poaceae* mixture*	Without fertilizers	$P_{30}K_{60}$	$P_{30}K_{60}$ + seeding *Trifolium repens* L.	$N_{60}P_{30}K_{60}$
Poaceae								
Cynosurus cristatus L.	5	5	4	2	3	2	–	4
Festuca pratensis Huds.	3	3	4	20	5	4	6	4
Festuca ovina L.	3	3	3	–	8	6	5	8
Festuca rubra L. s. str.	13	13	15	10	15	14	11	18
Calamagrostis arundinaceae (L.) Roth	4	4	6	3	+	+	+	–
Holcus mollis L.	8	6	7	3	9	7	5	9
Agrostis gigantea Roth	3	3	8	7	+	+	+	–
Agrostis canina L.	–	–	–	–	+	1	+	3
Agrostis tenuis Sibth.	1	1	–	–	+	+	–	–
Elytrigia repens (L.) Nevski	5	5	7	4	5	5	–	5
Phleum pratense L.	5	4	6	25	3	3	4	6

Table 2, Continued

Types	Haymaking use				Multipurpose use			
	Without fertilizers	$P_{30}K_{60}$	$N_{60}P_{30}K_{60}$	$N_{60}P_{30}K_{60}$ + seeding of the *Poaceae* mixture*	Without fertilizers	$P_{30}K_{60}$	$P_{30}K_{60}$ + seeding *Trifolium repens* L.	$N_{60}P_{30}K_{60}$
Poa palustris L.	7	7	10	3	2	2	–	4
Poa annua L.	+	+	–	–	3	3	2	–
Briza media L.	–	–	–	–	+	+	–	–
Deschampsia caespitosa (L.) Beauv.	4	4	1	+	5	4	2	2
Total types, %	60	57	71	74	57	52	35	63
Total types, pcs.	13	13	11	10	15	15	10	10
Fabaceae								
Trifolium montanum L.	4	5	1	–	1	2	5	2
Trifolium pratense L.	1	3	–	–	1	1	2	1
Trifolium repens L.	–	–	–	–	9	13	40	4
Total types, %	5	8	1	–	11	16	47	7
Total types, pcs.	2	2	1	–	3	3	3	3
Mixed grasses**								
Arnica montana L.	3	3	3	+	3	3	+	3
Anemone nemorosa L.	+	+	+	+	+	+	+	+
Blechnum spicant (L.) Roth	+	+	–	–	+	+	–	–
Heracleum spondylium L.	+	+	+	+	+	+	+	+
Capsella bursa-pastoris (L.) Medik.	4	4	2	3	4	4	3	3
Rhinanthus alpinus Baumg.	5	5	3	3	5	5	3	4
Rhinanthus minor L.	+	+	–	–	+	+	–	–
Campanula carpatica Jacq.	+	+	+	–	+	+	–	+
Ranunculus acris L.	+	+	+	+	+	+	+	+
Stellaria media (L.) Vill.	+	+	–	–	+	+	–	–
Carum carvi L.	+	+	+	+	+	+	+	+
Leucanthemum vulgare Lam.	4	4	4	4	4	4	4	4
Taraxacum officinale Webb. ex Wigg	5	5	5	4	5	5	2	5
Hieracium viscidulum Tausch	–	–	+	+	+	+	+	+
Cirsium arvense (L.) Scop.	–	–	+	+	+	+	+	+
Clinopodium vulgare L.	+	+	–	–	–	–	–	–
Potentila anserina L.	3	3	3	3	3	3	3	3
Potentila aurea L.	1	1	1	1	1	1	1	1
Potentila argentea L.	5	5	5	4	5	5	2	5
Galium aparine L.	–	–	–	–	+	+	–	–
Plantago lanceolata L.	2	2	2	+	2	2	+	2
Juncus castaneus Smith	+	+	+	+	+	+	+	+
Viola biflora L.	–	–	–	–	+	+	–	–
Equisetum sylvaticum L.	+	+	+	–	+	+	–	–
Rumex carpaticus Zapal.	+	+	+	1	+	+	+	+
Total types, %	35	35	28	23	32	32	18	30
Total types, pcs.	22	22	18	16	25	25	16	19
Cyperacea								
Carex digitate L.	–	–	–	–	+	+	–	+
Carex montana L.	–	–	–	–	+	+	–	+
Total types, pcs.	37	37	30	26	43	43	29	32

***Notes**: * – mix components: 1) Phleum pratense L., 6 kg/ha +2) Festuca pratensis Huds., 10 kg/ha; ** – the amount of mixed grasses is given together with Cyperacea*

It should be noted that for making $N_{60}P_{30}K_{60}$ in comparison with the background $P_{30}K_{60}$ the floral saturation of the studied coenosis decreased from 43 to 29 or by 14 species for multi-year use and from 37 to 30 or by 7 species for haymaking use. The lowest floral saturation was in the variants with sowing perennial grasses in the sod. For sowing the mixture of *Poaceae* herbs on the background of $N_{60}P_{30}K_{60}$ for haymaking use, the total

number of species decreased from 30 to 26 or by 4 species, and for sowing *Trifolium repens* L. for multi-year use on the background of $P_{30}K_{60}$ – from 43 to 29 or for 14 types.

The floral saturation of the phytocenosis in all variants of surface improvement was higher for multi-year use than for haymaking.

Most of the species (25) were from the Botanical group of mixed grasses together with *Cyperacea* with the highest share of 32%, also recorded on the same backgrounds and usage mode. *Arnica montana* L., *Capsella bursa-pastoris* (L.) Medik., *Rhinanthus alpinus* Baumg., *Leucanthemum vulgare* Lam., *Taraxacum officinale* Webb. ex Wigg, *Potentila anserina* L., *Potentila aurea* L., and *Potentila argentea* L., *Rumex carpaticus* Zapal were among the mixed grasses, the share of which was the largest, namely in the range of 1-5%. The remaining species listed in Table 2 were found singly. The modes of Use and fertilization did not naturally affect the share of species from the mixed grass group.

In second place on the same fertilizer options in terms of the number of species (15) was the Botanical group *Poaceae* with a share of 52-57% against the background of $P_{30}K_{60}$ and multi-level usage mode. *Festuca rubra* L. s. str. (14-15%), *Holcus mollis* L. and *Festuca ovina* L. (6-9% each), *Deschampsia caespitosa* (L.) Beauv., *Elytrigia repens* (L.) Nevski, *Festuca pratensis* Huds., *Poa palustris* L. and *Poa annua* L., *Phleum pratense* L., *Cynosurus cristatus* L. (4-5% each) occupied the largest share among *Poaceae* for these options. *Calamagrostis arundinaceae* (L.) Roth, *Agrostis gigantea* Roth. were present for haymaking use in the herbage with a share in the range of 3-8%, while for multi-year use they were found mainly singly. On the contrary, *Poa annua* L. more was in the grass stand for multi-armed use. The total number increased from 10 to 45% for sowing the mixture of *Poaceae* herbs with *Festuca pratensis* Huds. and *Phleum pratense* L. on the background of $N_{60}P_{30}K_{60}$.

The lowest number of species (3) was from the *Fabaceae* group with the highest share (47%) in the variant with seeding *Trifolium repens* L. against the background of making $P_{30}K_{60}$ for multipurpose use. Against the background of making $P_{30}K_{60}$ without seeding *Trifolium repens* L., the share of its wild population was 13%. Due to seeding *Trifolium repens* L., its share increased by 34% in the 3rd year of use. The share of *Trifolium montanum* L. was more under the haymaking regime than under the multi-towed one.

When analyzing the distribution of components by the life span of the meadow grass stand of the floodplain, it was revealed that regardless of the studied surface improvement options and use modes, among all species, most (24-37) belonged to perennials, with a share of 93-98% of the total crop weight (Table 3). Regarding surface improvement measures in both modes of use, the largest number of perennials with the largest percentage of the total crop mass was in the version without fertilizers and against the background of $P_{30}K_{60}$, and least of all for sowing seeds *Poaceae* or *Fabaceae* grass in the sod. With additional application of nitrogen in a dose of N_{60} against the background of $P_{30}K_{60}$ the number of perennials decreased, as well as the total number of species. The number of annuals and biennials was insignificant with fluctuations of 1-5 and 1 species, respectively, with a share of 2-7% and 0-3% of the total crop mass.

***Table 3**. Distribution of meadow grassland components by life expectancy depending on surface improvement measures, 3rd 2019 year of use*

Options for improvement measures	Number of types, pcs.				% Of the total crop weight		
	ʘ	ϴ	ϒ	Together	ʘ	ϴ	ϒ
Haymaking use							
Without fertilizers	4	1	32	37	4	1	95
$P_{30}K_{60}$	4	1	32	37	4	3	93
$N_{60}P_{30}K_{60}$	1	1	28	30	2	-	98
$N_{60}P_{30}K_{60}$ + seeding of the *Poaceae* mixture	1	1	24	26	3	-	97
HIP_{05}, t/ha							
Multipurpose use							
Without fertilizers	5	1	37	43	7	-	93
$P_{30}K_{60}$	5	1	37	43	7	-	93
$P_{30}K_{60}$ + seeding *Trifolium repens* L.	2	1	26	29	5	-	95
$N_{60}P_{30}K_{60}$	1	1	30	32	3	-	97
HIP_{05}, t/ha							

***Notes**: * ʘ – annuals; ϴ – biennials; ϒ – perennials*

The distribution of components by meadow grass stand families of the floodplain, depending on surface improvement measures, is shown in Table 4. Analysis of the results showed that 45 species of meadow plants from 21 families were recorded in the meadow grass stand of the floodplain with different improvement options and different use modes. The following families represented the species that took part in the formation of the meadow grass stand crop: *Asteraceae*, *Araliaceae*, *Fabaceae*, *Caryophyllaceae*, *Polygonaceae*, *Ranunculaceae*, *Poaceae*, *Apiaceae*, *Nelumbonaceae*, *Plantaginaceae*, *Scrophulariaceae*, *Rosaceae*, *Juncaceae*, *Equisetaceae*, *Brassicaceae* etc. Most of the species, namely 15, belonged to the *Poaceae* family. the *Asteraceae* family was the second with 5 types of herbs, the *Fabaceae* and *Rosaceae* families were on the third with 3 types of each, and the *Scrophulariaceae* and *Cyperaceae* families were the fourth with 2 types of each. The remaining families were represented by one species each.

***Table 4**. Distribution of components by families of meadow grass stand of the floodplain depending on surface improvement measures, pcs. (3rd year of Use 2019)*

Families	Haymaking use				Multipurpose use				Total types
	Without fertilizers	$P_{30}K_{60}$	$N_{60}P_{30}K_{60}$	$N_{60}P_{30}K_{60}$ + seeding of the *Poaceae* mixture*	Without fertilizers	$P_{30}K_{60}$	$P_{30}K_{60}$ + seeding *Trifolium repens* L.	$N_{60}P_{30}K_{60}$	
Asteraceae	3	3	5	5	5	5	5	5	5
Araliaceae	1	1	–	–	1	1	–	1	1
Blechnaceae	1	1	–	–	1	1	–	–	1
Fabaceae	2	2	1	–	3	3	3	3	3
Caryophyllaceae	1	1	1	–	–	–	–	–	1
Polygonaceae	1	1	1	1	1	1	1	1	1
Lamiaceae	1	1	–	–	–	–	–	–	1
Campanulaceae	1	1	-	-	1	1	–	1	1
Ranunculaceae	1	1	1	1	1	1	1	1	1
Poaceae	13	13	11	10	15	15	10	10	15
Apiaceae	1	1	1	1	1	1	1	1	1
Nelumbonaceae	1	1	1	1	1	1	1	1	1
Rubiaceae	1	1	–	–	1	1	–	1	1
Cyperaceae	–	–	–	–	2	2	–	–	2
Plantaginaceae	1	1	1	1	1	1	1	1	1
Scrophulariaceae	2	2	1	1	2	2	1	1	2
Rosaceae	3	3	3	3	3	3	3	3	3
Juncaceae	1	1	1	1	1	1	1	1	1
Violaceae	–	–	–	–	1	1	–	–	1
Equisetaceae	1	1	1	–	1	1	–	–	1
Brassicaceae (Cruciferae)	1	1	1	1	1	1	1	1	1
Total families	19	19	14	11	19	19	12	15	21
Total types	37	37	30	26	43	43	29	32	45

In the *Poaceae* family, most of the types were for multi-year use on options without fertilizers and against the background of $P_{30}K_{60}$. Among the surface improvement options, the largest number of families (19) was observed for multi-year use on options without fertilizers and against the background of $P_{30}K_{60}$, and the smallest (11-12) – for sowing the mixture of *Poaceae* herbs on the background of $N_{60}P_{30}K_{60}$ for haymaking use

and sowing *Trifolium repens* L. for multi-year use on the background of $P_{30}K_{60}$.

CONCLUSIONS

Floodplain meadow phytocenoses are mainly cereals and mixed grasses with a share of wild cereals of 57-58% (up to 15 of them % *Festuca rubra* L. s. str. and 5-6% of low-value ones in feed terms *Calamagrostis arundinaceae* (L.) Roth and *Deschampsia caespitosa* (L.) Beauv.), mixed grasses – 35-38% and unseeded *Fabaceae* 5-7%. When applying a set of measures for surface improvement of cereals and mixed grasses, low productive (within 1.95-2.15 t/ha of dry weight) floodplain mountain meadowlands, their species composition improved. For making $P_{30}K_{60}$ the content of wild plants increased by 2-5% *Fabaceae*, A $N_{60}P_{30}K_{60}$ – for 9-10% of unseeded cereals. For haymaking use and sowing a mixture of *Poaceae* with *Phleum pratense* L. and *Festuca pratensis* Huds. against the background of making $N_{60}P_{30}K_{60}$ in the sod in spring, their share increased to 74%, and to 44% or by 32% for multi-year use and sowing *Trifolium repens* L. against the background of making $P_{30}K_{60}$ quantity *Fabaceae* increased.

The highest floral saturation (43 species from 19 families and 93-98% from perennials) was observed in variants without fertilization and with the introduction of $P_{30}K_{60}$ for multi-year use, which is 4-14 species more compared to haymaking use, or with the introduction of $N_{60}P_{30}K_{60}$ and/or with sowing the mixture of *Poaceae* herbs on the background of $N_{60}P_{30}K_{60}$ for haymaking use, or sowing *Trifolium repens* L. against the background of $P_{30}K_{60}$ for multipurpose use.

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Динаміка видового складу фітоценозів заплавних гірських луків Карпат за поверхневого їх поліпшення

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Анотація. Проведеними дослідженнями різних авторів розроблено ряд заходів поверхневого поліпшення лучних угідь у різних ґрунтово-кліматичних умовах. Однак досліджень стосовно вивчення впливу таких заходів поверхневого поліпшення як застосування органічних і мінеральних добрив та підсівання злакових і бобових багаторічних трав у дернину на динаміку видового складу заплавних гірських луків Карпат ще не проводилось, що підтверджує актуальність даного дослідження. У статті наведено результати трирічних досліджень, проведених впродовж 2017–2019 рр. у селянському господарстві Мартищука В.Ф. (Верховинський район Івано-Франківської області) з вивчення особливостей трансформації видового складу природних фітоценозів заплавних луків р. Чорний Черемош гірсько-лісового поясу Карпат під дією поверхневого їх поліпшення із застосуванням органічних і мінеральних добрив та підсівання злакової суміші за сінокісного використання і *Trifolium repens* L. – за багатоукісного використання. Встановлено, що заплавні лучні фітоценози є переважно злаково-різнотравними з часткою дикорослих злаків 57–58 % (з них до 15 % *Festuca rubra* L. s. str. і по 5–6 % малоцінних у кормовому відношенні *Calamagrostis arundinaceae* (L.) Roth та *Deschampsia caespitosa* (L.) Beauv.), різнотрав'я – 35–38 % та несіяних *Fabaceae* 5–7 %. За застосування комплексу заходів поверхневого поліпшення злаково-різнотравних, низькопродуктивних (в межах 1,95–2,15 т/га сухої маси) заплавних гірських лучних угідь покращувався їх видовий склад. За внесення $P_{30}K_{60}$ на 2–5 % збільшувався вміст дикорослих *Fabaceae*, а $N_{60}P_{30}K_{60}$ – на 9–10 % несіяних *Poaceae*. За сінокісного використання за підсівання навесні в дернину суміші *Poaceae* з *Phleum pratense* L. і *Festuca pratensis* Huds. на фоні внесення $N_{60}P_{30}K_{60}$ частка їх збільшилася до 74 %, а за багатоукісного використання й за підсівання *Trifolium repens* L. на фоні внесення $P_{30}K_{60}$ кількість *Fabaceae* збільшилася до 44 % або на 32 %. Найбільша флористична насиченість (43 види з 19 родини та на 93–98 % з багаторічників) спостерігалася у варіантах без внесення добрив та за внесення $P_{30}K_{60}$ за багатоукісного використання, що на 4–14 видів більше у порівнянні з сінокісним використанням, або з внесенням $N_{60}P_{30}K_{60}$ та або з підсіванням суміші злакових трав на фоні $N_{60}P_{30}K_{60}$ за сінокісного використання, або підсівання *Trifolium repens* L. на фоні $P_{30}K_{60}$ за багатоукісного використання

Ключові слова: бобові, злаки, видовий склад, лучний фітоценоз, різнотрав'я, флористична насиченість

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Determination of the Level of Products Novelty Importance for Developing Product Innovative Policy

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Abstract. To substantiate the range of products of the enterprise there is a need to assess the potential of products in terms of the company's ability to manufacture these products, consumer opportunities to meet their needs for these products, and market opportunities to ensure a strategic position among similar products. The study used structural-logical and causal methods of analysis to determine the structure of the novelty of goods. The numerical method of multi-criteria decision making TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) was used to rank the product range of new products according to the level of importance of novelty. Weights of individual components to assess the importance level of novelty in the enterprise were determined by the method of analysis of hierarchies of T.L. Saati. The study used the classification of novelty by its functional focus, according to which consumer, market, and manufacturing novelty of goods are distinguished. The importance of novelty for the manufacturer is the conformity of the product to its innovative development strategy, determination of its place in the market, and prospects for further activities. The importance of the novelty of a new product for the company is proposed to be defined as a measure of the importance of the novelty level of the product for the development of the optimal product range in the product innovative policy of the enterprise. To assess the level of significance of the novelty of goods, criteria of novelty by its types were proposed. According to the results of the study it was found that industrial novelty characterizes the level of use of new technologies in the enterprise, market – the position of a new product on the market among analogues, and consumer – the level and way to meet consumer needs. Further research should relate to the development of appropriate guidelines for the formation of product range and its management based on the assessment of the level of significance of novelty

Keywords: novelty, novelty importance, level of novelty, level of novelty importance, product innovative policy

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INTRODUCTION

The development of a product innovative policy at the enterprise is one of the priority tasks for achieving the main goal of the enterprise – to increase profits. The definition of a product innovation strategy and ways to develop and implement a product innovative policy depend on many factors: the manufacturing industry, market share, internal capabilities of the enterprise, the level of competition, the purchasing power of potential buyers, the life cycle of manufactured goods, etc. The development of the company's product innovative policy is dynamic and requires constant monitoring of new requirements, opportunities, and achievements in the field of enterprise activity.

Making a decision to release a new product for any company is difficult and quite risky. When bringing another new product to the market, the manufacturer believes that the novelty that the new product is endowed with is sufficient for the consumer to perceive. However, the consumer and the manufacturer may perceive the novelty of a new product ambiguously, and the result of such ambiguity is that the novelty will not stay in the market, that is, there will be a situation of its complete failure [1].

Today, there is no single comprehensive system for classifying the types and levels of the novelty of goods. Existing approaches address only some aspects of this classification. The most universal and appropriate method for developing a methodology for determining the overall level of importance of product novelty is the classification of novelty according to its functional orientation. Elements of classification by functional orientation are covered in the studies of E.I. Nahornyi [1], Yu.S. Shiryaeva [2], P.R. Dixon [3], N.S. Kubyshyna, and A.P. Stasevych [4], E.M. Popovych, N.S. Kubyshyna [5], A. Lau, R. Yam, E. Tang [6], P. Sarkar, A. Chakrabarti [7].

The manufacturer expects that the level of novelty of the product offered to the market will be evaluated by potential buyers and will lead to an increase in sales volumes. If a product is a big seller, improving or modifying this product is not as important for the manufacturer as introducing a new product or modifying and upgrading an existing one which may lose its position. Therefore, the identification of symptoms of possible deterioration of the novelty of innovative products is important for the development of the product innovation range of the enterprise.

The level of market novelty is determined by the unique properties of the product among similar products on the market. This is determined by the extent to which the product has competitive advantages in the market and how sustainable they are. Consumer novelty is developed in the mind of the consumer and characterises the measure and method of meeting one's existing and new needs. This is determined by how much the product characteristics meet the requirements and needs of the consumer, and how much consumers want to purchase this product. However, in the scientific literature, the manufacturing, market, and consumer novelty of products that are planned to be put on the market are considered separately. Therefore, there is a need for a comprehensive analysis of the importance of product novelty from the standpoint of all three aspects: manufacturing; market, and consumer.

The object of research is the level of novelty of new products that are planned to be introduced to the market; the assessment of the importance of novelty will help dairy enterprises substantiate the most effective product assortment portfolio when developing a product innovative policy.

The purpose of the study is to construct methodological tools for assessing the level of importance of novelty in the context of the development of product innovative policy on the example of dairy industry enterprises.

LITERATURE REVIEW

Numerous researchers from different perspectives considered the problems of the novelty of goods, the research was aimed at determining the classification features of new goods and types of their novelty and innovations, the methodological foundations for the development of a commodity innovative product range.

J.-J. Lamben [8] considered in detail the issues of industrial marketing from the standpoint of creating value for the consumer, managing relationships with consumers and a trademark, developing new value propositions. He considers the development of consumer value for new products and its place in developing a product innovative policy.

F. Kotler, G. Armstrong, D. Saunders, W. Wong [9] to a greater extent considered the market aspect of the development of the product innovative policy of the enterprise. This is an issue of developing a new product from the standpoint of ensuring its competitiveness and substantiating the competitive strategies of the enterprise.

G. Sun, R. Govind [10] established that the level of product diversification in the market can cause positive and negative effects in the company's activities. They considered the market aspect of product diversification and suggested determining the level of its feasibility and dependence on the level of market turbulence.

T. Brzęczek [11], having considered the issue of expanding the product range, offers a methodology for analysing the company's product portfolio based on sales forecasting and assessing the effectiveness of product diversification. He established that the decision to introduce a new product or discontinue it from manufacturing should be grounded not by financial performance indicators, but from the standpoint of forecasting sales volumes. This determines the market aspect of the feasibility of introducing the product to market.

