**УДК** 342.813:657
**JEL Code** Q17, Q54, Q55
**DOI** https://doi.org/10.33146/2307-9878-2021-2(92)-136-146

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# Напрями інноваційного розвитку сільського господарства в контексті кліматичних змін

***Анотація.*** *Сучасний стан розвитку сільського господарства характеризується проявом негативних тенденцій, що пов'язано із переважанням екстенсивних систем виробництва та зниженням інвестицій в сільськогосподарські дослідження, тоді як вплив на навколишнє середовище та природні ресурси постійно зростає. Крім цього, одним із найбільших викликів XXI століття стає зміна клімату, що чинить несприятливий вплив на соціально-економічні та природні системи і вимагає розробки напрямів адаптації галузі до кліматичних змін. Метою даного дослідження є обґрунтування основних напрямів інноваційного розвитку сільського господарства в контексті кліматичних змін. Дослідження виконано на основі системного підходу з використанням широкого спектру загальнонаукових та спеціальних методів. Встановлено, що зміни клімату безпосередньо впливають на сільське гогосподарство країни, яке сильно залежить від погодних і кліматичних умов. Основним інструментом адаптації галузі до кліматичних змін має бути впровадження інновацій, результатом чого стане його інноваційний розвиток. Систематизовано основні напрями інноваційного розвитку сільського господарства в контексті кліматичних змін: біологічні (нові сорти, гібриди сільськогосподарських культур, нові типи, породи сільськогосподарських тварин), техніко-технологічні (новітні технології в рослинництві та тваринництві), хімічні (добрива, засоби захисту рослин, регулятори і стимулятори росту), організаційно-економічні (організація підприємства, менеджмент, маркетинг), соціальні (соціальний розвиток людини), напрями розвитку альтернативної енергетики (виробництво енергії з відновлюваних джерел) та діджиталізації (цифрова трансформація виробничих процесів).*

***Ключові слова:*** *інновації, інноваційний розвиток, сільське господарство, кліматичні зміни, інноваційні системи землеробства, біоенергетика, діджиталізація.*

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# Trends of Innovative Development of Agricultural Business in the Context of Climate Changes

***Abstract.*** *Current state of the development of agricultural business is characterized by negative trends caused by the prevalence of extensive production systems and the reduction of investments into agricultural research, while the influence on the environment and natural resources is constantly increasing. Besides, climate change is one of the greatest challenges of the XXI century, which exerts a negative influence on social-economic and natural systems and requires the development of the ways for the industry to adapt to climate changes. The purpose of the article is to substantiate the main areas of innovative development of agricultural business in the context of climate change. System approach as well as the application of a wide range of general scientific and special methods make up the framework of the research. It has been established that climate changes directly affect the agriculture of the country that greatly depends on climate and weather conditions. The main tool to adapt agriculture to climatic changes should be the introduction of innovations resulting in its innovative development. The article also presents the systematization of the main directions of innovative development of agricultural business in the context of climatic changes: biological (new cultivars, hybrids of agricultural crops, new types and breeds of agricultural animals), technical and technological (advanced technologies in plant and animal production), chemical (fertilizers, plant protection agents, plant growth regulators), organizational and economic (business organization, management, and marketing), social (social development of a person), development directions of alternative energy (energy production from renewable sources), and digitalization (digit transformation of production processes).*

***Keywords:*** *innovations, innovative development, agriculture, climatic changes, innovative systems of arable farming, bioenergetics, digitalization.*

**Problem statement.** Agriculture is the main area of human activity that influences food security and welfare as well as the environment inhabited by people. However, the influence of agriculture falls beyond the scope of classical economic functions showing the relation between agricultural production (transformation of resources into agricultural products and services) and functioning of nature or social life. Integral approach to agriculture also reveals its non-economic functions.