S.M. Ilyashenko [12], S.M. Illiashenko, Y.S Shypulina, N.S. Illiashenko [13] examined the content of the product innovative policy of the enterprise and the methodological basis for choosing priority areas for its development, considering the internal and external conditions of innovation activity at the enterprise. Special attention was paid to substantiating the modification of the product range from the standpoint of its development life cycle. The criteria for assessing the product range includes the following: the level of demand, the level of profitability, the level of risk, adaptive capabilities, the level of competitiveness and the use of strategic potential. These five assessment criteria cover mainly the market and consumer aspects of introducing new products to the market.

V.M. Kobelev, O.S. Proshutya [14] considered the success factors of introducing a new product to the market, among which the leading place is occupied by competitive strategies.

E.I. Nagorny [15] proposed a methodology for assessing the novelty of innovative products and products that have been on the market for a long time. The proposed methodology is based on determining a set of properties of innovative products that characterise its radical change relative to its market counterpart.

N.S. Kubyshyna, A.P. Stasevych [4] proposed a model for launching a new product on the market for a milk processing enterprise based on the use of tools for developing a product range and the concept of a new product. In general, the proposals relate to the development of a product and market strategy for a new product.

M. Nieto, L. Santamaría [16] noted that radical innovations are critical factors for product success in the market, and the level of product innovation is considered as the level of its novelty. The authors considered the role of a cooperative strategy, the type of partner, and the variety of shared networks to achieve a higher level of novelty of innovative products.

W.-L. Hsieh, P. Ganotakis, M. Kafouros, Ch. Wang [17] examined the level of innovative novelty from the standpoint of the type and geographical location of partners, and in the context of whether the enterprise is engaged in open or closed innovations.

J. Qiu, X. Li, Y. Duan, M. Chen, P. Tian [18] and R. Chan, Z. Li, D. Matsypura [19] considered the issues of developing an assortment policy and optimising it for trade enterprises from the standpoint of determining its consumer value.

D. Tok, X. Chen, X.-Y. Chu [20] considered the factors that influence the consumer's evaluation and choice of goods, the market value of the goods.

J. Richetin, E. Demartini, A. Gaviglio, E.-C. Ricci, S. Stranieri, A. Banterle, M. Perugini [21] conducted a study of food attributes that are important to the consumer, focusing on various manufacturing processes labelled as "conventional" or "industrial". Thus, they considered the value of the product in terms of its technological capabilities.

Nevertheless, special attention should be paid to solving the problem of determining the level of importance of the product novelty as its quantitative characteristic for further use as a tool in marketing testing of a new product and deciding whether to expand or discontinue its manufacturing.

MATERIALS AND METHODS

To achieve the purpose set, it is proposed to rank the product range of the enterprise that is planned to be launched on the market, in terms of determining the level of importance of novelty. To rank the product range of new products, the TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution) method was used, which is one of the numerical methods for making multi-criteria decisions. The TOPSIS method was first developed in 1981 by C.L. Hwang, K. Yoon [22; 23]. This method is based on the statement that the chosen alternative should be the closest to the ideal best solution and the farthest from the ideal worst solution. This method allows comparing many alternatives based on several criteria. TOPSIS has a simple mathematical apparatus, in addition, using computer support, it is a fairly convenient practical method. Figure 1 schematically shows the hierarchy of the task of ranking the product range of new products at dairy enterprises by the level of importance of novelty for the enterprise.

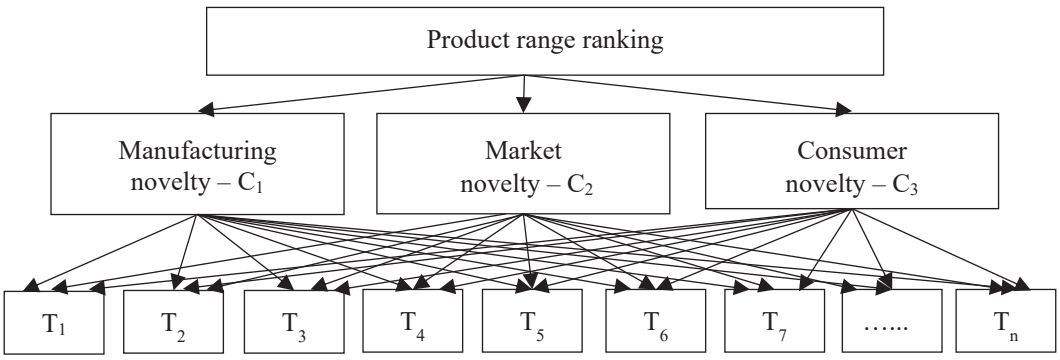

***Figure 1**. Hierarchy of the task of ranking the product range of new products by the level of importance of novelty for the development of product innovative policy*

***Source**: created by the authors*

Table 1 shows the scale of the point assessment of the level of the market, manufacturing, and consumer novelty and the characteristics of the importance of novelty to rank the product range.

***Table 1**. Interpretation of the results of assessing the market, manufacturing, and consumer novelty and the overall level of importance of product novelty in accordance with the desirability scale of E. Harrington*

Novelty levels	Interval of the novelty indicator
Radical novelty (pioneer product)	[0.81-1.00]
Clear, substantial novelty	[0.64-0.80)
Satisfactory novelty	[0.38-0.63)
Minor novelty	[0.21-0.37)
Dubious novelty	[0.00-0.20)

***Source**: built based on [24]*

To develop an effective methodology for determining the level of importance of novelty, it is necessary to perform the following tasks:

– determine novelty types;

– select determining factors for each type of novelty;

– select appropriate measurement indicators for each type of novelty;

– define formulas for calculating the level of novelty;

– make payments;

– make the results on each type of novelty for calculating the integrated indicator consistent;

– analyse the obtained research results and develop managerial influences regarding the work with the analysed assortment.

After determining the structure of different types of novelty for new products and establishing their main characteristics, which are most important when introducing a new product to the market, the level of importance of novelty by its types is determined. The desirability scale of E. Harrington is used to rank and interpret the indicator of the general level and individual structural components of novelty importance (Table 1) [24]. This scale belongs to the psychophysical ones, it is used to establish a correspondence between physical and psychological parameters.

According to the TOPSIS methodology the multicriteria assessment of the priorities of the importance of identified new products occurs in the following sequence of stages:

First step. Development of a scale for identifying goods by the level of importance of novelty by its individual components (Table 2). A questionnaire was created to assess each component of novelty. The working group consisted of 12 experts with appropriate competencies and powers. Technologists, marketers, managers, and specialists in various fields of activity of dairy enterprises took part in the survey.

***Table 2**. Desirability scale of E. Harrington to assess the characteristics of the importance of novelty of new products according to the criteria for substantiating the product range*

Level of importance of novelty	Characteristics of novelty importance by criteria		
	(C_1) manufacturing	(C_2) market	(C_3) consumer
[0.00; 0.20)	Modification of the parameters	The product does not have the market novelty present in competitors, demand falls	Change in consumer habits
[0.02; 0.37)	Improvements and minor parameter changes	The product is not unique, some competitors have it in their portfolio, demand is stable	Change in the level of satisfaction of a need
[0.37; 0.63)	Substantial parameter change	The product has certain functional advantages over similar ones, demand is growing	Change in the way of meeting a need
[0.63; 0.80)	Qualitative transformation of functions and operating principle	The product differs considerably from similar products on the market, demand is growing	Creation of a new need
[0.80; 1.00]	The emergence of qualitatively new functions and operating principle	There are no analogues of the product on the market, yet demand is forecasted	Attraction of a new consumer

***Source**: compiled by the authors*

The second step. The normalisation of the matrix of certain assessments (i.e., obtaining a dimensionless matrix) by the formula:

$$t_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{n} x_{ij}^2}} \quad (1)$$

i – number of analysed products; i=1...n; j – the number of criteria used to assess new products, j=1...3.

As a result of behavioural normalisation, a normalised dimensionless matrix in which all values vary from 0 to 1 is obtained.

The third step. Normalised assessments are weighted according to the weight coefficients of the criteria for the types of novelty of goods. The weight of the assessment criteria is also determined by experts as a result of the survey conducted.

$$T_{ij} = t_{ij} w_{ij} \quad (2)$$

w_j – weight j – of criterion for assessing the type of novelty of the product j=1...3.

Fourth step. Calculating the squares of distances to T_j^+ (maximum value T_{ij} by j) and T_j^- (minimum value T_{ij} by j). As a result, S_i+ and S_i- is calculated for each product according to the formulas:

$$S_i^+ = \sqrt{\sum_{j=1}^{n} (R_{ij} - R_j^+)^2} \quad (3)$$

$$S_i^- = \sqrt{\sum_{j=1}^{n} (R_{ij} - R_j^-)^2} \quad (4)$$

The fifth step. Risk rating using the formula:

$$R_i = \frac{S_i^-}{S_i^- + S_i^+} \quad (5)$$

Similarly, a multi-criteria assessment of other risks is conducted. The consistency of experts opinions was checked by the concordance coefficient using the formula:

$$K_{con} = \frac{12 \cdot \sum_{j=1}^{n} {d_j}^2}{m^3 (n^3 - n) - m \sum_{i=1}^{m} T_i} \quad (6)$$

$$d_j = S_j - \frac{\sum_{j=1}^{n} S_j}{n} \quad (7)$$

$$S_j = \sum_{i=1}^{m} R_{ij} \quad (8)$$

$$T_i = \sum_{l=1}^{L} ({t_l}^3 - t_l) \quad (9)$$

where n – number of parameters studied; m – number of experts; where L – number of groups of linked ranks; t_l – the number of linked ranks in each group.

The statistical value of the concordance coefficient is checked using the Pearson criterion, which is calculated using the formula:

$${\chi_p}^2 = \frac{\sum_{j=1}^{n} {d_j}^2}{m \cdot n(n+1) - \frac{1}{n-1} \sum_{i=1}^{m} T_i} \quad (10)$$

Using an integral indicator of the level of novelty of a product, arbitrary goods for various purposes can be compared, and the level of innovative activity of the enterprise can be determined. Yet commonly, indicators of the level of importance of commodity, consumer and market novelty separately are much more useful. When developing and launching a new product on the market, the manufacturer will use different strategies depending on the values of these indicators.

RESULTS AND DISCUSSION

Determination of the novelty structure to assess the level of its importance

When substantiating the range of products that are planned to be introduced to the market, it becomes necessary to assess the potential of products in terms of the ability of the enterprise to manufacture these products, the ability of consumers to meet their need for these products, and the ability of the market to ensure the strategic position of products among similar products-analogues of competitors.

For that purpose, it is proposed to use the level of importance of product novelty. Therefore, it is necessary to clarify the content of the concepts "level of novelty" and "the importance of novelty" for new products that are planned to be launched on the market.

Level of novelty– a measure of the difference between a new product and similar products that are already known to the market and consumers.

Development and optimisation of the product range, determination of the location of a new product is one of the main tasks of the company's product innovative policy. Each product group in general and each product in particular occupy a certain place and are important for the enterprise. The Explanatory Dictionary of the Ukrainian language edited by I.K. Bilodid defines the term "important" as having an outstanding value; serious [25]. For the manufacturer, all products are important, otherwise, they would have been discontinued, each product has its own level of importance.

Product importance for an enterprise is proposed to be defined as a measure of the importance of manufacturing goods in accordance with the achievement of the main goal of the enterprise's activity and ensuring competitive advantages.

The level of importance of novelty for certain types of products is often a more informative indicator for assessing and making decisions about certain actions in relation to this product.

The criteria for determining the level of importance of a product from the standpoint of an enterprise can be the following:

- the product is a brand identity of the TM;
- share of goods in total manufacturing;
- profit from the sale of goods;
- product novelty;
- availability of raw materials;
- sales network;
- logistics network;
- market segment.

The share of each assortment group of goods and each product separately at the enterprise is determined depending on demand, manufacturing capacity, availability of raw materials, profit from sales and other factors. By introducing a new product to the market, the manufacturer determines and evaluates its place in its product range and in the market. In addition to the presence of novelty in the product, the importance of this novelty for the manufacturer, its compliance with innovative development strategy, the establishment of its place in the market, and prospects for further activity are crucial [26].

Importance of novelty of a new product for an enterprise is proposed to be defined as a measure of the importance of the level of novelty of the product for the development of an optimal product range in accordance with the product innovative policy of the enterprise. The importance of the novelty of the same new product for different enterprises may vary, depending on the position of the enterprise in the market, on the state of material and technical support, image, position among competitors in the market, etc.

Analysis of researchers' approaches to determining the importance of types of novelty has shown that the most appropriate way to develop a methodology for determining the overall level of novelty of a product is to classify novelty according to its functional orientation. According to this criterion, consumer, market, and manufacturing novelty of the product is distinguished, the characteristics of which are shown in Table 3.

***Table 3**. Main characteristics of product novelty by its types*

Feature	Types of novelty		
	Manufacturing	**Market**	**Consumer**
Content	Characterises the level of use of new technologies, a new way of organising manufacture, and new raw materials in the manufacture of goods	It is determined by the share of a new product among similar products at a certain point in time and characterises the level of consumer awareness about the product and its properties	Characterises the measure and method of meeting existing and new consumer needs with a new product in comparison with previously known ones
The one who determines	**Manufacturer**	**Manufacturer and consumer**	**Consumer**
Assessment indicators	– organisation of manufacturing; – raw materials for manufacturing; –manufacturing technology; – external product parameters; – manufacturing equipment	– volume of advertising – list of trademarks, brands; – product image; – marketing campaign; – time and methods of information dissemination; – share among analogue products; – volume and geography of sales markets; – emergence of the next new product	– appearance; – price; – consumer properties; – level of satisfaction of the need; – quality; – safety; – after-sales service; – receptor properties (taste, smell, touch); – symbolic and status characteristics; – aesthetic qualities

***Source**: developed based on [6-7]*

The overall novelty importance indicator should be calculated using novelty importance indicators for each of its types separately since in most cases they have different values and indicate different advantages of new products. Therefore, it is necessary to determine the main components of a particular type of novelty, that is, to form a structure of novelty of the product, based on which the importance of each type of novelty of the product will be assessed. To assess the level of importance of the novelty of goods, the proposed criteria for novelty by its types are presented in Figure 2.

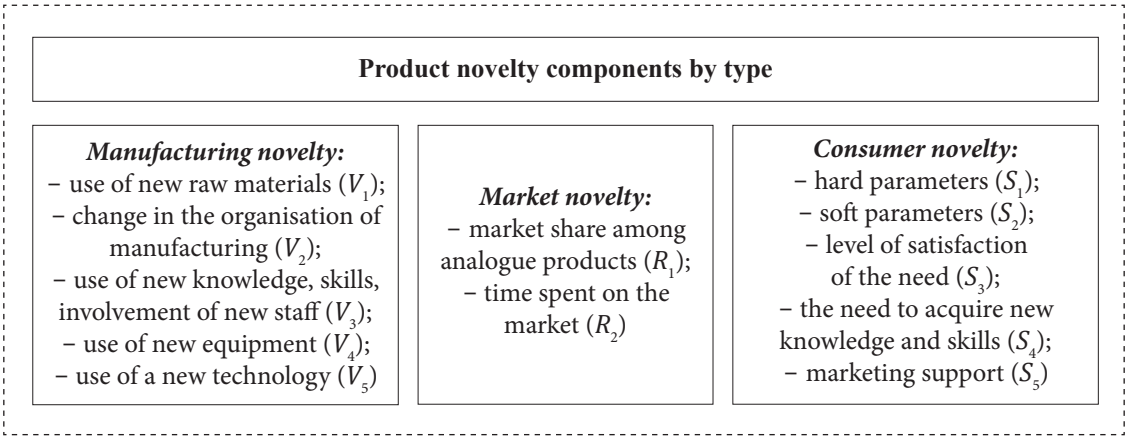

Figure 2. *Product novelty structure by components*

Source: *compiled by the authors*

Hereinafter the content essence of each component of the developed structure of product novelty by its types with the substantiation of the selected assessment criteria is considered.

Manufacturing novelty characterises the level of technological and technical changes in the product, the level of knowledge intensity, the need for new equipment, and accordingly, is in direct ratio to the invested funds, it is acquired during the manufacturing process. To understand the essence of this definition, the main stages and components of product manufacturing need to be considered.

Manufacturing is a set of interrelated labour and natural processes, as a result of which raw materials and materials are transformed into finished products. It provides for the availability of professional knowledge and skills and requires a complex combination of them with decisions, actions, is the main task of management, and an important area of investment in business, is responsible for most of the recruitment, the main means of meeting consumer requests, and is a decisive factor in the profitability of the enterprise and its development. To increase the competitiveness of finished products, the manufacturing process must add value to them.

Using a simple resource-product model, manufacturing is defined as a recycling process in which the cost of manufacturing a product that consumers need is added to the resource.

Resources for manufacturing are natural, human, and material, used for the manufacturing of finished products. Each of these types of resources has a certain number of properties, and the common property of all resources is scarcity, which results in a limited volume of manufacturing and the desire for their best use.

Determination of manufacturing novelty is the exclusive right of the manufacturer since only they have complete information about all the conditions of manufacturing goods, about the features of the organisation of the manufacturing process at the enterprise, about the manufacturing potential of the enterprise, so the group of experts that determines manufacturing novelty should consist of specialists who created the product from its idea to promotion to the market. They directly affect the decision-making on putting new products into the manufacturing and discontinuing the manufacturing. To assess the manufacturing novelty of the product, the indicators shown in Figure 2 are used, which reflect the manufacturing potential of the enterprise for manufacturing new products.

Market novelty characterises, firstly, the market share, which is determined by the position of the product among competitors, the marketing complex, innovative methods of promotion and sale of a new product, secondly, the time to enter the market, which includes the speed of innovation activity, flexibility, and readaptation to rapidly growing and changing consumer requirements.

Thus, the main indicators that characterise the level of market novelty of a product are the time of product entry into the market and the share of projected sales volume (Fig. 2). The selected indicators best reflect the advantages of this product in the market and the opportunities to be implemented to expand the market share. These indicators denote the level of market development today and the possibility of its growth in the future. Moreover, the level of influence of these indicators correlates.

Consumer novelty characterises the product in terms of meeting a new need or other levels of satisfaction of the need. The rapid level of change in needs, their growth, and insistence are the main characteristics of the modern consumer. Accordingly, high requirements are put forward: to the marketing complex, product positioning, the creation of such a novelty in the product that will be perceived by the consumer. Important in this case is the preliminary development of consumer needs for this product and the subsequent desire to purchase it. Definition of *consumer novelty* is the most complex since each consumer subjectively perceives the level of change in a new product and assesses those properties of the product that cannot be measured by physical assessments.

The problem of quantifying the size or property of an object that is not measured in physical units was solved by researchers in qualimetry. Notably, the issue of a quantitative assessment of the quality level is simpler, since certain state standards and technical conditions for the manufacturing of each type of product are defined by law, that is, there is a certain standard for comparison. When determining the importance of novelty, there are no standards or certain regulatory requirements. The object of comparison is taken as the nearest product-analogue or a generalising image of the most similar products previously known to the consumer.

Regarding consumer novelty, a product can take a considerable place among a number of analogues and substitutes, that is, become competitive in the market, only being of high quality, meeting certain generally accepted quality standards. In addition, the product must meet the obvious expectations of the consumer: technically (the type of operation), aesthetically, and pricewise. Product quality in marketing is the level of satisfaction of the need, solving the problems of the consumer. Therefore, quality for the consumer can be assessed by a number of consumer parameters of the product, which are criteria for consumer novelty and will be used to assess it (Fig. 2).

Quite important and relevant is the issue of determining the level of novelty of a product, by its different types and by the general level of novelty, which would allow comparing not only homogeneous goods but also any arbitrary goods. The main reasons for the difficulty of finding this indicator are the lack of certain legal requirements and provisions for recognising a product as new, limited and insufficient information, subjectivity and relativity of researchers' estimates, and the time of existence of the product.

Innovative support for the development of product innovative policy of dairy industry enterprises

Dairy products are everyday goods, and an important role for the buyer is played by their image and brand name, habits, price level, the naturalness of components, quality, etc. As a rule, consumers prefer dairy products of the same brand, and for them to change their habits, the level of consumer novelty should be noticeable or, with the same level of consumer properties and quality, the price should be lower.

Innovative products are divided into "new for the market" and "new for the enterprise". Over the past ten years, the food industry products in Ukraine, which are new to the market, accounted for an average of about a fifth of the innovative products sold [27]. Over the past three years, the dairy industry has consistently accounted for 11.4% of food products sold. The share of consumer spending on dairy products was about 15.0% of total food expenses, while the consumption of dairy products per person was less than 50% of the scientifically based standard [28].

The main trends in the development of dairy cattle breeding and the dairy industry in Ukraine are: 1) a decrease in milk manufacturing; 2) a decrease in milk consumption per person; 3) an increase in the average annual milk yield from one cow (over the past ten years – a doubling); 4) an increase in the level of profitability; 5) a stable level of self-sufficiency in milk.

The dairy market is highly competitive and differentiated, with a large number of assortment groups and assortment items in each. There are no radically new products. The main part of new products is modified and upgraded analogue products, in which consumer and/or functional properties have been changed to a certain extent.

Analysis of the innovative activity of dairy enterprises of Ukraine in 2015-2019 showed that the following trends can be noted: the volume of innovative products sold increased 1.9 times; the share of innovative dairy products in the entire dairy increased from 11.6% to 16.3%; the share of innovative dairy products in the food innovation industry was on average at the level of 11.4%; the share of innovative products of the dairy industry, which is new to the market, did not have stable dynamics, averaged 20% of all innovative products; the number of innovatively active enterprises was in the range from 23 to 31 enterprises (of which 15 to 26 enterprises introduced innovative products) [27]. The number of new products per enterprise that introduced commodity innovations in the food and dairy industries is shown in Figure 3.

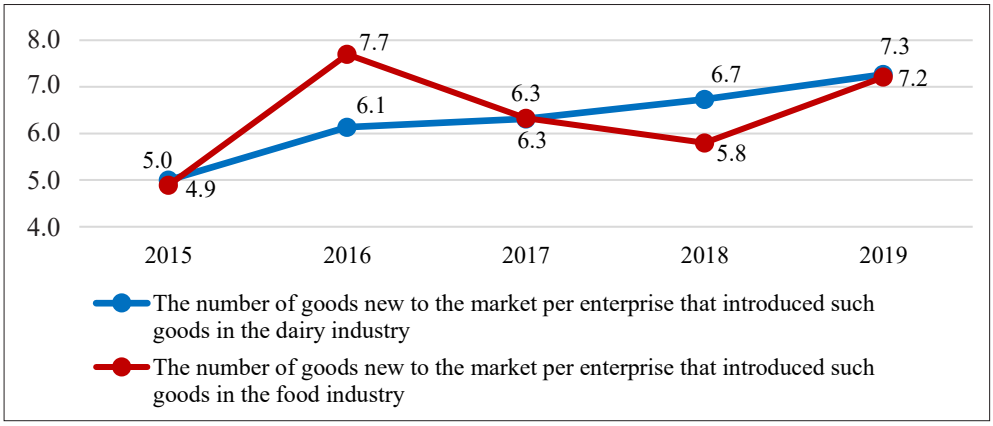

***Figure 3**. The number of new products per enterprise that introduced innovations in the food and dairy industries*
***Source**: calculated by the Author according to the State Statistics Service [27]*

Determination of the level of novelty of new products was conducted according to the methodology developed by the All-Union Institute of Technical Aesthetics, which is proposed in the studies of V.F. Grinev [29], A.N. Romanov, Y.Y. Korlyugov, S.A. Krasilnikov [30] for five dairy industry enterprises (LLC "Lubenskyy molochnyy zavod", Dairy Company LLC "Galychyna", "Fh Tetyana 2011", LLC "Yagotynsky butter plant", LLC "Favor"). The novelty levels and innovative changes by the dairy product groups are shown in Table 4.

***Table 4**. Innovative changes in dairy products of the studied enterprises in accordance with the level of novelty*

No.	Subgroup name	Change in product parameters according to the level of novelty			
		(0%; 20)	[20%; 30%)	[30%; 50%)	[50%; 70%]
1	Milk	New packaging	New packaging, new fat content, extended shelf life	–	Lack of lactose
2	Kefir	New packaging	–	Probiotic supplements, omega 3, new fermentation method	Lack of lactose
3	Yogurt	New packaging, addition of a different flavour	New packaging, new fat content, addition of new flavour, new density	Addition of probiotics, beneficial bacteria, new fermentation method, new thickness	Lack of lactose
6	Ice cream	New packaging	Addition of a new flavour	–	McShake liquid ice cream
7	Fermented milk products (dessert, drink)	–	Addition of a new flavour, new packaging	–	New product ayran, iolakton, herolakt, biolakt, new sour milk product

***Source**: compiled by the authors*

During the study period, all enterprises actively introduced new products with different levels of novelty; products with a slight level of novelty – milk and butter in new packaging, yoghurts with the addition of new flavours. Most of these products were manufactured by LLC "Galychyna" and LLC "Favor". Products with a low and medium level of novelty – products with the addition of new flavours, packaging of a different level of quality and safety, the addition of various vitamins, bacteria, new fermentation methods, a considerable change in the consumption period. Such products were introduced by all the enterprises studied. Products with a high level of novelty – products that were first manufactured at the enterprise and given that dairy products of different manufacturers are very similar, they can be considered market novelty products: liquid ice cream, cream desserts, soft cheese, fermented dairy products for special nutrition, sourdough, herolakt, iolakton, ayran, lactose-free dairy products, goat's milk products, etc. The largest innovators in this segment were LLC "Yagotynsky butter plant" and "Fh Tetyana 2011". Qualitatively new products with a high level of novelty were not introduced into manufacturing.

Assessment of the level of importance of novelty of new products on the example of dairy industry enterprises

Hereinafter the importance of the novelty of new products using the TOPSIS method is considered. Criteria C_1, C_2, C_3 (Fig. 1) determine assessments of the importance of the novelty of a new product for the enterprise, respectively, manufacturing C_1 (technological change, level of manufacturing costs, quality, cost), market C_2 (characteristics of market attractiveness, marketing complex), and consumer C_3 (development of a new need, a new level of satisfaction of the need) changes.

At the first stage, the structure of novelty and its main indicators were determined to assess the level of importance of novelty of new products. The results of the study are shown in Table 3 and Figure 2.

To determine the weight of each component of novelty, the method of analysing the hierarchies of T.L. Saati is used [31]. According to this method, indicators for various criteria are compared using a nine-point scale. Comparing two objects A and B for priority or changes in a certain parameter of one of the objects, certain levels of the studied indicators and their corresponding preference ratings are highlighted (Table 5). Comparing assessments of changes in all indicators allows setting their priorities and provides them with a numerical assessment of advantage, which is a prerequisite for determining the level of novelty.

Enterprises differ in capacity, sales market priorities, and product range features, so the weight of criteria for assessing overall importance should be determined by experts for each enterprise separately.

***Table 5**. Levels and assessments of changes and advantages of A and B objects*

Level of change between A and B	Assessment	Advantage level between A and B	Assessment
No change	1	Equally important	1
Minor change	3	Slight advantage of A over B	3
Considerable change	5	Considerable advantage of A over B	5
A clear change	7	A clear advantage of A over B	7
A clear absolute change	9	Absolute advantage of A over B	9
Intermediate change values	2, 4, 6, 8	Intermediate preference values	2, 4, 6, 8

***Source**: [31]*

The proposed methodology was tested at dairy enterprise LLC "Favor" TM "AMA". This is a medium-sized dairy company that is not a market leader. The main competitive advantage is a niche position. Most of the products (75%) are marketed as medical products, for special dietary nutrition and infants. The main consumers are children's educational institutions, medical and health-improving institutions. Effective new methods of organising product promotion are delivery of goods to the consumer by own transport, an online store, various promotions and gifts for the holidays. The last year has shown the need to find new markets, as most educational institutions were closed during quarantine conditions. Therefore, the expansion of the delivery boundaries can be recommended (new consumers of health-improving institutions), online delivery.

The company is engaged in internal research as it has highly qualified personnel (1 professor and 2 candidates of technical sciences). The company uses technologies with a short (up to one day) consumption period while preserving all the nutritional properties.

Table 6 shows the weight coefficients of individual components for assessing the level of novelty importance at the Favor LLC.

***Table 6**. Weighting factors w_j to assess the importance of manufacturing (C_1), market (C_2), and consumer (C_3) novelty of products of Favor LLC*

Enterprise	Weighting factors w_j			Coefficient of consistency of expert opinions
	Criterion C_1	Criterion C_2	Criterion C_3	
Favor LLC	0.225	0.324	0.451	0.621

***Source**: compiled and calculated by the authors*

The second step. The normalisation of indicators for assessing the level of novelty importance is conducted using the formula (1). The study was conducted for 20 products of Favor LLC, the novelty characteristics and product coding are shown in Table 7.

***Table 7**. Characteristics of novelty and coding of the studied types of dairy products of Favor LLC*

Product code	Product name	Novelty
$A_{3.1}$	"Naturel" yoghurt	Natural sourdough, new packaging
$A_{3.2}$	Plain yoghurt	New packaging
$A_{2.1}$	"Omega 3" kefir	New design, omega 3 added to the ingredients
$A_{1.1}$	"Kakao-moloko"	New packaging
$A_{9.1}$, $A_{9.2}$, $A_{9.3}$	Fermented dairy products "Do snidanku" with mushrooms, a mixture of herbs, paprika	New product with new cream-based flavours
$A_{6.1}$	"Albuminnyi" cheese	New product, 15 mineral elements, albumin
$A_{6.2}$	"Liubytelskyi" brine cheese with herbs	New taste
$A_{3.3}$	"Krem-briule z karamelnym smakom" yogurt	New taste
$A_{9.4}$	Fermented milk drink "Iolakton zi steviieiu"	A new product containing acidophilic bacilli, bifidobacterium, and streptococcus
$A_{3.4}$	"Strachatella" yogurt	New flavour with the addition of chocolate powder
$A_{10.1}$, $A_{10.2}$, $A_{10.3}$	Cream dessert "Karamel", "Horikhovyi", "Vanilnyi"	New product
$A_{3.5}$	"Polunytsia" cream yogurt	New fat content percentage
$A_{9.5}$, $A_{9.6}$, $A_{9.7}$	Sour-milk dessert with vanilla flavour, chocolate flavour, berry flavour	New product (new starter culture and flavours)
$A_{6.3}$	"Liubytelskyi" cheese with chilli pepper	New taste

***Source**: compiled by the authors*

The third step. Normalised and weighted assessments of product novelty criteria normalised by formula (2) are presented in Table 8.

The fourth step is to calculate S_i+, S_i- squares of distances to R_j^+ (maximum value of R_{ij} by *j*) and R_j^- (maximum value of R_{ij} by *j*) by formulas (3) and (4). The calculation results are presented in Table 9. At the fifth step, new products are rated using formula (6). The results of product rating are presented in Table 9.

***Table 8**. Normalised dimensionless assessment matrix for new products of Favor LLC according to established criteria*

Product code	Assessment criteria Normalised scores			Assessment criteria Weighted normalised scores		
	Market novelty (C_2)	Manufacturing novelty (C_1)	Consumer novelty (C_3)	Market novelty (C_2)	Manufacturing novelty (C_1)	Consumer novelty (C_3)
$A_{3.1}$	0.123	0.214	0.151	0.040	0.048	0.068
$A_{3.2}$	0.012	0.026	0.083	0.004	0.006	0.037
$A_{2.1}$	0.215	0.352	0.213	0.070	0.079	0.096
$A_{1.1}$	0.312	0.213	0.322	0.101	0.048	0.145
$A_{9.1}$	0.523	0.583	0.621	0.169	0.131	0.280
$A_{9.2}$	0.523	0.583	0.621	0.169	0.131	0.280
$A_{9.3}$	0.523	0.583	0.621	0.169	0.131	0.280
$A_{6.1}$	0.465	0.634	0.532	0.151	0.143	0.240
$A_{6.2}$	0.361	0.156	0.161	0.117	0.035	0.073
$A_{3.3}$	0.234	0.152	0.186	0.076	0.034	0.084
$A_{9.4}$	0.542	0.653	0.416	0.176	0.147	0.188
$A_{3.4}$	0.398	0.227	0.226	0.090	0.051	0.102
$A_{10.1}$	0.586	0.352	0.405	0.190	0.079	0.183
$A_{10.2}$	0.586	0.352	0.405	0.190	0.079	0.183
$A_{10.3}$	0.586	0.352	0.405	0.190	0.079	0.183
$A_{3.5}$	0.006	0.081	0.032	0.002	0.018	0.014
$A_{9.5}$	0.520	0.452	0.345	0.168	0.102	0.156
$A_{9.6}$	0.520	0.452	0.345	0.168	0.102	0.156
$A_{9.7}$	0.520	0.452	0.345	0.168	0.102	0.156
$A_{6.3}$	0.456	0.125	0.315	0.148	0.028	0.142
Weight	0.324	0.225	0.451			
maximum R_j^+	–	–	–	0.190	0.147	0.280
minimum R_j^-	–	–	–	0.002	0.006	0.014

***Table 9**. S_i+, S_i-, R_i calculation results for ranking new products of Favor LLC*

Products	S_i+	S_i-	R_i	Rank
$A_{3.1}$	0.278	0.078	0.220	12
$A_{3.2}$	0.337	0.023	0.064	13
$A_{2.1}$	0.230	0.129	0.359	9
$A_{1.1}$	0.189	0.169	0.472	7
$A_{9.1}$	0.026	0.338	0.929	1
$A_{9.2}$	0.026	0.338	0.929	1
$A_{9.3}$	0.026	0.338	0.929	1
$A_{6.1}$	0.056	0.303	0.843	2
$A_{6.2}$	0.247	0.132	0.349	10
$A_{3.3}$	0.253	0.105	0.294	11

Table 9, Continued

Products	S_i+	S_i-	R_i	Rank
$A_{9.4}$	0.094	0.283	0.752	3
$A_{3.4}$	0.226	0.132	0.369	8
$A_{10.1}$	0.119	0.263	0.689	4
$A_{10.2}$	0.119	0.263	0.689	4
$A_{10.3}$	0.119	0.263	0.689	4
$A_{3.5}$	0.350	0.012	0.034	14
$A_{9.5}$	0.134	0.238	0.640	5
$A_{9.6}$	0.134	0.238	0.640	5
$A_{9.7}$	0.134	0.238	0.640	5
$A_{6.3}$	0.187	0.195	0.511	6

***Source**: calculated by the authors*

Checking the consistency of experts' opinions on the concordance coefficient using formulas (6)-(9) showed that K_{1con}=0.612, K_{2con}=0.621, K_{3con}=0.701 which indicates a sufficient level of consistency of the experts' opinions.

The importance of the concordance coefficient was assessed by the Pearson consistency criterion using formula (10). For market, manufacturing, and consumer novelty, the value of the concordance coefficient is not random, and therefore the results obtained can be used for research.

According to the ranking, the level of novelty importance was determined, and products were divided into five groups in accordance with the Harrington scale. Table 10 shows the importance levels of the novelty of new products of Favor LLC.

***Table 10**. Average rank of novelty importance of new products of Favor LLC*

Novelty importance levels	Product name	Average rank
Radical importance of novelty	$A_{6.1}$, $A_{9.1\text{-}3}$	1.5
Substantial importance of novelty	$A_{9.4}$, $A_{9.5\text{-}7}$, $A_{10.1\text{-}3}$	4
Satisfactory importance of novelty	$A_{1.1}$, $A_{6.3}$	6.5
Minor importance of novelty	$A_{2.1}$, $A_{3.1}$, $A_{3.3}$, $A_{3.4}$, $A_{6.2}$	10.0
Dubious importance of novelty	$A_{3.2}$, $A_{3.5}$	13.5

***Source**: calculated by the authors*

The calculations made determined the product the novelty of which is most considerable for the enterprise. The analysis showed that the highest, "radical" and "substantial" importance were the products "Albuminnyi" cheese ($A_{6.1}$), fermented dairy products "Do snidanku" with different flavours ($A_{9.1\text{-}3}$), "Iolakton zi steviieiu" ($A_{9.4}$), "Desert kyslomolochnyi" with different flavours ($A_{9.5\text{-}7}$), "Krem-deserty" with different flavours ($A_{10.1\text{-}3}$). Therefore, when developing a product innovative policy, these products will provide the company with the best competitive advantages. For their manufacturing, the company has the appropriate manufacturing potential and expects to increase the volume of their manufacturing. "Kakao-moloko" ($A_{1.1}$) and "Liubytelskyi" cheese with chilli peppers ($A_{6.3}$) had "satisfactory" importance of novelty, they have a lower level of importance of novelty, but the manufacturer hopes that these products will be perceived as new for some time, so some marketing measures may be required to maintain their market position and extend their life cycle. "Minor" and "dubious" novelty values were "Omeha 3" kefir, "Liubytelskyi" cheese with herbs and various yoghurts ($A_{2.1}$, $A_{3.1}$, $A_{3.3}$, $A_{3.4}$, $A_{6.2}$, $A_{3.2}$, $A_{3.5}$). Although there are many competitors in the market for these products, the manufacturer has its own consumer and expects the corresponding volume of product sales. For such products, marketing measures to retain customers of such products or develop a strategy to withdraw them from the market and replace them with others can be proposed.

For the studied enterprise, the most considerable is consumer novelty, since most of the products of TM "AMA" are dietary, medical, and designed for consumption in children's institutions. Therefore, the company should aim its efforts in the area of creating and consolidating the loyalty of its customers, considering changes in their habits, anticipating new needs, and attracting new consumers.

CONCLUSIONS

Testing of the proposed methodology for assessing the level of importance of product novelty was conducted at the milk processing enterprise Favor LLC for 20 types of its innovative products in the context of determining their manufacturing, market, and consumer novelty.

According to the results of the analysis, it was discovered that on average, consumer novelty prevails for all innovative products of the enterprise, market novelty is in second place, and manufacturing novelty is in third place. Expert assessment of the importance of these novelty levels in the overall assessment of the importance of novelty conducted according to the method of T.L. Saati showed a similar result.

A relatively high level of consumer novelty indicates the existence of a loyal consumer of the company's products. Ultimately, everything is decided by the consumer, while meeting their needs and preferences, which are determined by eating habits and sometimes unstable tastes, is a crucial goal for the development of any enterprise. Favor LLC primarily fosters its efforts on the development of consumer needs. The highest consumer level of novelty among the studied products is in fermented dairy products "Do snidanku" with mushrooms, a mixture of herbs, and paprika, and in "Albuminnyi" cheese. These products get the highest advantage among consumers, do not require considerable marketing and innovation support. The company understands the target audience and knows what functional properties of these products can ensure consumer loyalty.

The average level of importance of market novelty for all the studied products of Favor LLC occupies the second position after consumer novelty. Market novelty characterises the competitive position of the company's products among similar ones that are represented on the market. This is largely determined by the competitive advantages of products, using which the company wins in the market. Cream desserts "Karamel", "Horikhovyi", and "Vanilnyi" received the highest level of importance of market novelty. These products are considerably different from those offered by competitors, and therefore create unique opportunities for the enterprise to expand market share and provide a sustainable competitive advantage in the long term. For that purpose, it is necessary to expand consumer awareness about the useful properties of these products and form new distribution channels.

Manufacturing novelty takes third place in terms of the average level of importance of twenty innovative products of Favor LLC. Manufacturing novelty reflects the level of innovation in the manufacturing at the enterprise, namely equipment and technological processes. Thus, it shows how close the manufacturing process is to the best practices of dairy manufacturing. The highest level of importance of manufacturing novelty was given to the fermented milk drink "Iolakton zi steviieiu" and "Albuminnyi" cheese. For the manufacturing of these products, the company uses advanced technologies and modern equipment.

The generalised level of importance of the market, manufacturing, and consumer novelty of Favor LLC products was calculated using a multi-criteria assessment of the TOPSIS method. The results of the analysis showed that the top five included fermented milk products "Do snidanku" with mushrooms, a mixture of herbs, paprika, "Albuminnyi" cheese, and fermented milk drink "Iolaktion zi steviieiu". These products occupy a crucial place in the product innovative policy of the enterprise under study. The top five outsiders included cream yoghurt "Polunytsia", "Naturel" yoghurt, plain yoghurt, "Krem-briule iz karamelnym smakom" yoghurt, and "Liubytelskyi" brine cheese with herbs. These products require grounded decisions regarding their manufacturing and sale by the enterprise.

This method of assessing the level of importance of product novelty can become a powerful tool for substantiating the product innovative policy of an enterprise. This applies to solutions for timely delivery and decommissioning of products, preliminary testing of the product before introducing it to the market. In addition, this method allows determining the disadvantages and advantages for each type of innovative product in the product innovation portfolio of the enterprise in the context of its manufacturing, market, and consumer novelty.

This technique can be used by enterprises of various industries in different markets. For that reason, it is necessary to specify indicators for assessing the market, manufacturing, and consumer novelty which will reflect the features of the activities of specific enterprises in specific markets.

Further research should concern the development of appropriate methodological recommendations for the creation of the product range and its management based on the assessment of the level of importance of novelty.

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Визначення рівня значущості новизни продукції для формування товарної інноваційної політики

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Анотація. Для обґрунтування асортименту продукції підприємства виникає необхідність оцінити потенціал продукції з точки зору можливості підприємства виробляти дану продукцію, можливості споживачів задовольняти свою потребу у цій продукції і можливості ринку щодо забезпечення стратегічної позиції продуктів серед аналогічних товарів-аналогів конкурентів. У процесі дослідження використовувався структурно-логічний і причинно-наслідковий методи аналізу для визначення структури новизни товарів. Числовий метод прийняття багатокритеріальних рішень TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) використовувався для ранжування товарного асортименту нових товарів за рівнем значущості новизни. Вагові коефіцієнти окремих складових для оцінки рівня значущості новизни на підприємстві визначались за методом аналізу ієрархій Т.Л. Сааті. У дослідженні було використано класифікацію новизни за її функціональною спрямованістю, відповідно до якої виділяють споживчу, ринкову та виробничу новизну товару. Значущість новизни для виробника означає відповідність товару його інноваційній стратегії розвитку, визначення його місця на ринку та перспектив подальшої діяльності. Значущість новизни нового товару для підприємства пропонується визначати як міру важливості рівня новизни товару для формування оптимального товарного асортименту в товарній інноваційній політиці підприємства. Для оцінки рівня значущості новизни товарів були запропоновані критерії новизни за її видами. За результатами дослідження було встановлено, що виробнича новизна характеризує рівень використання нових технологій на підприємстві, ринкова – позицію нового товару на ринку серед аналогів, а споживча – рівень і спосіб задоволення потреб споживача. Подальше дослідження має стосуватись розроблення відповідних методичних рекомендацій щодо формування товарного асортименту і управління ним на основі проведеної оцінки рівня значущості новизни

Ключові слова: інновації, товарний асортимент, ринкова новизна, споживча новизна, виробнича новизна, товарна інноваційна політика

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Methodological Aspects of the Military-Economic Significance of Agriculture and Modern Problems of Military Food Resources in Ukraine

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Abstract. Today, the study of the military-economic significance of agriculture is given considerable attention by both the leadership of the Armed Forces of Ukraine and the state as a whole, so the main purpose of the article is to determine some methodological aspects of the military-economic significance of agriculture to strengthen the military-economic potential of the state and reveal the problems of using food resources for military purposes. In the article, the authors analyse statistical data on the dynamics of the main indicators that characterise the military-economic significance of the agro-industrial complex in the general system of national security of the state, as well as the dynamics of their growth over the years, with further research of correlations between these indicators and defence expenditures of Ukraine in order to develop recommendations for assessing the importance of indicators for the development of the agricultural sector in ensuring a sufficient level of military-economic potential of the state. Through the analysis, the economic capabilities of the state to provide Armed Forces were established, the views on determining the share of GDP in the protection of national interests in order to strengthen the country's MEP were formed, the main priorities for further development of the country as a whole were formulated. Also in the article, using the method of an expert survey based on pairwise comparisons, the indicators of the contribution of the main components to the overall indicator of sufficiency of the level of military and economic potential of the state are evaluated in order to determine the importance of the agricultural sector in the development of this potential. Based on the results, it was determined that the basis of any MEP of the state is the stability of the functioning of industry and the agricultural sector, since this is the basis for ensuring the country's defence capability as a whole. The collected statistical data and practical results obtained can be useful for specialists in the defence and agricultural sectors of the state, as well as scientists for conducting further research in the area defined in the article

Keywords: armed forces, army, national security of the state, war, food products

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INTRODUCTION

The national interests of Ukraine today require the immediate development and implementation of a set of measures to ensure the effective use of available resources for economic progress, increasing and strengthening the defence potential (DP) and military-economic potential (MEP) of the state. The study of the issues of assessment and balanced development of the state's MEP is one of the main components of the problems of further development of Ukraine as a whole [1-5].

Ukraine now has a significant potential for the availability of human, labour, natural, material, energy, technical, intellectual, scientific, production resources [6-10], which, if used correctly, can contribute to the acceleration of economic, social, and military development of the state by creating a competitive economy [1-4]. The national interests of Ukraine require the immediate development and implementation of a set of measures to ensure the effective use of available resources for the purpose of economic progress, increasing and strengthening the defence and military-economic potential of the state [11-13].