Perception of agriculture from the perspective of the efficiency of a producer, maximization of economic profit, and increase of production efficiency has led to the deformation of its functions. It is related to the approach that equaled agricultural activity to the industrial one and in this way attributing industrial character to the activity of agricultural enterprises [1]. Such activity made it possible to achieve considerable progress in the economic sphere, however, it became a catalyst of the imbalance both in the environment and the social sphere. Economic pressure has led to the systemic planning of the mechanisms of commercialization, specialization and concentration as well as capital-intensive intensification in agriculture.

It should be mentioned that neither market nor institutional mechanisms could effectively prevent direct and indirect consequences of such planning, which was stressed upon in the analysis of UNO [2].

The key functions of agriculture are implemented not only through agricultural activity but due to the complex of activities that comprise different factors and conditions including those that are independent of agriculture. Thus, agricultural activity providing sustainable development includes the production of a certain number of products of proper quality, protection of soil, water and air, proper handling of waste, adherence to biodiversity, adaptation of the branch to climatic changes as well as the functions related to the improving of life quality in a rural area.

In a broader context such target-aimed development of agriculture requires the introduction of innovations, which, on the one hand, will promote the stable development of the sector and the adaptation of agricultural enterprises to climate changes, and, on the other hand, they will increase their competitiveness and economic development.

**Literature review.** Challenging aspects of the innovative development of economy is the subject matter of the research of many outstanding foreign and national economists. The following works are worth mentioning: R. Rauter [3], F. Gault [4], J. Chen & X. Yin [5], A. Distanont [6], B.S. Silvestre [7] et al., which focus on current innovation paradigm, the role of innovations in

the sustainable development of society, and in the increasing competitiveness of enterprises, etc.

Considerable contribution in studying and systematization of innovation, in defining the priorities of innovative development of the economy of Ukraine and the role of the state in this process, in the formation of the institutional environment of innovative development were made by the scholars V.D. Bakumenko & S.A. Popov [8], V.I. Hevko [9], V.O. Husiev [10], O.I. Datsii [11], M.M. Zermoshenko [12], V.M. Haiets [13].

It should be mentioned that innovative activity in agriculture develops dynamically along with the understanding that there is a complex relation of innovative solutions on the technological basis with the natural environment and is also the subject of the research in numerous papers of M. Lobas, V. Rossokha, D. Sokolov [14], L. Kustrych [15], Yu. Nesterchuk [16], S. Sokoliuk [17], O. Shubravska [18] et al.

However, despite a great number of scientific developments, the issues of innovative development of agricultural enterprises in the context of climate changes remain under investigated and require further research.

**The purpose of the article** is to substantiate the main areas of innovative development of agricultural enterprises in the context of climate changes.

**Research methodology.** Methodological background of the research is made up from the principles of general scientific and fundamental cognitive theory of investigated phenomena and processes, the laws of the development of economic systems, publications of national and foreign researchers on the issues of innovative development of agricultural enterprises. The research was performed on the basis of a system approach using a wide range of general scientific and special methods.

**Main results of the research and discussion.** The issues of innovative development of agriculture in the context of climate changes require further detailed research and systematization. Review of literature sources on the investigated subject area made it possible to single out the following types of innovations: biological, technical and technological, chemical, organization and economic, social, alternative energy, and digitalization.

*Biological innovations*. Climate changes exert direct influence on the functioning of agricultural enterprises since their performance takes place directly in the natural environment when using animal and plant organisms. Therefore, biological development in the branch lies in the creation of the new best varieties of agricultural crops and animal breeds in terms of quality and quantity. New improved cultivars of agricultural crops in plant production are the factors that activate agricultural production.

The use of up-to-date technologies in selection including in vitro culture, molecular markers, genetic modification of plants, micro-methods for the evaluation of the quality of plant material at early stages of growing can shorten the cycle of propagation, control genes transplantation, improving the efficiency of selection and, as a result, cut the costs of developing of new cultivars.

This, in the first place, leads to the application of new technologies in plant production, aimed at achieving particular qualitative and quantitative changes necessary for manufacturers and cause biological progress.