The study of the issues of assessment and balanced development of the state's MEP is one of the main components of the problems of further development of Ukraine as a whole. The concept of MEP characterises the objectively existing maximum opportunities in the state to meet military needs in the event of its involvement in the war. In each specific case, the degree of practical use of these opportunities, the level of their transformation into real military-economic power are determined by many reasons: military-political, economic and military-technical, and so on.

There is also an opinion that the MEP of the state can be considered part of the economic potential (EP) [7], which reflects the military and economic capabilities of the state, which can be aimed at meeting material needs and completing the Armed Forces for warfare:

$$MEP=K_u \cdot EP \quad (1)$$

where MEP – military-economic potential, %; – economic potential utilisation ratio (0<<1); EP – economic potential, %.

That is, with this approach, the MEP is a set of economic resources of the state (Fig. 1), which can be allocated and used to build up the economic foundations of the military power of the state.

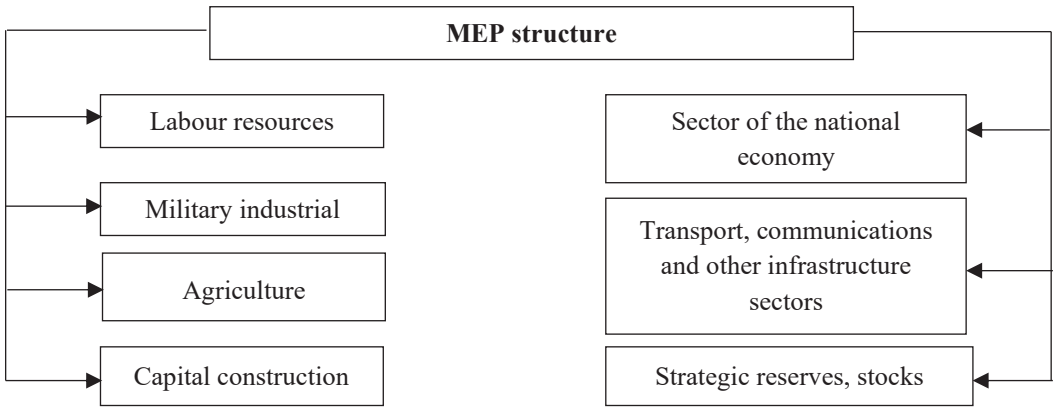


Figure 1. *MEP structure*

The issue of ensuring a sufficient state of the MEP of the country becomes particularly important in the conditions of combat use of units and subunits of the Armed Forces of Ukraine in the performance of tasks for their intended purpose, as well as significant differences between the needs for the development of the military component of the state and the resources available to meet these needs, which are actually allocated to maintain the military potential (MP) of the state today [1]. The lack of resources significantly depends on the ideas formed in society, including theoretical ones, about the role and place of the military organisation (Armed Forces of Ukraine) in the national security system of the country, about the objective needs and the final effectiveness of its activities in the actual geostrategic, cultural-historical and economic-technological conditions [3; 4; 14; 15].

One of the most important conditions for the material support of the state population, the stability of the national economy, and the sufficiency of the Armed Forces of Ukraine is the sustainable production of food and agricultural raw materials in peacetime and wartime. Agriculture is one of the important elements of the economic potential of Ukraine, so its role in ensuring a sufficient level of MEP in order to increase the protection of the national interests of the state is quite significant, so the study of the military-economic significance of agriculture is given considerable attention by both the leadership of the Armed Forces of Ukraine and the state as a whole. For the defence of the state, a combat-ready army, a strong rear are necessary, and for any army that performs tasks for their intended purpose, it is necessary to provide sufficient food for military personnel in their places of deployment [5-6; 14; 15].

In the modern conditions of development of Ukraine, the problem of rational use of sources of meeting the needs of all sectors of the national economy is

quite acute. It is important today to have the necessary supplies of food and raw materials and their rational placement, maintenance and storage. Many new influences are exerted by the modern hybrid war on the territory of Ukraine on the solution of issues of mobilisation of sources of food supply for the army, organisation of agricultural production and distribution of products.

Analysis of recent research and publications shows [15-20] that in the current conditions of development of the Armed Forces of Ukraine and the state as a whole, taking into account the factors of the presence of armed conflict on the territory of Ukraine and the occupation of part of the territory, the requirements for providing the needs of the armed forces of Ukraine with food are sharply increasing, which in turn affects the growth of requirements for agriculture of Ukraine in conditions complicated by the loss of about 4% of acreage. Today, during the ongoing armed conflict, a number of urgent problems arise for the agricultural sector. One of the main problems is to meet the ever-growing needs of the population and the Armed Forces in food products, and industry in agricultural raw materials. This problem is very strongly connected with the socio-economic development of the country and the nature of the modern war. Its successful solution provides for further improvement of agricultural production and ensuring the stability of its functioning during combat operations [1; 6].

Therefore, the *purpose of the study* is to reveal the main methodological aspects of the military-economic significance of agriculture and modern problems of military food resources in Ukraine today.

MATERIALS AND METHODS

During the research, the methods of statistical analysis were used to collect and process the collected statistical data on the dynamics of the main indicators that characterise the development of the agro-industrial complex of Ukraine over the years. Regression and correlation analysis methods were also partially used to study the relationships between the studied indicators of the development of the agro-industrial complex and defence expenditures of Ukraine for the study period. When assessing the importance of the main components of the military-economic potential, the method of pairwise comparisons of these components was used. Also, the study and construction of graphical dependencies and predicted trends took place using methods of mathematical statistics and graphical display of results.

The article used the method of an expert survey to determine the importance of stability in the agricultural sector and the functioning of industry for the country's defence capability. Using content analysis, the dynamics of the main indicators characterising the military and economic importance of the agro-industrial complex in the overall national security system of the state were highlighted, as well as indicators of the dynamics of the share of industry, agriculture and other income in the GDP of Ukraine, changes in exports and imports of industrial and agricultural products of Ukraine, GDP growth of Ukraine and growth of defence expenditure of Ukraine.

RESULTS AND DISCUSSION

Correct identification and full satisfaction of the needs of the population and the Armed Forces of Ukraine for food in peacetime or wartime, and industry for raw materials has a significant impact on the development of the military economy and the combat readiness of the Armed Forces of Ukraine. The general need of the state for food and agricultural raw materials in both peacetime and wartime is determined by the need to create reserves for the current provision of the population, the Armed Forces of Ukraine and industry, as well as the creation of guaranteed state reserves of food and raw materials and established food reserves for the mobilisation deployment of the army.

The main factor that determines the needs of the Armed Forces for food is their number. Over the years of independence of Ukraine, the size of the Ukrainian Armed Forces has changed constantly, and food needs have changed accordingly. Historically, until the 19th century, wars were fought by small armies and their food needs were met mainly at the expense of accumulated supplies in peacetime [10; 14; 19]. At the same time, military operations did not cover a large territory, so little human resources were diverted from agriculture, that is, this did not have a significant impact on the production of agricultural products. In the 19th century, when the number of belligerent armies increased significantly, states began to use not only accumulated reserves to provide armies, but also widely use the requisition of food from the population living in war zones. During this period, the cost of food and uniforms for the army accounted for 80% of all military expenses.

In the 20th century, the number of armies increased significantly compared to the previous period, for example, in the first World War, the Russian Army increased from the initial state of 1,423 thousand people to 15,338 thousand people at the end of the war, that is, more than 10 times. The annual use of important products increased from 696 thousand tons at the beginning of the war (1914) to 5,668 thousand tons in 1916, that is, by 8.1 times [6]. During the Second World War, the warring countries mobilized 1.5 times more people in the army than in the first World War, which in turn significantly increased the need for agricultural products. The growth of the absolute needs of the Armed Forces of Ukraine for food during military operations is always accompanied by a decrease in its share in the total amount of military expenditures. This is due to a sharp increase in spending on weapons and military equipment (WME) in the case of active hostilities [4; 20]. That is, the wars of the twentieth century significantly increased the negative impact on agriculture. The need to withdraw significant human and material resources

from agriculture for military needs caused an inevitable reduction in agricultural production, which made it difficult to solve the problems of providing food and agricultural raw materials.

Today, in modern wars of the 21st century, such consequences of the impact of the war on agriculture should be especially carefully taken into account, since the total volume of needs of the Armed Forces of Ukraine for food, and industry for raw materials tends to increase significantly [1-15]. Analysing the biggest wars of the 20th century, more than 40 million tonnes of food was used to supply the army of the USSR during the war against Germany, which is four times the consumption of ammunition and 2.5 times the consumption of petrol and lubricants for the same period. In modern wars, this ratio changes in the direction of reducing the volume of agricultural products, because scientific and technological progress reduces the number of armies, but increases the need for the consumption of ammunition and material and technical means.

The modern development of the Armed Forces of many countries of the world creates prerequisites for the emergence of new types, branches of the armed forces, services, and, accordingly, new contingents of military personnel, new conditions of military service that require changes in the structure and content of the food supply system of the armed forces. Changes that occur in the nature and methods of conducting modern combat operations have a significant impact on the organisation and development of the food supply system of the armed forces. There is a need to develop qualitatively new types of products that should have a small mass and volume, but a sufficiently high caloric content, and also do not require significant cooking time, and most importantly provide the physiological needs of military personnel depending on their service conditions. Today, such products are available in almost all armies of leading countries of the world. These products are resistant to environmental influences and have a fairly long shelf life. Today, these are various types of completed rations and military rations, which should be manufactured on the scale of the Armed Forces of Ukraine by at least 100-200 special enterprises, and in the event of war, the number of these enterprises should be at least 1000. That is, today it is necessary to understand the importance of raising the requirements for mobilisation training of the food industry, which should not only master the production of new types of products for the armed forces in peacetime, but also be ready to sharply increase their production during a special period.

In general, to meet the needs of a large army, it is necessary to have a large amount of food, as well as agricultural raw materials for the production of uniforms, tools and special military products. Today, hundreds of thousands of tons of food products are used to supply the Armed Forces of Ukraine alone, and billions of hryvnias are used to purchase, store and restore them in strategic reserves (Tables 1-3).

***Table 1**. Dynamics of the main indicators that characterise the military-economic significance of the agro-industrial complex in the general system of national security of the state (2000-2007)*

No.	Indicator/Year	2000	2001	2002	2003	2004	2005	2006	2007
1	GDP (UAH billion)	175.888	211.175	234.138	277.355	357.544	457.325	565.018	751.106
2	Share of industry in GDP (%)	23.5	24	24.7	24.7	24	26.4	27	26.6
	Share of industry in GDP (UAH million)	41.33368	50.682	57.83209	68.50669	85.81056	120.7338	152.5549	199.794196
3	Share of agriculture in GDP (%)	15.5	16.1	14.5	11.9	11.7	10.3	8.4	7.2
	Share of agriculture in GDP (UAH million)	27.26264	33.99918	33.95001	33.00525	41.83265	47.10448	47.46151	54.079632
4	Share of other services in GDP (%)	61	59.9	60.8	63.4	64.3	63.3	64.6	66.2
	Other services (UAH million)	107.2917	126.4938	142.3559	175.8431	229.9008	289.4867	365.0016	497.232172
5	Export of agricultural products (%)	22	23	27	28	27	28	29.7	29
6	Import of agricultural products (%)	12	11	7	9	8	10.2	10	9

Table 1, Continued

No.	Indicator/Year	2000	2001	2002	2003	2004	2005	2006	2007
6	Total exports (UAH million)	189096.00	208765.00	213454.00	224565.00	225676.00	227252.00	253707.00	323205.00
	Total imports (UAH million)	176544.00	207654.00	218765.00	222234.00	222345.00	223555.00	269200.00	364373.00
	Export of agricultural products (UAH million)	41601.12	48015.95	57632.58	62878.2	60932.52	63630.56	75350.98	93729.45
	Import of agricultural products (UAH million)	21185.28	22841.94	15313.55	20001.06	17787.6	22802.61	26920	32793.57
7	Export of industrial products (%)	40	40	40	40	40	40	41	41
8	Import of industrial products (%)	70	69	69	66	66	64	63	61
9	Export of industrial products (UAH million)	75386.27	83472.2	85597.09	90315.77	91026.95	91928.84	102927.7	131501.341
10	Import of industrial products (UAH million)	124286.98	142865.95	150510.32	145563.27	146080.67	143142.27	168949.92	224052.96
11	Defence expenditure (UAH million)	4821.6	6650.3	6035.6	5899.8	8756.4	7151.7	7604.9	8886.9
12	Expenditure for the maintenance of the Armed Forces of Ukraine, UAH billion	3519.77	4854.72	4405.99	4306.85	6392.17	5220.74	4399.7	4987.8
13	Expenditures on food supply of the Armed Forces, UAH billion	1055.93	1456.42	1321.80	1292.06	1917.65	1566.22	1319.91	1496.34

***Table 2**. Dynamics of the main indicators that characterise the military-economic significance of the agro-industrial complex in the general system of national security of the state (2008-2014)*

No.	Indicator/Year	2008	2009	2010	2011	2012	2013	2014
1	GDP (UAH billion)	990.819	947.042	1079.346	1299.991	1404.669	1465.198	1586.915
2	Share of industry in GDP (%)	25.4	21.5	18.8	18.2	17.9	16.5	17.2
	Share of industry in GDP (UAH million)	251.668	203.61403	202.917048	236.598362	251.435751	241.75767	272.94938
3	Share of agriculture in GDP (%)	7.6	7.8	8.3	8.2	7.8	8.7	10.2
	Share of agriculture in GDP (UAH million)	75.30224	73.869276	89.585718	106.599262	109.564182	127.472226	161.86533

Table 2, Continued

No.	Indicator/Year	2008	2009	2010	2011	2012	2013	2014
4	Share of other services in GDP (%)	67	70.7	72.9	73.6	74.3	74.8	72.6
	Other services (UAH million)	663.8487	669.558694	786.843234	956.793376	1043.66907	1095.9681	1152.10029
5	Export of agricultural products (%)	32	33	34	37	34	27	28
6	Import of agricultural products (%)	9	7	8.4	8	8	8.9	9
	Total exports (UAH million)	444859.00	423564.00	549365.00	707953.00	717347.00	681899.00	770121.00
	Total imports (UAH million)	520588.00	438860.00	580944.00	779028.00	835394.00	805662.00	834133.00
	Export of agricultural products (UAH million)	142354.9	139776.12	186784.1	261942.61	243897.98	184112.73	215633.88
	Import of agricultural products (UAH million)	46852.92	30720.2	48799.296	62322.24	66831.52	71703.918	75071.97
7	Export of industrial products (%)	41	41	41	41	41	41	42
8	Import of industrial products (%)	60	59	54	61	64	64	67
9	Export of industrial products (UAH million)	181519.4	173326.4227	225448.9319	291359.743	296066.187	282234.749	319651.556
10	Import of industrial products (UAH million)	313498.09	258707.97	316033.54	472090.97	537158.34	518040.67	555532.58
11	Defence expenditure (UAH million)	9130.7	9907.7	12806	12477.6	16374.7	15281.6	27363.4
12	Expenditure for the maintenance of the Armed Forces of Ukraine, UAH billion	5966.5	7353.4	7005	9260.7	12096.5	12451.3	21802.2
13	Expenditures on food supply of the Armed Forces, UAH billion	1789.95	2206.02	2101.50	2778.21	3628.95	3735.39	7194.73

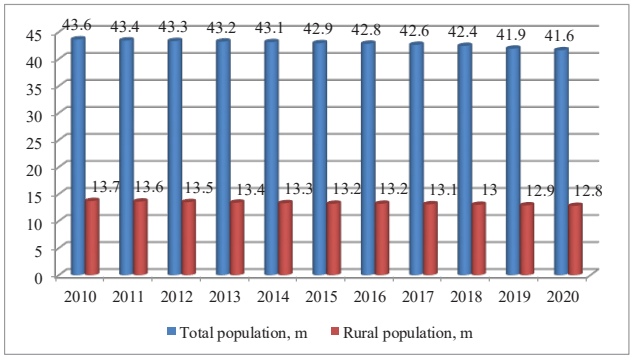
***Table 3**. Dynamics of the main indicators that characterise the military-economic significance of the agro-industrial complex in the general system of national security of the state (2015-2020)*

No.	Indicator/Year	2015	2016	2017	2018	2019	2020
1	GDP (UAH billion)	1988.544	2383.182	2908.233	3558.706	3974.564	4194.102
2	Share of industry in GDP (%)	16.7	17.7	18	17.6	16.4	14.6
	Share of industry in GDP (UAH million)	332.086848	421.823214	523.48194	626.332256	651.828496	612.338892

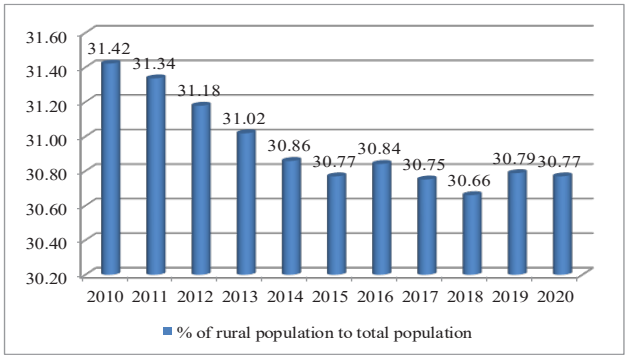
Table 3, Continued

No.	Indicator/Year	2015	2016	2017	2018	2019	2020
3	Share of agriculture in GDP (%)	12.1	11.7	10.2	10.1	9	9.3
	Share of agriculture in GDP (UAH million)	240.613824	278.832294	296.639766	359.429306	357.71076	390.051486
4	Share of other services in GDP (%)	71.2	70.6	71.8	72.3	74.6	76.1
	Other services (UAH million)	1415.843328	1682.526492	2088.111294	2572.944438	2965.024744	3191.711622
5	Export of agricultural products (%)	32	25	28	32	35	33
6	Import of agricultural products (%)	9	7	8	6.7	7.2	7
	Total exports (UAH million)	1044541.00	1174625.00	1430230.00	1608890.00	1636416.00	1637399.00
	Total imports (UAH million)	1084016.00	1323127.00	1618749.00	1914893.00	1947599.00	1681526.00
	Export of agricultural products (UAH million)	334253.12	293656.25	400464.4	514844.8	572745.6	540341.67
	Import of agricultural products (UAH million)	97561.44	92618.89	129499.92	128297.831	140227.128	117706.82
7	Export of industrial products (%)	43	40	42	39	46	42
8	Import of industrial products (%)	68	65	60	59	56	62
9	Export of industrial products (UAH million)	452286.253	474548.5	599266.37	622640.43	744569.28	682795.383
10	Import of industrial products (UAH million)	739298.91	857386.30	976105.65	1124042.19	1086760.24	1044227.65
11	Defence expenditure (UAH million)	52005.2	59348.9	74346.2	97024	106627.7	120374.1
12	Expenditure for the maintenance of the Armed Forces of Ukraine, UAH billion	36939.8	45854.2	52249.2	66987.7	78456.7	81087.09
13	Expenditure on food supply of the Armed Forces, UAH billion	13298.33	18341.68	21944.66	26795.08	34520.95	32434.84

Tables 1-3 show the dynamics of indicators that characterise the military-economic significance of the agro-industrial complex in the general system of national security of the state in order to study the relationships between indicators of the components of the economic potential of the state and military potential. In the current conditions of Ukraine's development, in addition to the declining population of Ukraine, the number of rural population is also decreasing annually (1-3% annually from the previous year) (Fig. 2a) and (Fig. 2b), which negatively affects the development of Ukraine's agricultural sector, but encourages the search for new alternative innovative ways to replace human labour with robotic machines. Today, the production and use of non-food products that are made from agricultural raw materials, namely cotton products, wool, linen fabrics, clothing and underwear, leather and textiles, has significantly increased.



a)



b)

***Figure 2**. Dynamics of a) the population of Ukraine, the rural population and b) the percentage of the rural population from its total number*

For the sustainable provision of the population and the army with food products, and industry with food raw materials, it is necessary to make a comprehensive use of all food sources, namely: current production of agricultural products; state reserves of food and agricultural raw materials; food reserves that were created in the Armed Forces of Ukraine in peacetime; commodity food resources of current consumption, which are allocated for supply to the population. These sources are the main ones and their products make up the centralised resources of the state as a whole. Additional sources include: production from agricultural enterprises of the Ukrainian Ministry of Defence and subsistence farms, as well as in the event of war in foreign territories, trophy foodstuff etc.

Modern warfare makes significant adjustments in the purpose of each of the sources, if the war is long-term as in Ukraine, then food supply is of particular importance in the process of preparing the Armed Forces to perform their assigned tasks. But if a war is fought in a short period of time with the use of weapons of mass destruction, the current production of agricultural products will not be essential for the conduct of hostilities, because in a short-term war the main burden of supplying the Armed Forces and the population of the state will fall on the advance creation of state reserves, stocks of current consumption, and stocks created specifically for the Armed Forces. Therefore, the creation and maintenance of large mobilisation and state food reserves in the required amount is an indispensable condition for uninterrupted supply of food to the Armed Forces and the population, restoring losses caused by enemy actions to provide assistance to areas of the state affected by the war. It should be noted that without creating the necessary state reserves (food reserves) in advance, it is impossible to ensure a successful defence war. The current provision of food to the population of the country and its Armed Forces, and the industry with the necessary agricultural raw materials, is always planned for a year, because agriculture has a certain cyclicity – from harvest to harvest [5; 7]. This determines the urge to have stocks that meet at least the annual need for food [15]. State reserves of food and agricultural raw materials must meet the needs of the national economy in case of emergencies (agricultural imbalances, natural disasters, crop failures, armed conflicts or wars).

In the modern conditions of development of Ukraine, when the country is in a state of long-term armed conflict, the level of threats of a full-scale invasion of the territory of Ukraine is more than 50% annually, the role of state reserves has gained its significant strength. During combat operations, the enemy can use nuclear weapons, weapons of mass destruction, bacteriological weapons, that is, the enemy can disable most of the industrial enterprises, as well as food industry enterprises and food supplies in order to create conditions for artificial hunger and demoralisation of the Armed Forces. In addition, economic and transport links between different economic regions of the state may be disrupted for a long period of time, which will significantly complicate wide maneuvers with food and raw materials reserves. Under these conditions, state reserves will play a major role in supplying the army and population of the country, as well as the functioning of the national economy as a whole. Depending on the time of the outbreak of war and the nature of enemy actions on the territory of the country, the products of current agricultural production can be obtained only in a year, that is, with a new crop [6-11]. Therefore, in order to guarantee the satisfaction of the needs of the state in the initial period of the war, it is necessary to have state reserves of food and agricultural raw materials in the amount of at least six months or even an annual need [12-15; 18-20].