Taking into account the climate change in Ukraine biological innovations in plant production should include:

– application of state-of-the-art technologies in selection, including in vitro cultures, molecular markers, genetic modification of plants, micro-methods to evaluate the quality of plant material at the early stages of growing, etc.;

– application of types and varieties of agricultural crops with a short vegetation period in southern areas, which will make it possible to obtain up to two-three yields of certain crops (for example, vegetables) and to use effectively the supplies of moisture and to form yielding capacity before the beginning of extremely high temperatures and drought;

– replacement of cultivars with those that are better adapted to climate changes;

– development of new cultivars of crops resistant to summer droughts and winters without snow, that have high indexes of photosynthesis productivity in stressful conditions of vegetation and resistant to biotic and abiotic threats;

– introduction of niche crops (chickpea, soya, safflower, sorghum, millet, etc.) and exotic crops (kiwi, persimmon, banana tree, Chinese date), peanut, sweet potato, black pepper, olive trees) with high drought resistance and export potential in the production [19].

However, it is necessary to mention that the development based on the methods of industrial intensification takes place as a result of synergy of the advantages obtained from the collaboration of each of these forms.

Innovative directions of animal breeding development refer both to breeding and raising animals and are caused, in the first place, by technological and organizational changes in agriculture. Firstly, it is caused by the increase in consumer demand for high-quality livestock products, improving standards related to raising and keeping animals, and their influence on the environment. Secondly, agricultural enterprises in order to increase their profit require cheaper, more effective and safe and ecological technologies based on the use of living organisms in the processes of agricultural production.

The work on animals used for agriculture is performed to achieve two goals: scientific and practical. Scientific research deals with genetic control over the functioning of physiological systems of animals and humans, and the development of genetic models of determinants of certain diseases.

On the other hand, practical aims include the changes of quality of animal products, for example, cow milk and quality of milk (improvement of the properties of protein products), increase of the amount of meat tissue, decreasing the amount of fat tissue, the changes of animals resistance to diseases and parasites (for example, hens resistant to bird flu virus, cows resistant to diseases caused by prions), improvement of feeding and metabolism and better digestion of forage, faster and controlled reproduction [20].

At the same time, negative external effects of agricultural production including not only the pollution of the environment but also safety and health of people require innovative solutions.

As to the climate changes and their influence on animal production, it requires zoo-meteorological research and the selection of such types and breeds of animals that are as little as possible dependent on the factors of the environment. The required meteorological information includes temperature and atmospheric relative humidity, amount of precipitation, wind velocity, solar-flux level, etc. Unfortunately, in Ukraine, such research is being performed at an insufficient level.

However, the relations between the productivity of animals and heat and cold stress, among different climatic anomalies and reproductive function of animals, quality of products, etc., are being investigated in the countries with developed animal raising [2]. This kind of research should form the basis for the breeding of innovative types and breeds of agricultural animals with the account of climate changes and application of biotechnologies, in vitro culture of animal cells, stem cells, production of monoclonal bodies, etc.

In vitro methods form an important safety strategy in case when protection cannot be done to provide the required population size. However, it is necessary to mention that ethical issues of the application of the above-mentioned technologies are still provoking discussions. Due to ethical cautions in agricultural practices, a lot of legal and regulatory acts of institutional character considerably restricting such innovations were introduced.

*Technical and technological innovations*. Enhancing of erosion and degradation of soils are some of the manifestations of the influence of climate changes on the agrarian resources of Ukraine. Therefore, there is the necessity in innovative developments in the sphere of advanced technologies of agricultural production and technical means of tilling soil, among which the application of innovative tillage systems plays an important role (table 1).

*Table 1*

**Innovation systems of arable farming and technologies of soil cultivation in Ukraine**

| System of farming | Content and specific features |
|---|---|
| Organic production technology | Soil protective, water-preserving, surface tillage; science-based crop rotations, introduction of perennial leguminous grasses, green manure crops in the structure of cultivated areas, application of organic fertilizers, manure, use of after-harvest residues, non-commercial part of harvest, mulching the surface of the field with plant residues helps to decrease the temperature of soil and moisture evaporation. Soil moisture increases on average by 28-32%. |
| No-till | Superficial layer of the soil is not loosened, direct seeding is applied; all plant residues are left on the surface and spread evenly on the field. Mulch considerably decreases moisture evaporation (by 80%), protects soil against erosion, deflation and man-made over-compactness. Decrease of $CO_2$ emissions into atmosphere as a result of the reduction of fuel spending in the annual cycle of field work. Decrease of dependence of the yield on climate conditions. |
| Strip-till | Combines the elements of the main and no-till methods of soil cultivation, when field is cultivated by strips, in which seeds are sown. These methods prevent water and wind erosion, and retain snow on the field. |
| Bio-enzym technology | The basis of the technology is the application of bentonite, which is good sorbent and nutrient for autotrophic bacteria. It is also a good hydrant (1gram of bentonite absorbs up to 12g of water). Accumulating water it swells, 16 times increasing its own mass: accumulates moisture that comes over a year and makes it possible to survive droughts. Bentonite is applied only once in 7-10 years. It create optimal nutritional and water regime even in extreme conditions. |
| Biogenic farming technology | The basis of this technology is created by energetic, organic and biogenic resources, whose organization-technological and micro-structural changes can considerably improve moisture supply and soil productivity. Mulch layer is formed from crushed brushwood. It eliminates deflation and water erosion, forms positive water balance of the soil. Mulch biomass as additional mulch is introduced at the rate of 10t/ha. To decay such amount of organic matter by microorganisms bio-fertilizers are applied. The second element of this system is local vertical soil tillage. |

*Source: compiled by the authors.*

The table 1 shows the main innovative tillage systems that can be used in the activity of agricultural enterprises to adapt them to climate changes.

Their application has a positive influence on the water and thermal regime of the soil, they prevent water and wind erosion, provide necessary nutritional balance of the soils, promote the production of safe high-quality products, and decrease the man-made load on the environment.

At the same time, it should be understood that there is practically no longer a unified system of soil tillage, and differential tillage dominates. Also, no methods of soil tillage can be regarded as the pattern for the whole territory of Ukraine because of the variety of soil and climate zones, sub-zones, soils, etc. [21].

Relevant measures as to the adaptation of agricultural enterprises to climate changes is the introduction of innovative ways of drainage and watering that provide effective use of water and high biological productivity of agricultural crops. Thus, in 2019 the Strategy on irrigation and drainage in Ukraine for the period to 2030 was adopted. It states that "regardless of weather conditions the use of irrigation and drainage helps to increase the yielding capacity of crops by 2-3 times compared to dry farming" [22].

There are 5485.3 thousand hectares of reclaimed lands including 2178.3 thousand hectares of irrigated lands and 3307 thousand hectares of drained lands with a corresponding meliorative infrastructure.

However, the state of land reclamation "according to the level of the application of available capacities of engineering irrigation and drainage infrastructure is characterized as critical with the threat of deterioration" [22].

Among innovative products for irrigation and drainage of cultivated land it is necessary to single out the application of the system of drip watering and sub-surface irrigation system, production of pumping equipment, watering tools (irrigation machine, tools of drip watering, shut-off and control valves, safety valves, automated equipment for technological processes of water application, distribution and drainage).

According to the data by V. Kovalskyi, the area of inter-farm irrigation system requiring modernization makes up 250000 – 300000 ha, and demand for the construction of new systems is about 200000 ha (the cost of 1 ha of drip irrigation system (mainly sub-surface) is $3000 – 3500) [23].

Afforestation belts play a very important role in the system of measures aimed at the adaptation of agriculture to climate changes, water accumulation, and drought control. They slow down wind velocity, retain snow and water in the fields, prevent deflation and water erosion of soils, improve micro-climate in the fields, and increase productivity of farming eco-systems and level of bio-diversity. Their influence on the yield of agricultural crops becomes apparent in all years: during droughts, dusts storms, and even under favorable conditions of vegetation period [24].