Most of the world's militarised countries, such as the United States, Germany, Russia, China, etc., pay considerable attention to creating and maintaining proper food reserves in state reserves. For example, in the United States, the food and Agriculture Act of 1977 is still in force, which regulates three-year programmes for creating fixed reserve grain reserves in the amount of more than 40 million tons, which is approximately the annual demand for the country's population.

For the purpose of sustainable and continuous support of the army at the beginning of the war, when the rapid mobilisation of troops begins and there is a rapid increase in their number. The Armed Forces must have a sufficient number of operational mobilisation food supplies. In modern conditions, when there are threats to use nuclear weapons, weapons of mass destruction, the importance of mobilisation reserves increases significantly. In addition to the mobilisation deployment of troops and their advance to operational areas, these reserves should ensure the restoration of costs and losses in the first operations (combat operations), and there should also be a reserve of food to meet the needs that may arise as a result of the use of nuclear or bacteriological weapons. Today, most NATO countries have food supplies based on the three-month need of their armed forces. If we consider the situation in relation to Ukraine, then today in Ukraine, food supplies should not be less, because the intensification of armed aggression against Ukraine by Russia without the intervention of Western countries or NATO member countries can also last from a month to three according to experts [1; 19].

Analysis of the collected statistical data on the dynamics of the main indicators that characterise the military-economic significance of the agro-industrial complex in the general system of national security of the state (Tables 1-3) and their growth over the years (Tables 4-6) makes it possible to study the correlation between these statistics, which in turn will allow drawing conclusions about the importance of indicators of the development of the agricultural sector in ensuring a sufficient level of MEP of the state. Figure 3 shows the results of assessing the dynamics of the share of industry, agriculture and other incomes in Ukraine's GDP. From the data obtained, it can be seen that agriculture has adapted to operating in the conditions of the ongoing armed conflict on the territory of Ukraine(the level of change for 2014-2020 compared to the previous period was +0.8%), while industry has suffered irreversible losses so far and the level of decline compared to the period before 2014 was -6.2%.

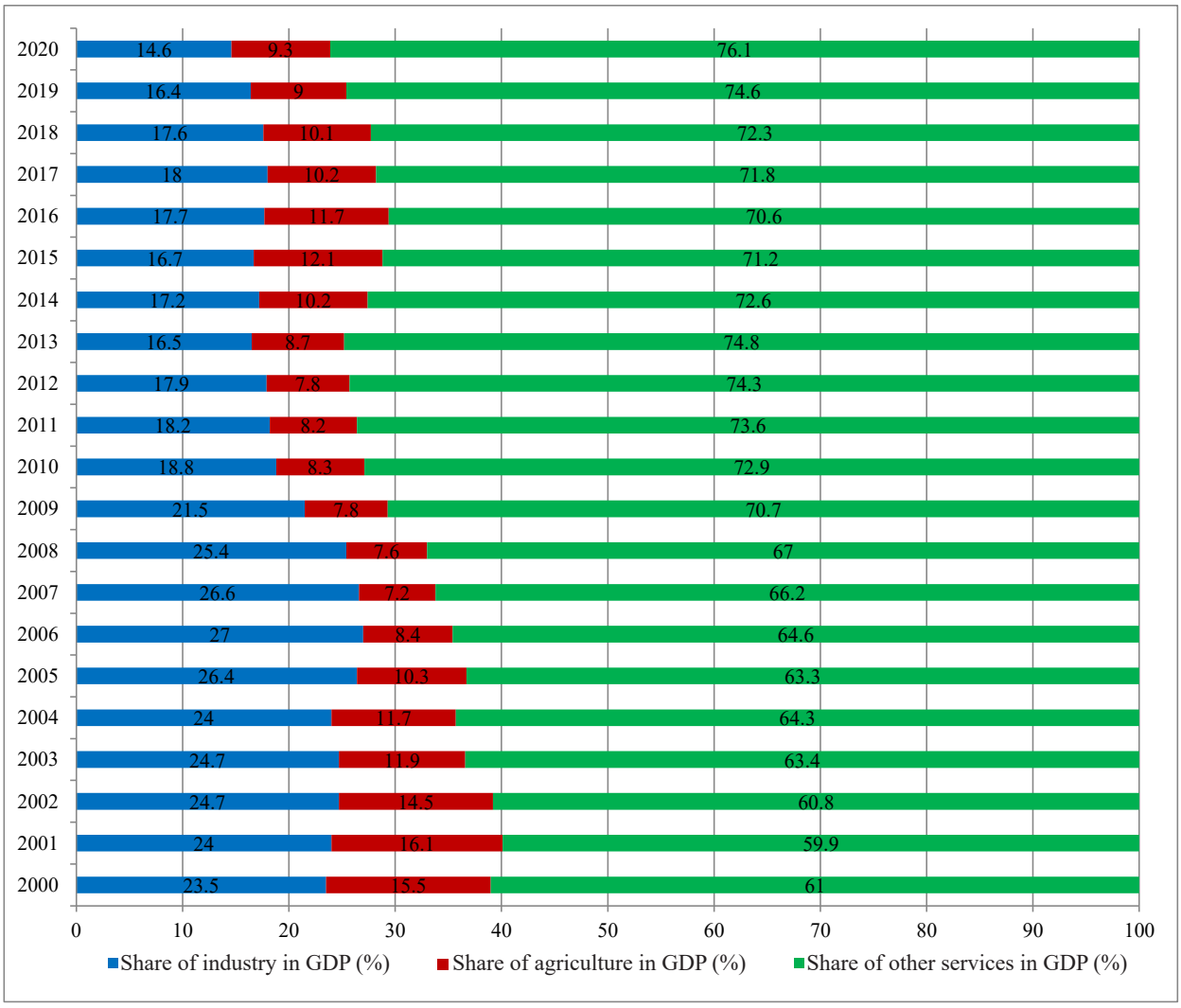


***Figure 3**. Dynamics of the share of industry, agriculture, and other incomes in GDP of Ukraine*

***Table 4**. Dynamics of growth according to indicators that characterise the military-economic importance of the agro-industrial complex in the general system of national security (2000-2007)*

No.	Indicator/Year	2000	2001	2002	2003	2004	2005	2006	2007
1	GDP growth, %	–	16.71	9.81	15.58	22.43	21.82	19.06	24.78
2	Increase in the share of industry in GDP (%)	–	2.08	2.83	0.00	-2.92	9.09	2.22	-1.50
	Increase in the share of industry in GDP (UAH million)	–	18.45	12.36	15.58	20.17	28.93	20.86	23.64
3	Increase in Share of agriculture in GDP (%)	–	3.73	-11.03	-21.85	-1.71	-13.59	-22.62	-16.67
	Increase in Share of agriculture in GDP (UAH million)	–	19.81	-0.14	-2.86	21.10	11.19	0.75	12.24
4	Increase in the share of other sources in GDP, %	–	-1.84	1.48	4.10	1.40	-1.58	2.01	2.42
	Increase in the share of other sources in GDP (UAH million)	–	15.18	11.14	19.04	23.51	20.58	20.69	26.59
5	Increase in export of agricultural products (%)	–	4.35	14.81	3.57	-3.70	3.57	5.72	-2.41
6	Increase in import of agricultural products (%)	–	-9.09	-57.14	22.22	-12.50	21.57	-2.00	-11.11
	Total export growth (UAH million)	–	9.42	2.20	4.95	0.49	0.69	10.43	21.50
	Total import growth (UAH million)	–	14.98	5.08	1.56	0.05	0.54	16.96	26.12
	Increase in export of agricultural products (UAH million)	–	13.36	16.69	8.34	-3.19	4.24	15.55	19.61
	Increase in import of agricultural products (UAH million)	–	7.25	-49.16	23.44	-12.44	21.99	15.29	17.91
7	Increase in export of industrial products (%)	–	0.29	0.29	0.29	0.29	0.29	0.29	0.29
8	Increase in import of industrial products (%)	–	-2.33	0.00	-5.04	0.30	-2.61	-2.02	-2.07
9	Increase in export of industrial products (UAH million)	–	9.69	2.48	5.22	0.78	0.98	10.69	21.73
10	Increase in import of industrial products (UAH million)	–	13.00	5.08	-3.40	0.35	-2.05	15.28	24.59
11	Increase in defence expenditure (UAH million)	–	27.50	-10.18	-2.30	32.62	-22.44	5.96	14.43
12	Increase in expenditure for the maintenance of the Armed Forces of Ukraine	–	27.50	-10.18	-2.30	32.62	-22.44	-18.66	11.79
13	Increase in expenditures on food supply of the Armed Forces of Ukraine	–	27.50	-10.18	-2.30	32.62	-22.44	-18.66	11.79

***Table 5**. Dynamics of growth according to indicators that characterise the military-economic importance of the agro-industrial complex in the general system of national security (2008-2014)*

No.	Indicator/Year	2008	2009	2010	2011	2012	2013	2014
1	GDP growth, %	24.19	-4.62	12.26	16.97	7.45	4.13	7.67
2	Increase in the share of industry in GDP (%)	-4.72	-18.14	-14.36	-3.30	-1.68	-8.48	4.07
	Increase in the share of industry in GDP (UAH million)	20.61	-23.60	-0.34	14.24	5.90	-4.00	11.43
3	Increase in Share of agriculture in GDP (%)	5.26	2.56	6.02	-1.22	-5.13	10.34	14.71
	Increase in Share of agriculture in GDP (UAH million)	28.18	-1.94	17.54	15.96	2.71	14.05	21.25
4	Increase in the share of other source in GDP, %	1.19	5.23	3.02	0.95	0.94	0.67	-3.03
	Increase in the share of other sources in GDP (UAH million)	25.10	0.85	14.91	17.76	8.32	4.77	4.87
5	Increase in export of agricultural products (%)	9.38	3.03	2.94	8.11	-8.82	-25.93	3.57
6	Increase in import of agricultural products (%)	0.00	-28.57	16.67	-5.00	0.00	10.11	1.11
	Total export growth (UAH million)	27.35	-5.03	22.90	22.40	1.31	-5.20	11.46
	Total import growth (UAH million)	30.01	-18.62	24.46	25.43	6.75	-3.69	3.41
	Increase in export of agricultural products (UAH million)	34.16	-1.84	25.17	28.69	-7.40	-32.47	14.62
	Increase in import of agricultural products (UAH million)	30.01	-52.52	37.05	21.70	6.75	6.80	4.49
7	Increase in export of industrial products (%)	0.29	0.29	0.29	0.28	0.28	0.28	0.28
8	Increase in import of industrial products (%)	-2.11	-2.15	-8.36	10.23	5.75	0.00	3.45
9	Increase in export of industrial products (UAH million)	27.56	-4.73	23.12	22.62	1.59	-4.90	11.71
10	Increase in import of industrial products (UAH million)	28.53	-21.18	18.14	33.06	12.11	-3.69	6.75
11	Increase in defence expenditure (UAH million)	2.67	7.84	22.63	-2.63	23.80	-7.15	44.15
12	Increase in expenditure for the maintenance of the Armed Forces of Ukraine	16.40	18.86	-4.97	24.36	23.44	2.85	42.89
13	Increase in expenditures on food supply of the Armed Forces of Ukraine	16.40	18.86	-4.97	24.36	23.44	2.85	48.08

***Table 6**. Dynamics of growth according to indicators that characterise the military-economic importance of the agro-industrial complex in the general system of national security (2015-2020)*

No.	Indicator/Year	2015	2016	2017	2018	2019	2020
1	GDP growth, %	20.20	16.56	18.05	18.28	10.46	5.23
2	Increase in the share of industry in GDP (%)	-2.99	5.65	1.67	-2.27	-7.32	-12.33
	Increase in the share of industry in GDP (UAH million)	17.81	21.27	19.42	16.42	3.91	-6.45
3	Increase in Share of agriculture in GDP (%)	15.70	-3.42	-14.71	-0.99	-12.22	3.23
	Increase in Share of agriculture in GDP (UAH million)	32.73	13.71	6.00	17.47	-0.48	8.29
4	Increase in the share of other sources in GDP, %	-1.97	-0.85	1.67	0.69	3.08	1.97
	Increase in the share of other sources in GDP (UAH million)	18.63	15.85	19.42	18.84	13.22	7.10
5	Increase in export of agricultural products (%)	12.50	-28.00	10.71	12.50	8.57	-6.06
6	Increase in import of agricultural products (%)	0.00	-28.57	12.50	-19.40	6.94	-2.86
	Total export growth (UAH million)	26.27	11.07	17.87	11.10	1.68	0.06
	Total import growth (UAH million)	23.05	18.07	18.26	15.47	1.68	-15.82
	Increase in export of agricultural products (UAH million)	35.49	-13.82	26.67	22.22	10.11	-6.00
	Increase in import of agricultural products (UAH million)	23.05	-5.34	28.48	-0.94	8.51	-19.13
7	Increase in export of industrial products (%)	4.14	-7.18	3.58	-8.27	14.95	-9.11
8	Increase in import of industrial products (%)	2.35	-5.25	-7.46	-2.73	-5.20	10.14
9	Increase in export of industrial products (UAH million)	29.33	4.69	20.81	3.75	16.38	-9.05
10	Increase in import of industrial products (UAH million)	24.86	13.77	12.16	13.16	-3.43	-4.07
11	Increase in defence expenditure (UAH million)	47.38	12.37	20.17	23.37	9.01	11.42
12	Increase in expenditure for the maintenance of the Armed Forces of Ukraine	40.98	19.44	12.24	22.00	14.62	3.24
13	Increase in expenditures on food supply of the Armed Forces of Ukraine	45.90	27.50	16.42	18.10	22.38	-6.43

Figure 4 shows the dynamics of exports and imports of industrial and agricultural products in Ukraine in the period of 2000-2020. Imports of industrial products have a slightly declining trend (on average in 2014-2020, the decline was 6.7% compared to the initial period), and exports have a growing trend (changes + 2.2%). Imports of agricultural products remained in their positions, fluctuations did not differ significantly to 1-1.5%, but agricultural products had a much greater dynamics of change to 5.7% on average. A significant factor in such fluctuations is the unstable military and political situation both around Ukraine and within it.

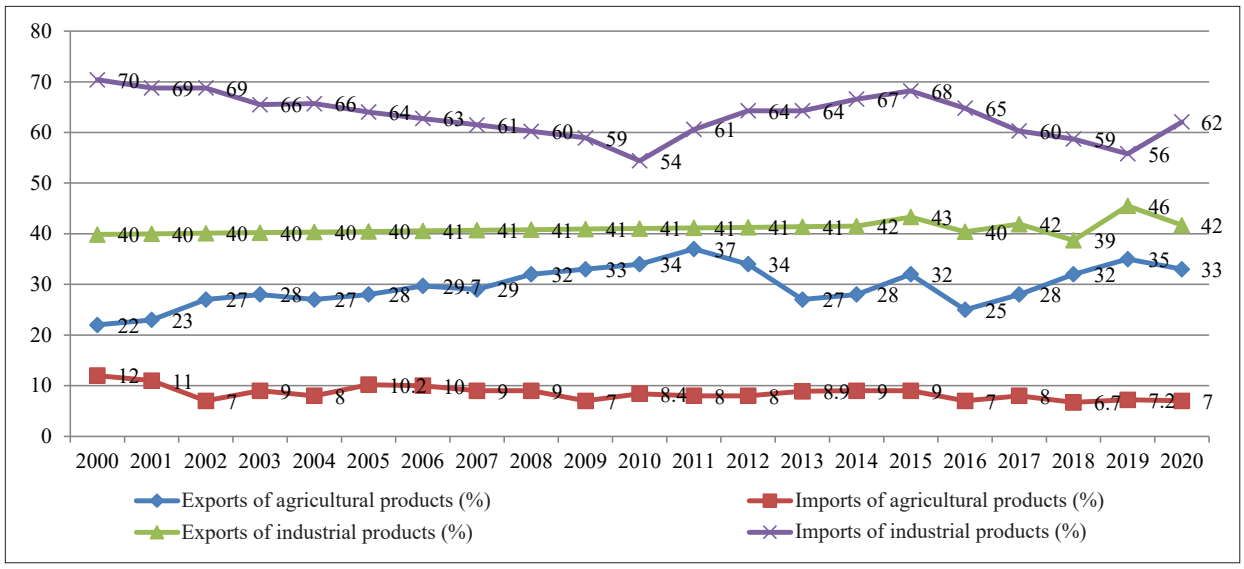


***Figure 4**. Dynamics of the share of industry, agriculture, and other incomes in GDP of Ukraine*

Tables 4-6 and Figure 5 show the dynamics of growth in defence expenditure, expenditure for the maintenance of the Ukrainian Armed Forces and expenditure on food supply. From the data obtained, it can be seen that these indicators are quite closely correlated with each other. Their correlation coefficient is almost 91.4%. Such a coincidence of increases in these indicators shows that the issue of maintenance, and especially food supply of the Armed Forces is an integral component of any defence budget, as well as the volume of expenses for the maintenance of the Armed Forces is from 70 to 80% of all defence expenditures of Ukraine today, which is a negative trend, because according to the experience of the leading countries of the world, this indicator should not exceed 50-60% depending on the number of Armed Forces.

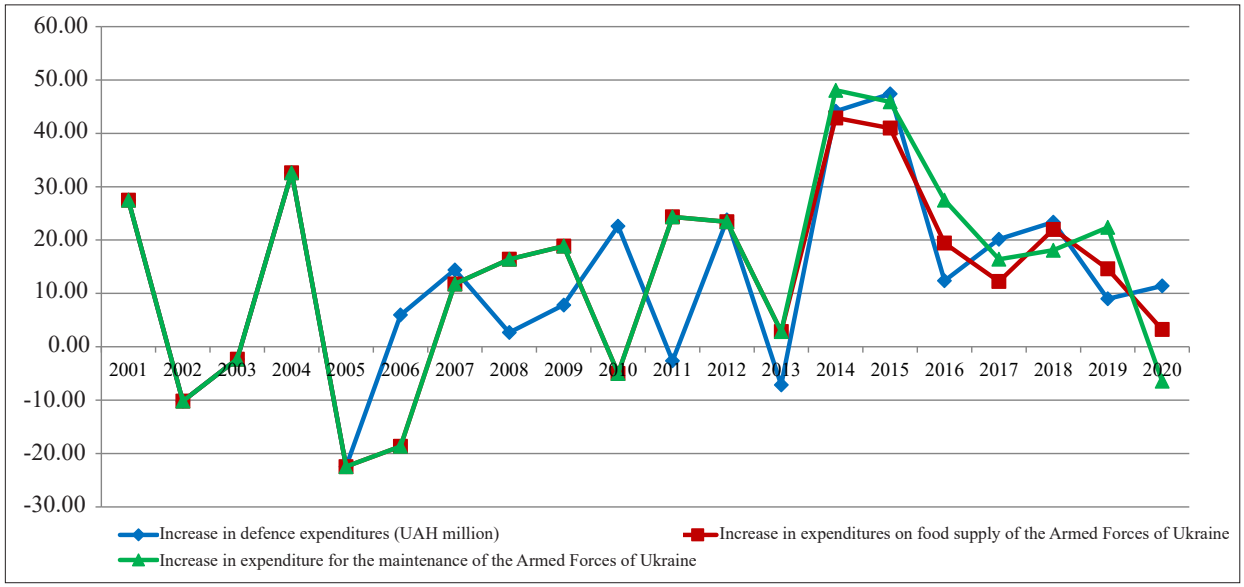


***Figure 5**. Dynamics of growth in defence spending, maintenance of the Armed Forces of Ukraine and its food supply*

Figure 6 shows a petal chart of changes in exports and imports of industrial and agricultural products of Ukraine for the period of 2000-2020 in order to form a general idea of the priority directions of development of the national economy of the state.

Figure 7 shows the dynamics of Ukraine's GDP growth and increase in defence expenditure. From the data obtained, it can be seen that even under the influence of significant destabilising factors, the overall dynamics still has a very stable and steady upward trend, which cannot be said about defence expenditure, which, even with a significant increase during 2014-2020, is still on a downward trend due to the impact of a number of negative factors.

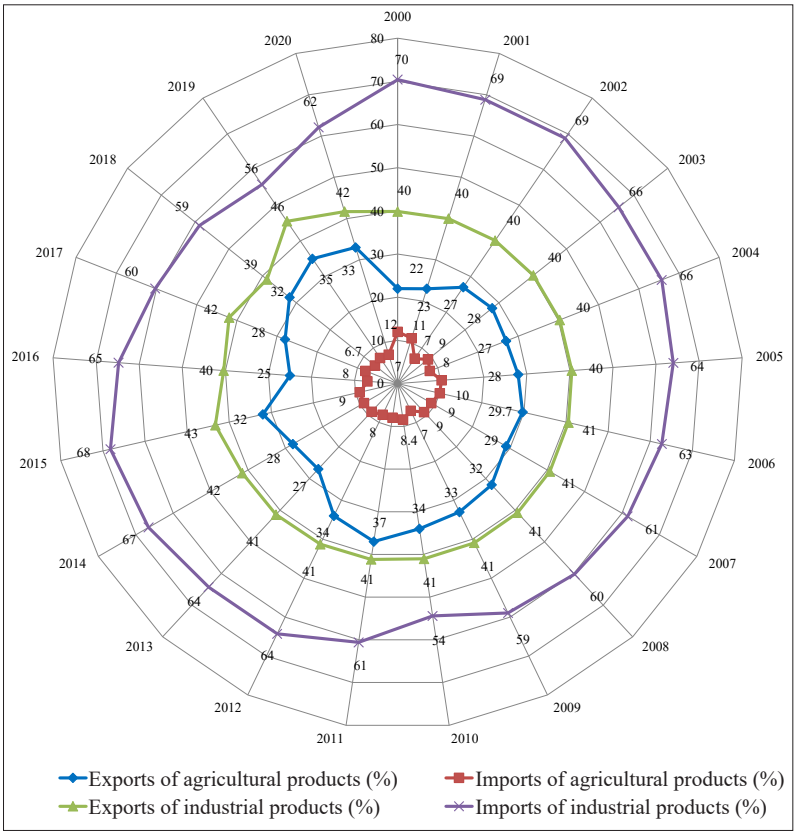


***Figure 6**. Petal chart of changes in exports and imports of industrial and agricultural products of Ukraine for the period of 2000-2020*

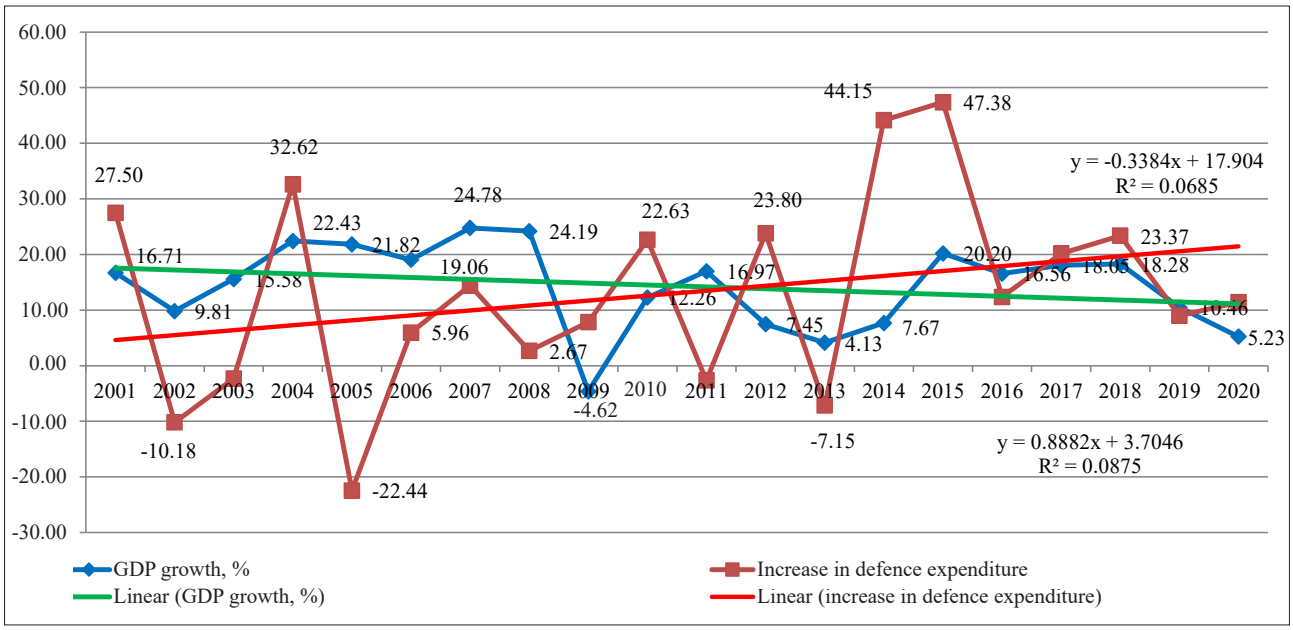


***Figure 7**. Ukrainian GDP growth rate and increase of the defence expenditure of Ukraine over the period 2000-2020 with linear trends*

The analysis makes it possible to determine the economic opportunities of the state to provide its Armed Forces, that is: to form views on determining the share of the country's GDP in order to protect national interests in order to strengthen the state's MEP; to form the main priorities for further development of the country as a whole. One of the most important priorities is and always will be the development of the country's agricultural sector, as the main source of ensuring the needs of the armed forces in the nutrition of personnel, because if there is no foodstuff, then there will be no army, and if there is no army, then there will be no state.

Therefore, the issues of military-economic significance of agriculture are one of the most pressing issues of the military economy, and the formation of reserves for the Armed Forces is the main element of effective preparation for combat operations during the defence of the state.

Today, when determining specific volumes of mobilisation and operational reserves, it is necessary to approach each strategic direction differentially in terms of possible combat operations, taking into account its operational and strategic importance, operational capacity, remoteness, transport links, economic development of the region, and so on. Established food supplies, especially those found in remote areas, should have some autonomy in their region. When accumulating reserves, it is advisable to place the main part of them within each strategic direction of combat operations, taking into account the appointment of troops, that is, their correct echelon plays an important role. According to experience, it is advisable to have 50% directly with the troops, while the remainder should be stored in bases and warehouses for government use, giving the Ukrainian Armed Forces the right to dispose of them in the event of a transition to operations in a special period. The storage conditions of reserves should ensure their safety, maneuver of reserves in necessary situations, as well as destruction in the event of a threat of capture of this territory by the enemy.

In the event that the war continues for three months, as is the case in Ukraine today, the current agricultural sector will be used indiscriminately to provide the Armed Forces. But according to the experience of the beginning of hostilities in 2015, in the first period, the provision of the Armed forces of Ukraine was at the expense of state reserves and food supplies. Today, the Armed Forces of Ukraine are provided in a combined way, that is, agricultural products of both current production are used, and products from warehouses and reserves of state significance are used in order to update reserves. During a large-scale war, the main role in providing the Armed Forces of Ukraine with food will be played by centralised reserves of the state, but additional sources will also be of great importance (volunteering, humanitarian aid, etc.).

It should be understood that a stable and steady supply of foodstuff to the army and population, and to industry with agricultural raw materials during combat operations, is possible only if maximum mobilisation and integrated use of all sources of agricultural production is possible. In modern conditions, the volume and rate of overgrowth of agricultural production today do not yet sufficiently meet the needs of the army and society. The problem of agricultural production growth rates remains one of the most acute economic issues in Ukraine.

The efficiency of agricultural production depends on natural, climatic and economic factors. Ukraine has the necessary natural and climatic factors for the effective development of agriculture, so for the development of agricultural production today, economic factors (machinery, technologies, organisation, development of the chemical industry, etc.) and factors of external influence (loss of part of the agricultural territory and the presence of an armed conflict on the territory of Ukraine) have the greatest weight. Today, the growth of the economic and military-economic significance of the agro-industrial complex (AIC) is an objective pattern in the development of the economy of any modern state. In terms of the cost of products produced by the agro-industrial complex and the volume of capital investments, this complex ranks first among other sectors of the national economy.

Today in Ukraine, the share of the agro-industrial complex is 30-40% of all production assets, and more than 40% of the working-age population. The final products of the agro-industrial complex, which are produced from agricultural matter, make up 40-60%, including food occupies more than 40% of these volumes. Ukraine today occupies one of the leading positions in the export of certain types of grain and legumes, as well as some types of other agricultural products. It should be understood that the rapid development of the agro-industrial complex will significantly increase the economic potential of the state, which in turn will increase the military potential, and thereby increase the level of protection of the national interests of Ukraine. Material and human resources that are employed in the agro-industrial complex are a significant source of increasing the mobilisation capabilities of the state economy. Currently, the military and economic opportunities of the agro-industrial complex are growing as a result of adapting the state economy to function in the context of a long-term armed conflict and as a result of re-targeting the necessary capital investments in this complex.

Agriculture has a number of specific features compared to industry. The main means of production in agriculture is land that cannot be evacuated from threatened areas, and it is also impossible to create a new one or replace it with anything. Agriculture also differs from other sectors of the national economy by seasonality of production, so in a modern war, agriculture is quite vulnerable. If military operations interfere with the implementation of sowing or harvesting in the required time frame, then this will lead to its loss or significant deterioration in the quality of products. In turn, the crop during the ripening period can become an object of destruction, that is, the active action of the enemy during the ripening period of the crop can significantly reduce the volume of agricultural production. At the same time, the restoration of agriculture will require not only a lot of effort and resources, but also a lot of time. Thus, today in Ukraine there is an acute problem of preparing agriculture for functioning in the conditions of combat operations and the use of the Armed Forces of Ukraine in part or in full. The preparation of agriculture for functioning in the conditions of military operations

(special period) largely depends on the extent to which the task of protecting agricultural production from enemy weapons and other damaging factors will be solved. Since the beginning of the war, changes in production conditions are significant for agriculture, so it is necessary to take measures in advance to reduce the vulnerability of agriculture and ensure its sustainable functioning in different natural and climatic zones, taking into account the economic characteristics of different areas. The nature of these measures is determined by the properties of the weapons that the enemy will use and the scope of the enemy's intentions to resolve an armed conflict or war. It should be understood that in a modern war, ensuring sustainable agricultural production will be one of the most difficult problems of the military economy, so the preparation of agriculture should take place in peacetime and on an ongoing basis, taking into account the build-up and maintenance of its high level during combat operations. One of the important directions for improving the efficiency of agricultural production is to provide it with qualified labour (human resources), so according to the experience of wars, the outflow of human resources from agriculture was 2-3 times less than from other sectors of the economy of states that took part in armed conflicts or wars.

Figure 8 shows the results of an expert survey conducted by the method of pairwise comparisons on the distribution of the share of the main components in the formation of the state's MEP.

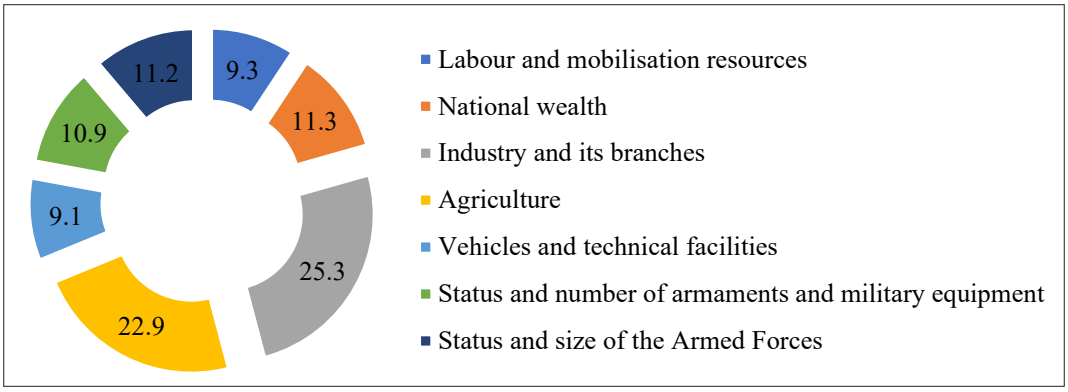


***Figure 8**. Distribution of the main components of the formation of the military-economic potential of the state*

From the results obtained, it can be seen that the basis of any MEP of the state is the stability of the functioning of industry and the agricultural sector since this is the basis for ensuring the defence capability of the country as a whole.

CONCLUSIONS

The successful development of the Ukrainian agro-industrial complex, taking into account the requirements of the current war, will make it possible to provide not only for the rapidly growing needs of the Armed Forces and the state in food and agricultural production, but also to accumulate sufficient state reserves to meet the projected military requirements. This, in turn, will significantly increase the possibilities of sustainable and efficient functioning of agriculture, even during hostilities. The realisation of these opportunities depends on the early implementation of agreed measures to ensure the sustainable functioning of the agricultural production system, as well as food supply to the state and its Armed Forces. The sustainable functioning of agriculture should be understood as its ability to produce established types of products in the required volumes in wartime.

Early implementation of scientific measures to ensure the sustainability of agricultural production will certainly contribute to the preservation of this vital element of the state's economic potential, and therefore, it will have a positive impact on the military capabilities of the state during its protection.

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Методологічні аспекти воєнно-економічного значення сільського господарства та сучасні проблеми продовольчих ресурсів воєнного призначення в Україні

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Анотація. На сьогодні дослідженню питань воєнно-економічної значимості сільського господарства приділяється значна увага як керівництвом ЗС України так і держави загалом, тому основною метою статті є визначення деяких методологічних аспектів воєнно-економічного значення сільського господарства для зміцнення воєнно-економічного потенціалу держави та розкриття проблематики використання продовольчих ресурсів воєнного призначення. У статті авторами проведено аналіз статистичних даних щодо динаміки основних показників, що характеризують воєнно-економічне значення агропромислового комплексу у загальній системі національної безпеки держави, а також динаміки приросту їх за роками з подальшим дослідженням кореляційних зв'язків між цими показниками та оборонними витратами України з метою розроблення рекомендацій щодо оцінювання важливості показників розвитку сільськогосподарської галузі у забезпеченні достатнього рівня воєнно-економічного потенціалу держави. За допомогою такого аналізу автори статті встановили економічні можливості держави щодо забезпечення власних ЗС, сформували погляди щодо визначення частки ВВП країни на захист національних інтересів з метою зміцнення ВЕП держави, сформували основні пріоритети подальшого розвитку країни загалом. Також у статті методом експертного опитування на основі попарних порівнянь оцінено показники внеску основних складових у загальний показник достатності рівня воєнно-економічного потенціалу держави з метою визначення важливості сільськогосподарської галузі у становленні цього потенціалу. За результатами було визначено, що основою будь-якого ВЕП держави є наявність стабільності функціонування промисловості та сільськогосподарської галузі, оскільки це основа забезпечення обороноздатності країни в цілому. Зібрані статистичні дані та отримані практичні результати можуть бути корисними спеціалістам оборонної та сільськогосподарської галузі держави, а також науковцям для проведення подальших досліджень за визначеним у статті напрямом

Ключові слова: збройні сили, армія, національна безпека держави, війна, продовольчі товари

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Public Management of Railway Transport Development based on the Principles of a Systematic Approach

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Abstract. The article is devoted to scientific and applied research on the problem of the formation and implementation of a universal, efficient and effective public management system for the development of railway transport in the changing socio-economic and political conditions of Ukraine. The definition of the category "public management of railway transport" and the problems of the railway industry as a whole was clarified. A universal, efficient and effective system of public management for the development of railway transport has been formed, containing all the necessary aspects: entrance to the system, working subsystems, exit, external environment, feedback, as well as the components and elements that are part of them. It has been proven that entrance into the system is the defining management and organizational link of the entire system. The main directions of introduction and development of elements of working subsystems are analyzed. Proposals on operational and strategic directions of improvement of public management of railway industry development in the following areas are presented: improvement of legislative and regulatory framework; full separation of the functions of public administration from the economic functions of railway enterprises; the development and implementation of a new public tariff management system; development of a progressive approach to the organization and management of passenger transportation and the introduction of a public administration system in the international security. It was concluded that the effective operation of the developed system and the successful introduction of areas of improvement of public management for the development of the railway industry will achieve the following results: create conditions for the development of free competition in the industry; increase the competitiveness of the railway industry in Ukrainian and international markets; achieve the desired indicators of railway industry efficiency and innovation growth

Keywords: elevated, improvement of management, systems approach, development, infrastructure

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INTRODUCTION

The sustainable socio-economic development of Ukraine depends entirely on the level of development of each branch of the national economy as a whole, as well as its individual infrastructure elements at the present stage. Integration into the world and especially into the European economic space is a defining priority of public administration at all levels. Thus, the stable development of the country's railway industry is a key prerequisite for the overall growth of all economic and social indicators of the country; enhancing its Ukrainian competitiveness in foreign markets; broadening and strengthening linkages among economic agents; enhancing the economic security of the state; development of foreign economic activity to ensure the European integration vector of development, etc. Rail transport, in fact, is the "blood circulatory system" of the Ukrainian economy, which implements a comprehensive influence on all aspects of the life of the state by promoting interregional and international cultural ties, socio-economic transformations, tourism cooperation between states, retail and wholesale trade, etc. [1]. But, it should be noted that today the system of the railway industry of Ukraine does not fully comply with the world and European standards, directives, standards, regulations, and requirements, as well as is significantly far behind in terms of the content of the legislative and regulatory technical base, infrastructure component, the quality of transportation and service services provided and other important aspects of the effective development of the industry as a whole. Thus, the above factors determine the relevance of the selected topic of research on the need to systematize the scientific, methodological and practical provision of sustainable development of the railway industry of Ukraine in the conditions of integration processes and its further improvement by creating and introducing a systematic approach to the formation of a universal and effective system of public management of the development of railway transport and the industry as a whole.

Public management of railway transport development is a complex, multi-component socio-economic system and has many unresolved problems and development prospects. Therefore, many scientific works of scientists and specialists of public administration, economics, and management are devoted to this issue, such as V.L. Dykan and H.Ye. Ostroverkh [1-3], Yu.L. Mokhova [4], A.O. Diegtiar et al. [5; 6], H. Eitutis et al. [7], I.V. Tokmakova et al. [8], V. Hudkova and Yu. Tiutiun [9], B.Ya. Ostapiuk [10], V.V. Matviienko [11], N.E. Avanesova et al. [12], V. Kruhlov and D. Tereshchenko [13], I.S. Lukasevych-Krutnyk [14] and others. But, despite the substantive and fundamental studies carried out by these scientists, the issues of the formation of a universal, efficient and effective system of public management for the railway transport development in the changing socio-economic and political conditions of Ukraine remain unresolved. The main purpose of the article is to study methods and models of public management of railway transport development based on a systematic approach. To achieve this purpose, tasks are as follows:

– to clarify the definition of the category "public administration of railway transport";

– to establish a universal, efficient and effective system of public administration for the development of railway transport;

– to identify the main elements of the system entrance;

– to analyze the main directions of implementation and development of elements of working subsystems;

– to provide proposals on operational and strategic directions of improvement of public management of railway industry development.

THEORETICAL ASPECTS OF CREATING A UNIVERSAL AND EFFECTIVE SYSTEM OF PUBLIC MANAGEMENT OF THE RAILWAY TRANSPORT DEVELOPMENT OF UKRAINE

Today, railway transport occupies a leading place among key sectors of the economy in Ukraine. It is a secure link for more than 80% of all freight and almost half of all passenger traffic. So the defining position of the railway transport of Ukraine is due to two interrelated factors, namely:

– significant economic, social, and technical advantages over other land, water, and air transport modes;

– the geographical position of Ukraine, through which significant transport and economic flows pass.

In order to establish a universal and effective system of public management of the railway transport development of Ukraine, it should be clarified the definition of "public management of the railway transport" by summarizing scientific works [4; 5; 7; 8] and highlighting the main systemic, organizational, and managerial problems that may prevent the continuous operation of the system [9-11] (Fig. 1). The research carried out in Figure 1 and the processing of scientific sources [6; 12; 15; 16] make it possible to form a universal system of public management of the railway transport development, the main feature of which is the presence of four interconnected subsystem units, namely: economic growth, the introduction of an innovative component and an integrated information environment.

As shown in Figure 2, the system is based on a system approach, that is, it contains all the necessary aspects: entrance, operating subsystems, exit, external environment, feedback, as well as the components and elements that are included in them.

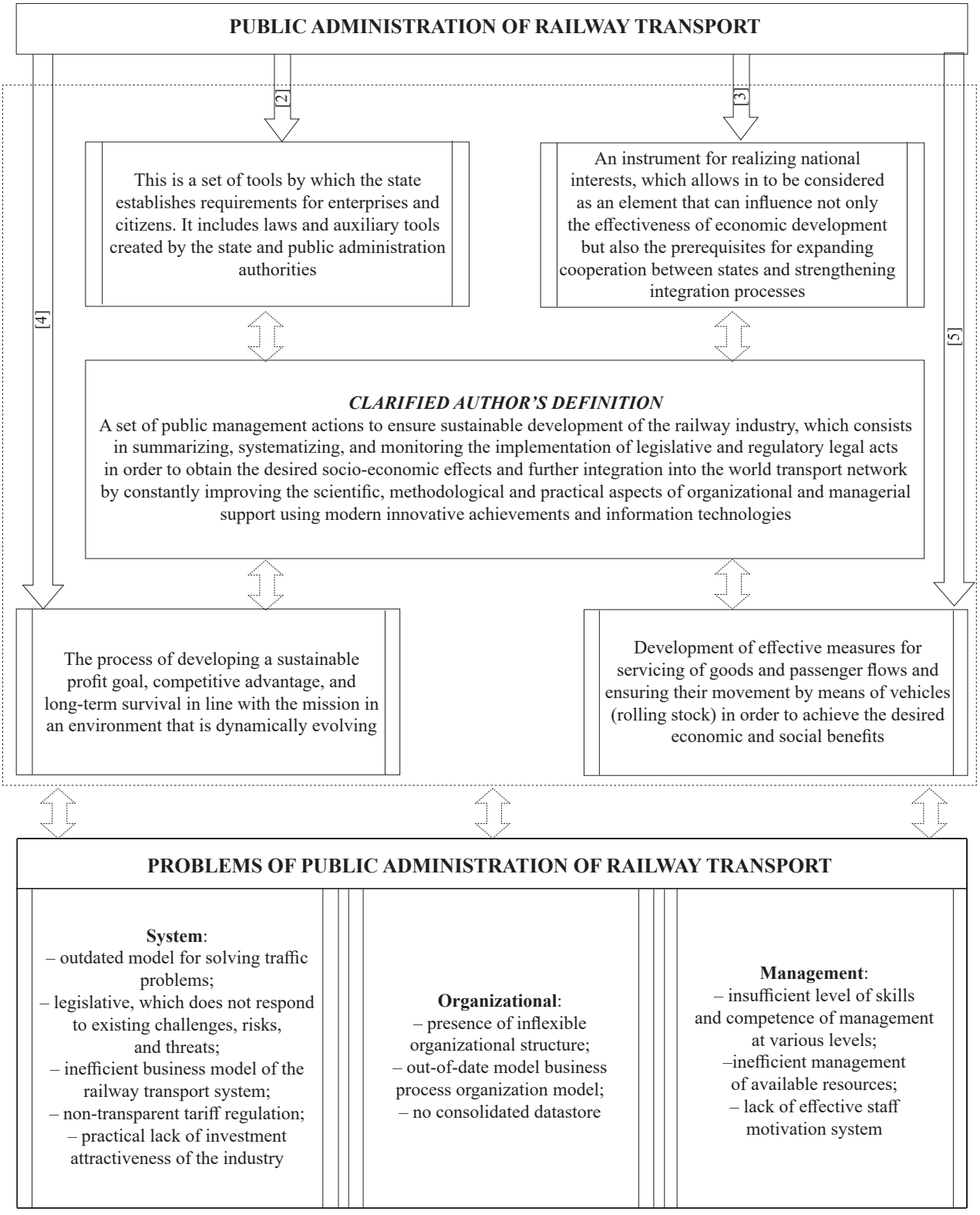

***Figure 1**. Clarification of the category "public management of railway transport" and problems of the railway industry*
***Source**: author's development based on the generalization of [4; 5; 7-11]*

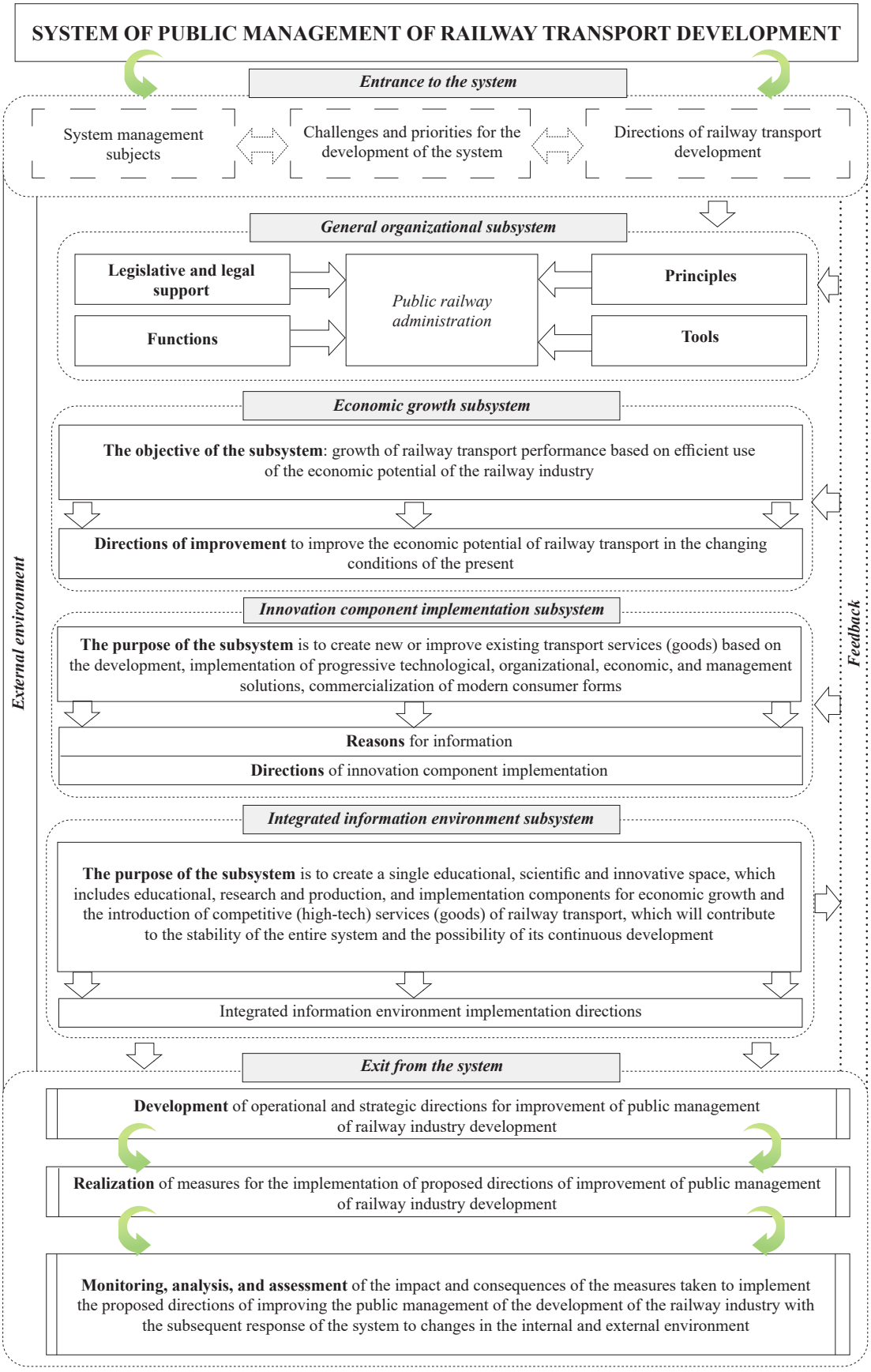

Figure 2. *Formation of the system of public management of railway transport development*
Source: *author's development based on the generalization of [6; 12; 15; 16]*

ANALYSIS OF ELEMENTS AND COMPONENTS OF THE ESTABLISHED SYSTEM OF PUBLIC MANAGEMENT OF THE RAILWAY TRANSPORT DEVELOPMENT

Therefore, in order to increase the scientific, methodological and practical value of the established system of public management of railway transport development, it is necessary to analyze each element and component of this system and provide proposals for improving their individual components.