Innovative technologies are also introduced in animal production to decrease climate influence on the production and quality of products. Among significant innovations, it is worth mentioning the technologies related to the advanced technologies of animal feeding, because climate changes in Ukraine lead to the decrease of forage reserve.

Besides, the composition and quality of food ration influence "health, reproduction ability, the intensity of growth and development, productivity parameters, ability to perform vital functions of animals" [25].

Introduction of the above-mentioned technologies leads to the decrease of forage consumption, free access of animals to forage through a modern system of forage distribution, increase of live weight, decrease of conversion coefficient, dose accuracy, and distribution of forage.

Innovative part is an essential pre-requisite for the creation and introduction of energy- and resource-saving technologies in animal production which suggests specialization of operations in raising and keeping animals, creation of proper microclimate, increase of livestock reproduction ability, effective organization of rest and diet of animals, effective use of cleaning, transportation and utilization of manure (excrements), etc. [25].

*Chemical innovations.* Chemicalization is an important element of the innovative development of agriculture and includes the application of fertilizers and plant protection agents on ecological principles. The application of growth stimulators and plant growth regulators allow humanity to increase the volume of agricultural production even under unfavorable environmental conditions and climate change. Optimization of the nutrition of agricultural crops enhances the development of the root system, accelerates the growth and development of plants, shortens the time of ripening, and eventually leads to the increase of yielding capacity, improvement of the quality of the grown produce, better harvesting, and storage.

According to the data of O.V. Sydiakina "over 4000 natural and synthetic growth stimulators of different origin and chemical composition have been approved". 69 preparations-plant growth stimulators, out of which 53 belong to biostimulators of natural origin are permitted for use in Ukraine.

A considerable part of preparations, especially of foreign production, contains amino acids, vitamins, macro- and microelements and other physiologically active compounds that enhance their positive influence on a plant body" [26].

Extremely important component in the application of chemical industry products is the accuracy of their dosage and application which became possible due to the use of nanotechnologies.

Advantages of nanotechnology innovations in intensive agriculture are related primarily to the increase of the efficiency of applied resources and decrease of production risk. Given technology is one of the most promising for the development of plant production. In the future the application of nanotechnologies will open absolutely new opportunities in agriculture, environmental protection, and technologies of foodstuff production.

The following main innovative products of chemicalization of agriculture can be singled out:

– nanocapsules for the use of pesticides, fertilizers, plant protection agents;

– nanosensors for monitoring the state of soil and growth of plants;

– nanosensors to reveal plant pathogenic agents;

– pesticides in the form of nanocapsules and nanoemulsion for the efficiency improvement of the action and solution in water.

*Alternative energetics.* The way of preventing global climate change, reduction of $CO_2$ emissions and greenhouse effect is the application of alternative sources of energy. According to the Energy Balance of Ukraine, the share of energy from renewable sources in the general structure of energy supply over the last decade increased from 2% in 2010 to 4.9% in 2019.

Agriculture has considerable potential of renewable sources of energy (table 2).

*Table 2*

**Potential of bioenergetics in agriculture in Ukraine, 2018**

| Type of biomasss | Theoretical potential, m t | Potential available for power industry | |
|---|---|---|---|
| | | % | m t o e |
| Cereal straw | 32.8 | 30 | 3.36 |
| Rape straw | 4.9 | 40 | 0.68 |
| By-products of corn for grain | 46.5 | 40 | 3.56 |
| By-products of sunflower (stems and heads) | 26.9 | 40 | 1.54 |
| Secondary wastes of agriculture (husk) | 2.4 | 100 | 1.00 |
| Wood biomass (wood fuel, wood wastes) | 8.8 | 96 | 2.06 |
| Wood biomass (dead wood, forest belt) | 8.8 | 45 | 1.02 |
| Biodiesel (rape) | - | - | 0.39 |
| Bioethanol (corn) dt. | - | - | 0.82 |
| Biogas from agricultural waste | 1.6 billion м$^3$ | 50 | 0.68 |
| Biogas from solid wastes landfill | 0.6 billion м$^3$ | 34 | 0.18 |
| Biogas from sewage water | 1.0 billion м$^3$ | 23 | 0.19 |
| Energy crops (willow, poplar) | 11.5 | 100 | 4.88 |
| Energy crops (corn for biogas) | 3.0 billion м$^3$ | 100 | 2.58 |
| Total | - | - | 23 |