I. Entrance to the system is the defining management and organizational link of the entire system and is characterized by the presence of three elements.

1. The system control subjects can be roughly divided into three hierarchical levels (Table 1).

***Table 1**. Subjects of public administration of the railway transport development system*

No.	Subject name	Main tasks of the subject
	I. Higher level of management	
1.1	Cabinet of Ministers of Ukraine	Manage the entire system, have broad authority, and directly and indirectly affect all other subsystems and system elements
1.2	Ministry of Infrastructure of Ukraine	
	II. Medium level of management	
2.1	State Agency for Railway Transport	Implementation of state policy, control of equal access to infrastructure, coordination of railway transport enterprises, registration and coordination of the activities of carriers, operators, industrial transport, subways, etc.
2.2	National Transport Regulatory Commission	Formation of an effective tariff policy in the transport services market, which belongs to the natural monopoly
2.3	State Transport Safety Authority	State supervision of traffic safety, including railway transport
2.4	Accident Investigation Commission	Performs the function of analyzing each force majeure situation that led to the accident and determines the ways to overcome it
	III. Low level of management	
3.1	PJSC "Ukrzaliznytsia"	Put into practice the decisions of the higher and middle management subjects, monitoring their implementation, and transmit the received information for its subsequent processing and improvement of their activities
3.2	Private carriers, railway rolling stock operators, freight forwarders	
3.3	Non-public railway transport: industrial, railway transport, access roads	
3.4	Subway	

***Source**: author's development based on the generalization of [16-19]*

2. The system should fulfill the following common objectives and focus on such development priorities:

– compliance with timeliness, completeness, and quality standards in the provision of services by railway transport to meet the needs of the population and social production;

– protection of the rights and freedoms of members of the community during their service by railway transport enterprises, as well as the focus on its safe operation and maintenance;

– balancing the necessary rate and proportions of the development of Ukraine's national transport system;

– creation of a reliable system of economic security of Ukraine, protection of legitimate interests of railway transport enterprises and consumers of transport services;

– creating favorable conditions for general economic and social growth, improving the competitiveness of the national economy in the international market, and improving the quality of life of all segments of the population.

3. The main directions of the efficient development of railway transport should be divided into two interrelated elements:

– transport policy direction (organizational and personnel; property; investment; financial and credit; tax; tariff, etc.);

– administrative direction (administrative and leisure; public oversight; administrative and regulatory).

II. The common organizational subsystem is the key link of the system and, using the following elements, forms an effective mechanism for organizing the work of all components and links of the system.The main elements of this subsystem include the following:

– legislative and legal support is a set of mechanisms that are developed and operate at both the national and international levels. They are divided into compulsory

or mandatory (national laws and regulations, treaty obligations) and voluntary (virtue covenants, codes of conduct, etc.) [20]. Their competent implementation should form a legal basis that applies all other elements and components of the system in work;

– the set of principles, functions, and tools of the general organizational subsystem in this study is proposed to be considered as follows (Table 2).

Table 2. *Principles, functions, and tools of the system of public management of railway transport development*

No.	Common organizational subsystem element	Main types
1	Principles	– Systematics – Quality of service provision – Legal support – Coenomic growth – Innovation – Informativity – Reliability and safety – Accessibility and financial transparency – Competitiveness
2	Functions	– Regulatory – Security – Control and supervisory – Price forming – Integrative
3	Tools	– Economic planning and forecasting tools – Plan adjustment tools – Operational and strategic management accounting systems – Generation and dissemination of knowledge – Continuous qualification staff training – Simulation of results – Information technology (problem-oriented databases)

III. Economic growth subsystem.

Today there is an urgent need to pay special attention to the development of mechanisms, tools, and directions for the economic growth of railway transport in Ukraine. The study proposes the following areas of improvement to increase the economic potential of railway transport in the changing conditions of the present:

– general updating of the state's transport system for the introduction of linkages between the different transport means, which will contribute to the socio-economic importance of the railway industry;

– improvement of the regulatory and legal environment in the field of financial and investment support for railway transport activities, which will create the basis for increasing the attractiveness of the industry among existing and potential Ukrainian and world investors and will lead Ukrainian legislation to the world and European norms and standards;

– improvement of organizational structures and management methods will make it possible to introduce modern management means and methods to achieve the desired financial and economic results and increase the economic potential of the railway industry as a whole;

– improving the system of training and education of personnel by transforming the system of traditional values and motivation will promote competition for prestigious jobs in the railway industry, which will increase the economic effect of the general introduction of innovations.

IV. Innovation component implementation subsystem.

The effective functioning of the railway industry of Ukraine takes place in difficult socio-economic conditions and is impossible without the activation of its innovative development in various directions. That is why to get out of this difficult situation it is necessary to introduce the systemic solution of problems of activation of innovation activity of enterprises of the railway industry, the formation of the unified research environment, efficient technologies of development and introduction of innovations, development of intellectual capital, and improvement of quality of products [2; 21]. Figure 3 describes the main reasons for innovation in the public management of railway transport development.

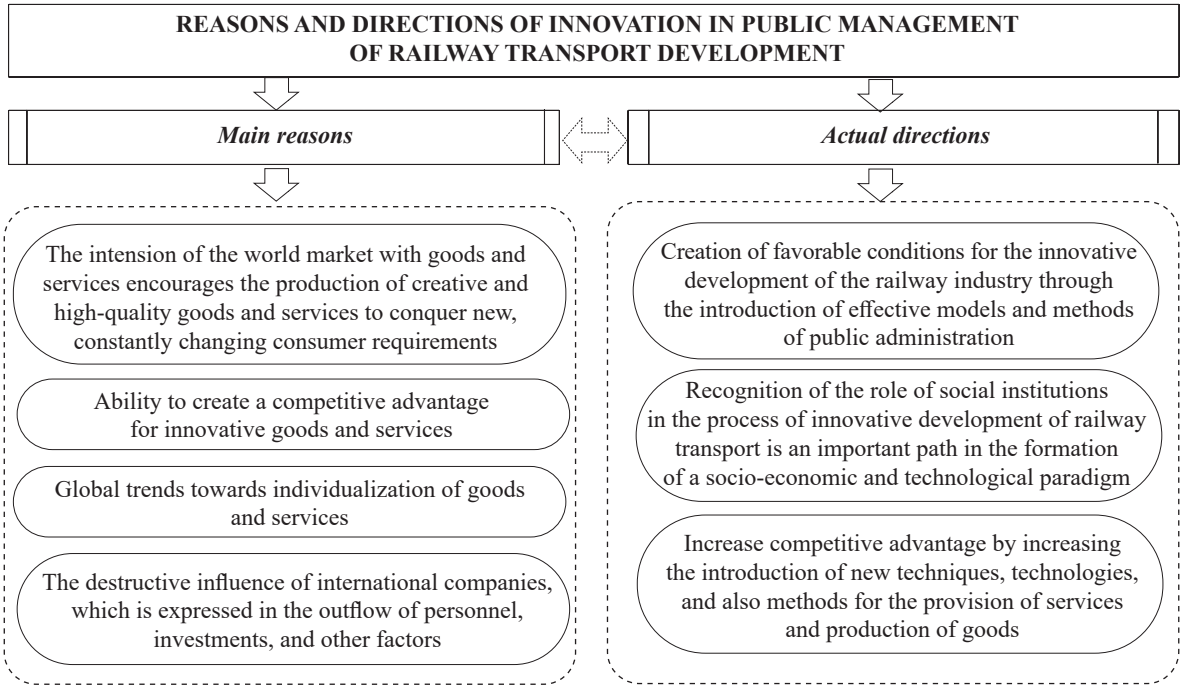

***Figure 3**. Reasons and directions of innovation in public management of railway transport development*
***Source**: author's development based on the generalization of [2; 3; 21]*

V. Integrated information environment subsystem.

An analysis of the current state of the railway industry of Ukraine found systemic shortcomings in the functioning of existing information systems, which significantly reduce the reliability and quality of information support for the entire cycle of creating a service (product), and therefore cause an increase in its duration and inefficiency of management decisions. Define the main directions of implementation of the integrated information environment:

– adaptive railway management information system in the changing conditions of the present;

– information system for monitoring the development of railway transport;

– information system for planning and programming the development of railway transport for short-term and long-term periods;

– information system of state control over railway transport development;

– an information system that accompanies the production of goods and services, including innovative.

At the exit from the system of public management of railway transport development, there are operational and strategic directions of improvement of public management of railway industry development, see Table 3.

***Table 3**. Operational and strategic directions of improvement of public management of railway industry development*

No.	Direction	Direction characteristic
1.	Improving the legislative and regulatory framework	– Establishment of an effective legislative framework in accordance with international standards – Development of an improved version of the Charter of Railway Transport of Ukraine – Ensuring financial and economic transparency of railway transport – Approval of the Procedure for initiation, preparation, and implementation of various projects, special attention should be paid to innovative
2.	Complete separation of the functions of public administration from the economic functions of railway enterprises	– Provision of a certain capacity of the main directions of railway transport – Control of the compatibility of railway transport with foreign countries – Evelopment of an effective investment policy for the railway industry (including raising funds from local budgets for investment) through the formation of a new investment support mechanism
3.	Development and implementation of a new public tariff management system	– Transparent tariff formation – Introduction of tariff simplification at the borders of the state – Development of a methodology for integrated tariff management – Introduction of progressive tariff methods – Formation of methodology for calculation of fees for railway transport services – Accounting of investment component in tariffs – Creation of an automated system of corporate-state management of railway transport (management of finance and resources, planning and implementation of cargo transportation, etc.)

Table 3, Continued

No.	Direction	Direction characteristic
4.	Development of a progressive approach to the organization and management of passenger transportation	– The introduction of a network of interconnected logistics centers and terminals with extensive capabilities – Construction of high-speed railway sections – Acceleration of border inspection posts of Ukraine – Enactment of international standards for the carriage of passengers – Improvement of social passenger transport
5.	Introduction of a public administration system in the international security	– Application of security management system certification procedures – Improvement of procedures and methods of state supervision and control of the safety of railway transport in accordance with international standards – Introduction of innovative security projects and programs – Technical and technological modernization of transport – Introduction of public-private partnerships – Application of long-term concessional lending mechanisms

Thus, the implementation of measures to implement the proposed directions for improving public management of the development of the railway industry will achieve the following practical results:

– to create conditions for the development of free competition in the industry;

– to increase the competitiveness of the railway industry in Ukrainian and international markets;

– to achieve the desired indicators of railway industry efficiency and innovation.

CONCLUSIONS

There were conducted scientific and applied studies of the problem of the formation and implementation of a universal, efficient and effective system of public management of the development of railway transport in the changing socio-economic and political conditions of Ukraine. The value of study consists in the scientific, methodological, and practical results obtained, namely:

1. The definition of the category "public management of railway transport" is clarified, which is considered in the article as a set of managerial influences of the state to ensure the sustainable development of the railway industry, which consists in summarizing, systematizing, and monitoring the implementation of legislative and regulatory legal acts to obtain the desired socio-economic effects and further integration into the world transport network by constantly improving the scientific, methodological and practical aspects of organizational and managerial support using modern innovative achievements and information technologies.

2. A universal, efficient, and effective system of public management of the development of railway transport has been formed, containing all the necessary aspects: entrance, working subsystems, exit, external environment, feedback, as well as components and elements that are part of them. The main feature of the developed system is the presence of four interconnected subsystem units, namely: economic growth, the introduction of an innovative component, and an integrated information environment.

3. The main elements of the system entrance are defined:

– system management subjects, which are divided into three levels of management and perform interrelated objectives;

– general tasks, priorities of the system operation are set out and the main directions of railway transport development efficiency.

4. Main directions of implementation and development of elements of working subsystems are analyzed:

– the common organizational subsystem is the key link of the system and, using a complex of elements, forms an effective mechanism for organizing the work of all components and links of the system;

– is proposed a set of improvement directions to increase the economic potential of railway transport in the changing conditions of the present;

– the reasons and directions of innovation in the public management of railway transport development are identified;

– the main directions of implementation of the integrated information environment have been investigated.

Proposals on operational and strategic directions of improvement of public management of railway industry development in the following areas are presented: improvement of legislative and regulatory framework; full separation of the functions of public administration from the economic functions of railway enterprises; the development and implementation of a new public tariff management system; development of a progressive approach to the organization and management of passenger transportation and the introduction of a public administration system in the international security. It was concluded that the effective operation of the developed system and the successful introduction of areas of improvement of public management for the development of the railway industry will achieve the following results: create conditions for the development of free competition in the industry; increase the competitiveness of the railway industry in Ukrainian and international markets; achieve the desired indicators of railway industry efficiency and innovation growth.

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Державне управління розвитком залізничного транспорту на основі принципів системного підходу

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Анотація. Стаття присвячена науково-прикладним дослідженням проблеми формування та впровадження універсальної, ефективної та дієвої системи державного управління розвитком залізничного транспорту в мінливих соціально-економічних і політичних умовах України. Уточнено визначення категорії «державне управління залізничним транспортом» та проблеми залізничної галузі в цілому. Сформовано універсальну й ефективну систему державного управління розвитком залізничного транспорту, що містить усі необхідні аспекти: вхід до системи, робочі підсистеми, вихід, зовнішнє середовище, зворотний зв'язок, а також компоненти та елементи, які є їхніми частинами. Доведено, що вхід у систему є визначальною управлінською та організаційною ланкою всієї системи. Проаналізовано основні напрями впровадження та розвитку елементів робочих підсистем. Представлено пропозиції щодо оперативно-стратегічних напрямів удосконалення державного управління розвитком залізничної галузі за напрямами: удосконалення законодавчої та нормативно-правової бази; повне відокремлення функцій державного управління від економічних функцій залізничних підприємств; розробка та впровадження нової державної системи управління тарифами; розвиток прогресивного підходу до організації та управління пасажирськими перевезеннями та запровадження системи державного управління в міжнародній безпеці. Зроблено висновок, що ефективне функціонування розробленої системи та успішне впровадження напрямів удосконалення державного управління розвитком залізничної галузі дозволить досягти таких результатів: створити умови для розвитку вільної конкуренції в галузі; підвищення конкурентоспроможності залізничної галузі на українському та міжнародному ринках; досягти бажаних показників ефективності залізничної галузі та інноваційного зростання

Ключові слова: підвищений, удосконалення управління, системний підхід, розвиток, інфраструктура

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Strategy for the Development of Public-Private Partnership in the Context of Global Changes

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Abstract. In modern science and practice, public-private partnership is the interaction of the public and private sectors: in a broader sense, any cooperation in various spheres of public life, supporting society with entrepreneurship and strengthening its social role. The intensification of the process of public-private partnership development is due to the steady growth of demand for public services and increased attention of a wide range of people to optimise their provision. Today, public-private partnership has become an important tool for attracting investment to create a modern public service infrastructure. The purpose of this study is to examine possible strategies for the development of public-private partnerships in the context of decentralisation. The methodological basis of the presented research is a combination of theoretical methods: information synthesis and analysis, classification, systematisation. In addition, an analysis of the scientific literature on the research subject was conducted during the study. In particular, articles on public-private partnerships were analysed. As a result of the study, the general trend towards decentralisation of power and reform of local self-government was established, which means transferring more powers to local state structures, where the state, represented by a territorial community, becomes one of the main subjects. It is proved that partnerships between local communities and business structures, including foreign ones, considerably expand the competence of local authorities, in particular, attract investment in the development of urban infrastructure. Based on the analysis of European experience and considering the specific features of Ukrainian legislation, the most acceptable forms of cooperation between the state and companies were identified: private partnership investment agreements, asset management agreements, leases, concessions, and joint venture agreements. The practical value of the study is that the highlighted results will be useful for public and private sector managers

Keywords: concession, partnership, project, local government, territorial community

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INTRODUCTION

In modern science and practice, public-private partnership (PPP) is considered the interaction of the public and private sectors: in a broader sense, any cooperation in various spheres of public life, supporting society with entrepreneurship and strengthening its social role. In a narrower sense, PPP is a partnership in the implementation of socially important investment projects [1]. Today, the PPP is a recognised and proven comprehensive mechanism of society that combines the efforts of the state (state and local authorities) and private organisations to optimise the creation and use of infrastructure and the provision of public services. Among the many interpretations of public-private partnerships, one of the most successful is the definition of the UN Economic Commission for Europe. According to UN Commission, PPP is an innovative long-term contract for the development of infrastructure and public services, funded and motivated by the private sector which is generally owned by the state [2]. Notably, today various versions of the English term "public-private partnership (PPP)" are used. In Ukraine, as in most post-Soviet countries, the term public-private partnership is used mainly in the field of regulation and research. The term is even used in official translations of international documents, such as the Ukrainian version of the Green Paper on public-private partnerships and Community law on public contracts and concessions, prepared by the European Commission in 2004. The Commonwealth of Independent States Model law also uses the term "public-private partnership". Legislation and research also use phrases such as "public-private partnership", "interaction between the state and business" [3], etc.

The study of the experience of public-private partnership shows that its development is an objective process that has certain traditions in many countries, however, it intensified only recently because of the growing demand for public services and increased attention to optimising service provision, due to the budget deficit. In recent decades, PPPs have become an important form of infrastructure projects. World practice generally confirms the success of PPP as a tool for attracting investment to create a modern infrastructure of public services. Moreover, the relationship between the development level of the country and the degree of PPP implementation can be observed [4]. The dynamics of public-private partnership projects in the world has a steady upward trend. Various studies consider the possibility of implementing such projects in certain areas and certain groups of countries. The World Bank's Public-Private Partnership Legal Resource Centre project mainly covers 139 countries divided into six regions: Latin America and the Caribbean; Europe and Central Asia; East Asia and the Pacific; South Asia; the Middle East and North Africa; Sub-Saharan Africa [5]. Public-private partnership is an extremely complex phenomenon that covers not only economic but also social and state-administrative relations. The fastest spread of PPP occurs in developed countries, where there are strong guarantees of property rights, the state does not interfere in business without excessive force, and investors are confident in the stability of the economy and legislation. Regulated risk distribution is also vital [6]. The search for new approaches to creating an effective system for regulating public-private partnership in Ukraine is driven by the need to ensure economic growth, including with the reform of the existing economic model, which is characterised by insufficient foreign investment, low participation in the global value chain, and market imbalance.

The purpose of this study is to examine possible strategies for the development of public-private partnerships in the context of decentralisation.

MATERIALS AND METHODS

The methodological basis of the presented research is a combination of theoretical methods. In the course of the research, the following methods were used: information synthesis and analysis, classification, systematisation. In addition, in the course of the study, the scientific literature on the research subject was analysed. In particular, articles on public-private partnership. In the context of this study, the scientific literature on the research subject was analysed. Methods of analysis and synthesis are used in modern natural sciences, humanities, and social sciences. These methods are characterised by special applications and modifications depending on their application for each specific industry. Analysis and synthesis are universal, oppositely focused ways of understanding an object, concept, or phenomenon. They are used in theoretical research and in practice, especially in experimental activities. The analysis allows obtaining knowledge about individual elements of the subject in various aspects of its existence. Synthesis shapes an idea of the structure and properties of the system and creates a relationship between its main characteristics. These methods were used to define "public-private partnership". The characteristics of public-private partnerships were considered and analysed using analysis and synthesis methods. Induction is a method of cognition that is based on a formal logical conclusion that allows drawing a general conclusion based on individual facts. In other words, it is the shift of thinking from individual to general. Thus, the main characteristics of a public-private partnership were determined using the induction method.