*Source: data of the Bio-energetic Association of Ukraine.*

According to the evaluation of Bio-energetic Association of Ukraine in 2018 energy potential from biomass makes up 23m toe. The main components of this potential are by-products of plant production (in general 10 m toe or 44% of the total potential of biomass) and energy crops (in total 7.5 m t toe or 32% of the general potential).

Ukraine has enormous potential in the development of bioenergy production. Ukraine has well-developed agriculture and the wastes of its activity give excellent raw material base.

According to State Agency on Energy Efficiency and Energy Conservation, the use of only 37% wastes from the performance of livestock farms and crop-growing farms provides over 10 billion m$^3$ of gas.

Special attention should be paid to the creation of biogas stations based on livestock breeding complexes. Common practice of production wastes (manure) storage in open piles and lagoons leads to the deterioration of ecology in surrounding areas. Utilization of manure in large amounts is expensive, and fines for the violation of sanitary regulations make up large sums of money.

To produce biogas from manure becomes not only the solution of the present situation but also the way to obtain additional profit from the sales of thermal and electric energy.

Introduction of innovative bio-energetic technologies in agriculture solves a number of problems in agricultural production: it decreases the contamination of the environment with dangerous substances, including liquid and solid waste from the performance of livestock farms; creates new opportunities to obtain additional monetary income; it provides food and energy safety of the state; generates new employment; develops mechanical engineering industry and biotechnology, decreases the dependence of agricultural producers on the import of fuel, etc. (figure 1).

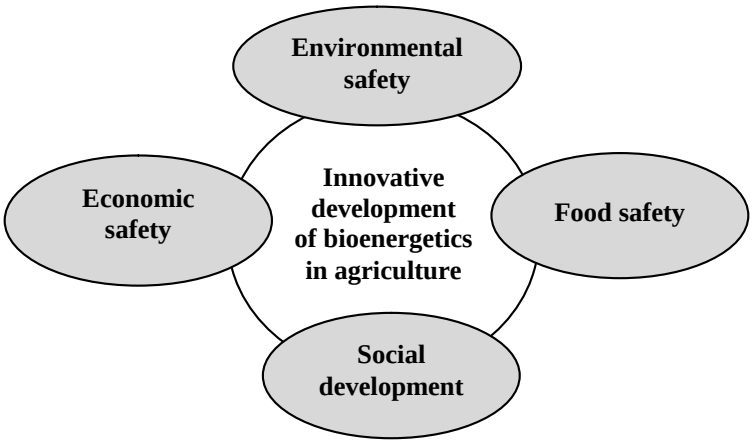


*Figure 1*. **Importance of bioenergetics for the development of agriculture**
*Source: created by the authors.*

*Digitalization.* Current innovative development of agriculture in Ukraine is founded on the digital transformation of agrarian business. Digitalization means the transition of information field into digital technologies.

At present "Industry 4.0" is a global trend, which is the stage of digitalization of economy where analysis of Big Data and current space technologies play an important role. The share of digital economy in GDP of developed countries up to 2030 will reach 50-60%. Application of geo-information technologies in agriculture is possible at regional as well as state levels for vertical (among different levels of management) and horizontal (among farms and organizations of one level) coordination of actions.