Classification is a method of combining classification elements into classification groups. There are two main classification methods: hierarchical and faceted. Hierarchical classification method. This method is characterised by the fact that the initial set of information objects is gradually divided into groups (classes) of the first level of division, then into groups of the next level, etc. Systematisation is the process of combining various knowledge about objects (phenomena) of objective

reality into one scientific system that determines their unity. Systematisation is a reflection of the material unity of the world, and it studies the main connections between these objects (phenomena). It is based on the classification, analysis, and synthesis of the main properties of a particular objective system. It is performed in the form of corresponding logical systems – theories, hypotheses, etc. A necessary condition for systematisation is the promotion of the main idea, which can lead knowledge to logical unity. The starting point of the systematisation process is the adoption of certain principles that formulate the main idea. Systematisation is always one-sided since logical systems cannot comprehensively reflect the laws of objective systems. The dialectical discrepancy between the science being focused on a comprehensive systematisation of knowledge and the impossibility of its implementation is solved by improving human reality cognition. At the final stage of the study, scientific literature, in particular scientific articles, was analysed. The studies of Ukrainian and international researchers were reviewed. In analysing the studies, certain conclusions were drawn, which are presented in the final part of the study.

RESULTS AND DISCUSSION

In recent years, the issue of public-private partnership and its role in modernising the economy of industrial regions have become very relevant. The introduction of PPP is primarily related to the need to attract a considerable amount of investment to finance and improve the effectiveness of socially important projects at the regional level. Abroad, public-private partnerships are considered an alternative to privatisation, as such partnerships allow public authorities to receive funding from the private sector without losing control of public facilities. Most of the public-private partnership projects implemented in these countries are infrastructure projects, the privatisation of which in many countries is considered inappropriate for strategic reasons to prevent socio-economic discrimination or for other reasons. At the international level, the public-private partnership has not been systematically interpreted. As for the European Union (EU), the term "PPP" is not defined at the community level. The European Commission, the EU's highest executive body, uses a relatively general interpretation of public-private partnership [7]. Systematisation and generalisation of existing approaches to the interpretation of public-private partnership allows noting that this term should be considered as a technology of public-private interaction to effectively attract and use financial resources and business opportunities in conditions of limited investment resources. Figure 1 shows the main specific features of public-private partnership as an economic category [2].

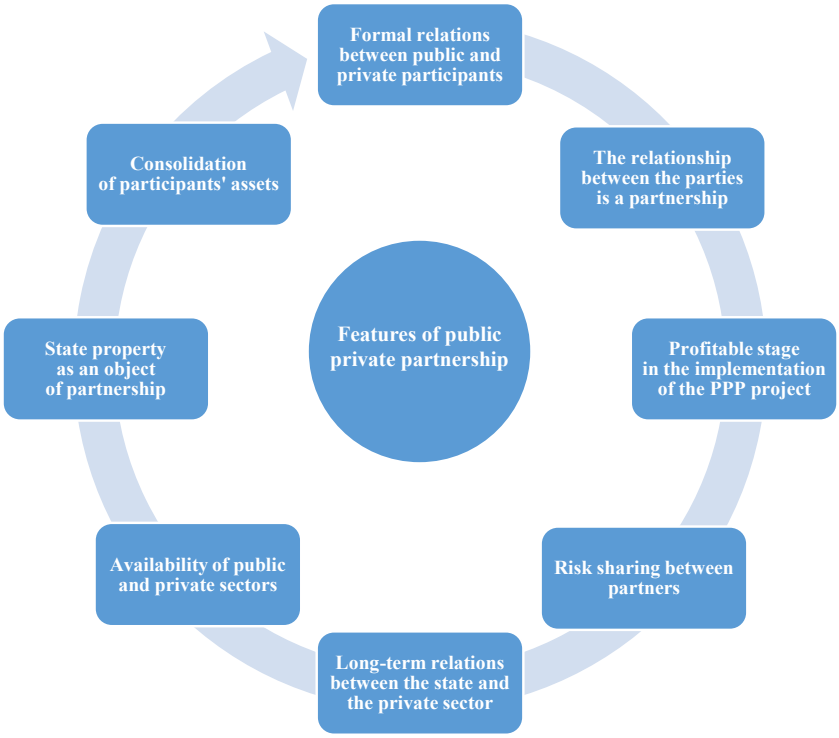

Figure 1. *Key features of public-private partnership*

Source: *compiled by the authors*

The development of legislation on public-private partnership, or rather its forms, should be divided into four stages [8]:

– stage 1 – The Law of Ukraine "On Concessions" and related draft laws;

– stage 2 – The Law of Ukraine "On Public-Private

Partnership" and numerous resolutions of the Cabinet of Ministers of Ukraine, orders of the Ministry of economic development and trade of Ukraine;

– stage 3 – The Law of Ukraine "On Amendments to Certain Laws of Ukraine Concerning the Elimination of Regulatory Barriers to the Development of Public-Private Partnership and Investment Promotion in Ukraine";

– stage 4 – draft law of Ukraine "On Concessions" (on public-private partnership) [9].

During 2015-2021, researchers report positive trends in the development of public-private partnership in Ukraine. Figure 2 shows the number of projects in the public-private sector for 2015-2021.

Notably, public-private partnership projects are mainly implemented in the field of public utilities, such as water collection, purification, and distribution and services in the field of collection/use and disposal of household waste [10]. The variety of PPP forms provides an opportunity for the widespread use of private capital to solve many problems of local self-government in the production of public goods and services.

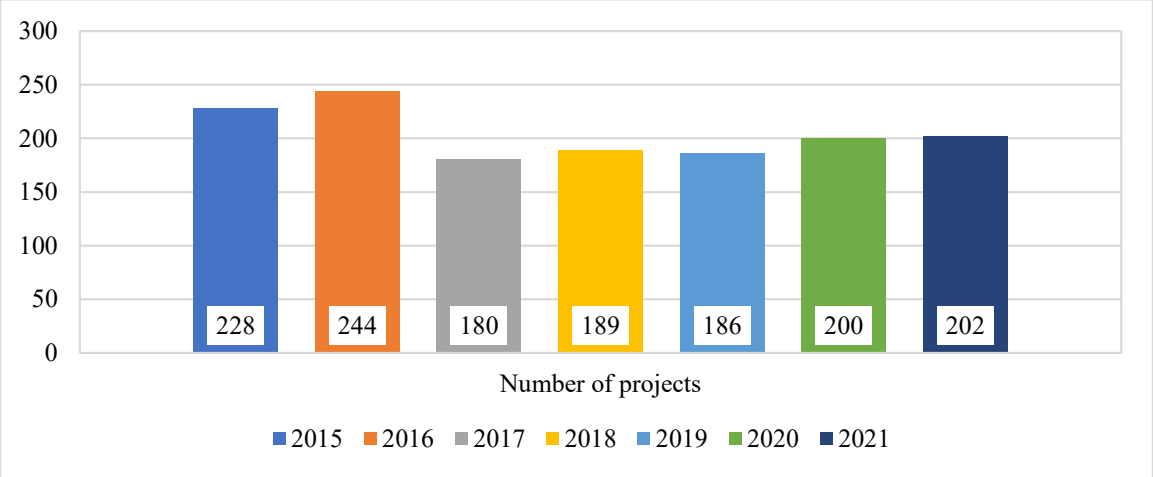

***Figure 2**. Public-private partnership for 2015-2021*

***Source**: compiled by the authors*

PPPs are used in many areas of economic activity considering their specific characteristics: exploration and production of mineral deposits, with the exception of those carried out in accordance with the provisions of production sharing agreements; production, transportation, and supply of thermal energy, distribution and supply of natural gas; construction and/or operation of highways, railways, railway bridges, overpasses, tunnels, underground passages, seaports, river ports and their infrastructure; mechanical engineering; collection, purification, and distribution of water; health; tourism, recreation, leisure, culture, and sports; ensuring the functioning of irrigation and drainage systems; waste management, except for production, distribution, and supply of electricity; property management; provision of social services, administration of a social institution; production and implementation of energy-saving technologies, construction and major repairs of residential buildings completely or partially destroyed as a result of military operations on the territory of the anti-terrorist operations; installation of modular buildings and construction of temporary housing for internally displaced persons; provision of educational and medical services; management of architectural monuments and cultural heritage [11].

Therefore, based on the above, it should be specified that the system of public-private partnership is one of the components of the transformation of economic relations, which improves the infrastructure of the region. Joint work of public authorities and economic entities reduces potential risks when implementing new projects that can improve the region's infrastructure. Public-private partnership is primarily a mutually beneficial economic relationship that is based on long-term projects, minimises costs, increases resource efficiency, and allows getting positive results from the implementation of a new project. The social component of public-private partnership is reflected in the development of regional infrastructure with the involvement of the public in the development of projects. The main role of the community: to motivate local authorities; to determine the socio-economic and socio-political conditions of the project during the implementation of the public-private partnership mechanism; the community acts as the final consumer of public-private partnership projects [12].

The mechanism of public-private partnership is based on the extra-budgetary investments in various types of infrastructure and objects of production and non-production. The main role of public authorities is to: develop infrastructure and ensure sustainable development of socio-economic relations (orientation of public authorities and the private sector to the needs of territorial communities). The joint work of the public and private sectors creates opportunities for the parties to reap the benefits of innovative development and to

participate in globalisation and integration. In modern conditions, public-private partnership is at an early stage of its development in Ukraine, the main obstacles are institutional (existing political instability in Ukraine, constant changes in the legislative framework regulating business, low coordination of state bodies, short-term planning budget, lack of experience, management skills, and development of intellectual property relations) and legal barriers (lack of standard documents, imperfect concession legislation) [13]. The main obstacles to the development of public-private partnership in Ukraine are presented in Figure 3.

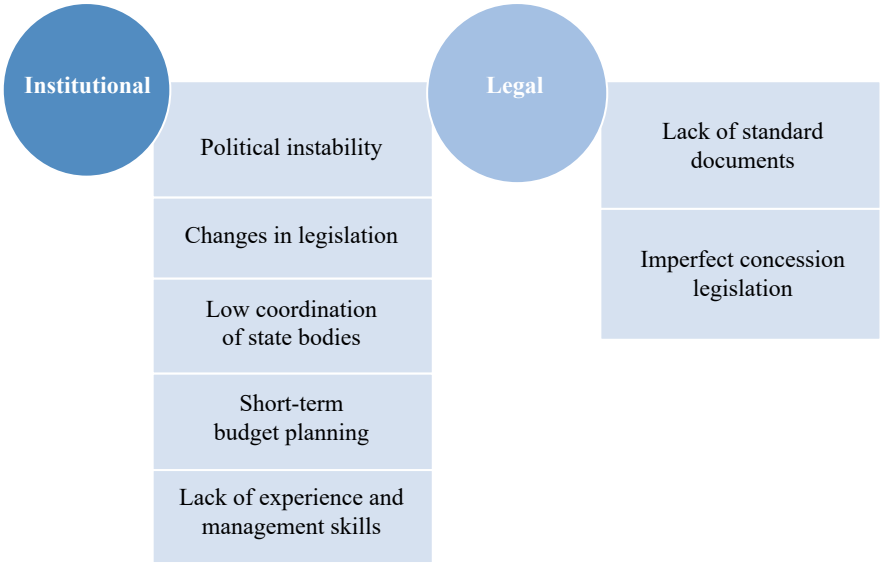

Figure 3. *Negative factors affecting the development of public-private partnership in Ukraine*
Source: *compiled by the authors*

Considering all the above, it is possible to set the main goals of public-private partnership, which the Ukrainian state should be aimed at. The main goals of public-private partnership are:

– improving the legislative framework of Ukraine;
– developing common concepts;
– establishment of regional centres;
– information support from the state;
– educational support from the state;
– scientific and expert support from the state.

The introduction of a mechanism for implementing forms of public-private partnership requires the introduction of organisational, managerial, economic, sectoral, and informational measures that will considerably contribute to the development of the public-private partnership [14]. The basis of organisational and managerial measures is the following: the creation of financial institutions for the development of public-private partnership for the purpose of investing and guaranteeing private investment; the establishment of non-financial institutions for the development of Public-Private Partnership; the development of the management system; advanced training of civil servants; the introduction of the issue of public-private partnership in academic training programmes for public administration and local self-government bodies; the organisation of training, seminars, round-table conferences that could cover the issues of public-private partnership [15]. Important economic measures include reimbursement of the cost of the project, construction, modernisation, participation in tenders; introduction of state credit mechanisms and insurance of imports of investment equipment; provision of state guarantees for loans; compensation for losses caused by currency fluctuations; use of modern market financing tools (securities); reduction of tax rates, exemption from taxes and fees, deferral of certain taxes and fees, etc.; provision of subsidies [13]. The industry activities include the implementation of PPP pilot projects, considering the specific features of the industry; the establishment of a programme for the PPP development in various economic sectors; the formulation of a package of methodological documents for the PPP implementation in various sectors of the economy; the development of legislative provisions for the PPP promotion and support; the introduction of mixed forms of ownership in certain sectors, cooperation between public and private companies [11].

The basis of information activity is: popularising the positive practice of public-private partnership in society; creating programmes in educational institutions to train qualified civil servants in the field of public-private partnership; conducting an information campaign among business representatives, informing about the advantages of such partnership and creating an image of the state as a bona fide partner; implementing an information strategy, distributing brochures, attracting partners to conferences, round tables, seminars, short-term courses that could highlight issues of public-private

partnership; adapting international experience of successfully implemented projects [8]. A large number of Ukrainian and international researchers have studied the issues of public-private partnership in Ukraine and the world. Hereinafter some of the works that cover the issue of public-private partnership are considered.

Ireland was late with the public-private partnership since it was only introduced in 1998. Prior to the credit crunch, Ireland followed the British model of public-private partnerships in transport, education, housing/urban renewal, and water/sewerage. Public-private partnerships were recently blocked during the credit crunch and recently renewed due to a scheme to stimulate internal infrastructure. This article considers Ireland as a junior participant in public-private partnerships and the relationship between adoption models and sustainability characteristics of Irish public-private partnerships. The article uses an analysis of documents and previous interviews to examine the reasons for Ireland's interest in public-private partnerships, which cannot be explained solely by economic considerations. It is appropriate to consider three explanations: voluntary adoption – when the British model has been continuously monitored by an internal modernisation plan; forced adoption, when public-private partnership policies are imposed on public sector organisations; and institutional isomorphism, where institution building and changes in public-private partnerships are encouraged to help public sector organisations gain institutional legitimacy. The authors found evidence for all three models: forced adoption has become increasingly relevant in recent years, which may negatively affect sustainability if incentives for voluntary adoption and institutional capacity-building are not strengthened; forced adoption, where public-private partnership policies are imposed on public sector organisations; institutional isomorphism, where institutional development and changes in public-private partnerships are encouraged to help public sector organisations gain institutional legitimacy [16].

Public-private infrastructure partnerships based on private financing are popular around the world, including renewed interest in the United States, but their effectiveness remains controversial. This article examines the meaning of PPP and its success, outlines multiple interpretations of both. The study proposes a new conceptual model of the PPP phenomenon, which includes five levels of meaning: project, implementation method, policy, management tool, and cultural context. There are many criteria by which the success of PPP can be estimated. They are as focused on policy and management as they are on the more conventional goals of utilitarian policy related to project implementation or value for money. The authors note that the government pursues dozens of different goals, given the mixed international results in terms of price and quality to date [17]. The following study under review complements the development of public-private partnership infrastructure projects, which are a fast-growing way to provide infrastructure services. PPP infrastructure projects generally have a long-life cycle, but the changes that such a project undergoes at all stages of its life cycle are understudied. This article contributes to project research as it examines the changes that the PPP infrastructure project undergoes during its life cycle and suggests how these changes can be managed. The study is based on a detailed study of road transport PPP in California over a twenty-year period. The study under consideration shows that the development phases of PPP are characterised by dramatic changes in the composition of stakeholder networks and the use of institutional logic. First, using social media analysis, the authors map the network of stakeholders in the case of PPP and demonstrate how the network of stakeholder's changes in four stages. Second, the authors identify how different stakeholders use formal and informal institutional logic in their interactions and demonstrate that the dominant institutional logic used in PPP changes from informal to formal over the course of the PPP life cycle. The authors also demonstrate how this change in the dominant institutional logic of PPP corresponds to dynamism in the stakeholder network [18].

Uncertainty about construction costs and operating income are the two main risks in public-private partnership projects in the transport sector. This uncertainty puts projects at risk of not meeting the annual debt repayment obligations. When a project generates insufficient cash flow to service debt in a given year, it generally has to use short-term financing by borrowing short-term loans [19; 20]. With revenue-related risk-sharing mechanisms, supported projects can eliminate unexpected interest payments. The considered article has a twofold purpose: first, to estimate the cost of refinancing PPP motorway projects caused by a lack of funds; second, to critically examine the cost of the conditional financial support option and compare it with the cost of the minimum income guarantee option to save refinancing costs for debt repayment. An integrated real options valuation model is created, which uses the utility method to determine the cost of technical project risk (for example, excess construction costs) and the risk-free pricing method to evaluate market risk (for example, future traffic). The proposed model has good tolerability for including various risk factors, regardless of technical or market risks, random variables, or processes [21-24]. The proposed model helps stakeholders better understand and measure the burden of securing annual debt repayment in an uncertain cash flow environment [25].

Contractual and relational practices are defined as actions performed and reproduced due to the dual position of actors: at the partnership level and at the parent organisation level. In the PPP, complementarity and contradictions between public, bureaucratic logic and private, market logic determines the structural

requirements for actors. Unpredictable and innovative management methods arise from the reflexive ability of actors to balance different requirements. This structure allows studying the complex interaction of relationships and contractual relations, illustrated by the example of the Dutch PPP [26]. The use of public-private partnerships (PPPs) has been steadily increasing in the United States since the early 1990s. Considerable differences in cost and schedules were observed in infrastructure design and construction projects. Thus, the purpose of this article is to quantify the cost and schedule of recently completed PPP projects in the US transportation sector and compare them with their non-PPP counterparts. The authors C. Benítez-Ávila, A. Hartmann, G. Dewulf [26] collected and validated data from professional datasets, publicly available websites, and structured interviews with key project participants. The article presents the results of 25 completed PPP transport projects. All projects in the dataset were completed between 1995 and 2013; the project cost ranged from 18 billion to 2.1 billion and amounted to about 14 billion. According to the analysis, the average cost growth was 3.22% and the average schedule growth was 1.2%; compared to the conventional "design-proposal-assembly" offer, these results show excellent performance. This article covers the effectiveness of PPP projects in the US transportation sector and compares the results with previous studies on the international PPP market [27].

Based on the regional transit case study in Denver, Colorado, this article describes and explains the emergence of global public-private infrastructure partnerships as a new extraterritorial mechanism for financing and implementing transport infrastructure projects in the major metropolitan areas of the USA. Unlike conventional public-private partnerships with local financing, the PPP includes a global (i.e., extraterritorial) consortium of construction firms and private sector investors, which enters into a long-term contract with a regional public agency to finance, operate, maintain, and supply strategic investments in transport infrastructure. In 2004, voters in the Denver region approved a $ 4.7 billion sales tax increase to fund the FasTracks programme of the Denver Regional Transportation District. 122-mile length of light and suburban railways along six corridors. Due to a lack of regional funding, the Denver Regional Transportation District subsequently signed a contract with the public-private partnership organisation. This contract prescribed the Eagle P3 project funding and subsequent granting to the Airport in Denver. The authors foresee a great research potential in the studies of PPP contractual agreements, provided they consider local control over infrastructure assets and the integrity of supporting regional joint management agreements [28].

CONCLUSIONS

The general trend towards decentralisation of power and reform of local self-government means the transfer of more powers to local state structures, where the state represented by the territorial community becomes one of the main subjects. It is proved that partnerships between local communities and business structures, including foreign ones, considerably expand the competence of local authorities, in particular, attract investment in the development of urban infrastructure. A public-private partnership is a set of property, financial-economic, organisational-managerial, and legal relations between the state and a private partner in models of financing, ownership, and management relations. In the course of the research, the experience of world science in approaches to defining the public-private partnership was summarised. Researchers are studying key approaches to defining public-private partnerships with international financial organisations and development institutions. The main characteristics of PPP as an economic category are covered based on analysis, systematisation, and generalisation of existing approaches of world science to its interpretation. It was discovered that a public-private partnership operates based on a "division of property" through a voluntary exchange of powers.

The state performs a partial transfer of property rights (the right to receive, the right to administer, the right to control the use of property, the right to change the value of the contract's capital, and the right to transfer certain property rights to others). The organisation of property relations within the framework of the PPP is primarily focused on achieving a synergistic effect from the cooperation of specific potentials of private and state property. It is proved that with a considerable delay in the introduction of public-private partnerships in the world, this practice has now gained experience in public-private partnerships in various sectors and fields of activity. The experience of public-private partnership in the world confirms the successful practice of introducing contractual and institutional forms of partnership between the state and the private sector in various sectors of the economy. The considerable development of public-private partnership in Western countries is due to historical features. Based on the analysis of European experience and considering the specific features of Ukrainian legislation, the most acceptable forms of cooperation between the state and companies were identified: private partnership investment agreements, asset management agreements, leases, concessions, and joint venture agreements.

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Стратегія розвитку державно-приватного партнерства в умовах глобальних змін

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Анотація. У сучасній науці та практиці державно-приватне партнерство розуміється як взаємодія державного та приватного секторів: у більш широкому сенсі як будь-яка співпраця у різних сферах суспільного життя, підтримка суспільства підприємництвом та посилення його соціальної ролі. Активізація процесу розвитку державно-приватного партнерства зумовлена стійким зростанням попиту на державні послуги та підвищеною увагою широкого кола людей до оптимізації їх надання. На сьогодні державно-приватне партнерство стало важливим інструментом залучення інвестицій для створення сучасної інфраструктури державних послуг. Метою представленого дослідження є вивчення можливих стратегій розвитку публічно-приватного партнерства в умовах децентралізації. Методологічною базою дослідження є поєднання теоретичних методів наукового пізнання: метод синтезу та аналізу інформації, метод класифікації, метод систематизації. Також у процесі дослідження було проведено аналіз наукової літератури з тематики дослідження. Зокрема, було проаналізовано наукові статті з тематики публічно-приватного партнерства. У результаті дослідження була визначена загальна тенденція до децентралізації влади та реформування місцевого самоврядування, що означає передачу дедалі більше повноважень місцевим державним структурам, де держава в особі територіальної громади стає одним із головних суб'єктів. Доведено, що партнерські відносини між місцевими громадами та бізнес-структурами, у тому числі іноземними, значно розширюють компетенцію місцевих органів влади, зокрема, залучають інвестиції у розвиток міської інфраструктури. На основі аналізу європейського досвіду та врахування особливостей українського законодавства були визначені найбільш прийнятні форми співпраці між державою та компаніями: інвестиційні договори приватного партнерства, договір управління активами, договір оренди, концесії та договір про спільне підприємство. Практична цінність представленого дослідження полягає у тому, що висвітлені результати будуть корисними для управлінців державного та приватного сектору

Ключові слова: концесія, партнерські відносини, проєкт, місцеве самоврядування, територіальна громада

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