The review of literature sources [27-28] makes it possible to highlight the main areas of the development of agricultural enterprises involving up-to-date IT technologies:

– development of the systems of precision farming using technologies of global navigation satellite systems and systems of Earth remote sensing;

– drone technologies;

– systems of remote accounting and control of material and technical facilities;

– data mining and scenario planning;

– agro-scouting that suggests the use of mobile applications for monitoring.

Digital farming (digitalization of management) – management systems of agrarian production based on IT achievements (figure 2). Innovative development of plant production is related to the implementation of the concept of precise farming. At present about 30% of agricultural enterprises of Ukraine introduce these technologies. It is necessary to mention that these enterprises are of different sizes from small-sized to large-sized agro-holdings. The main idea of precise farming lies in the application of a particular approach to every field and even to a certain plot.

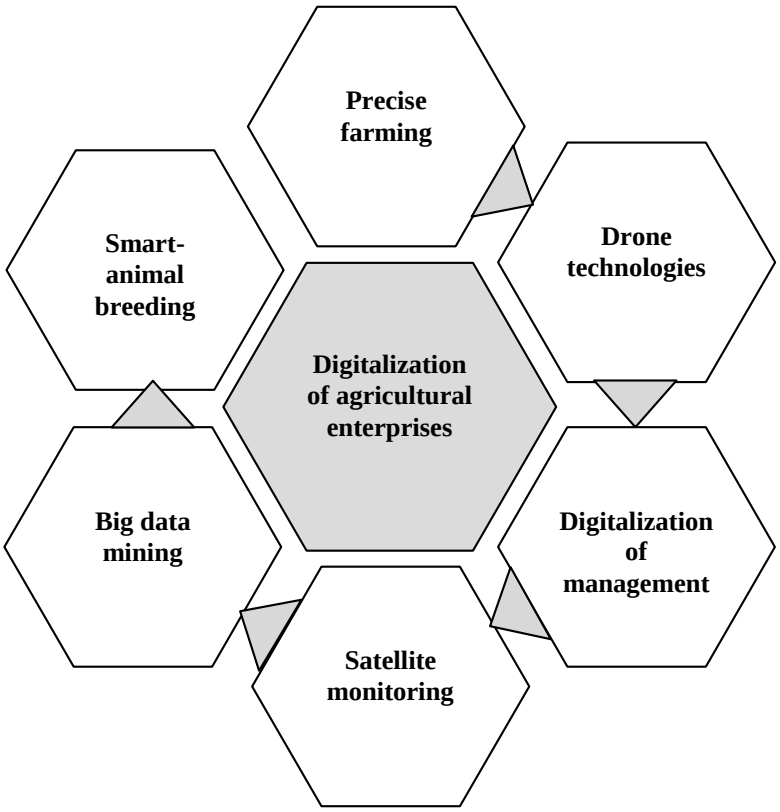


*Figure 2.* **Main directions of agricultural enterprises digitalization**
*Source: created by the authors.*

This implies differential seeding rates, fertilizers and plant protection agents, smart irrigation and other means to achieve maximum productivity of the plot.

Various technologies are applied in precise arable farming, such as GPS technologies, geographical information systems (GIS), yield monitor technologies, variable rate technology, technology of Earth remote sensing, control of technical means, etc. Precise farming is used at all main stages of agricultural production.

Advantages of precise farming compared to traditional approaches of running a farming business are as follows: improvement of yielding capacity and quality of agricultural produce; optimization of resources usage (machinery, land bank, personnel); increase of economic efficiency of production, optimal usage of expendables

(minimization of expenses); minimization of the negative influence of agricultural production on the environment; improvement of land quality, and information support of agricultural management.

Usage of drones is one of the digital technologies used in agriculture. The term "remote-piloted vehicle" refers to remotely piloted or autonomously flying objects with high-precision equipment of satellite positioning – RTK GPS.

Photooptical sensors installed on remote-piloted vehicles collect data about locality during the flight. New maps designed on their basis allow the farmers to manage cars automatically for treatment, fertilizing and plant protection as well as harvesting. They make it possible to adjust the number and time of treatment and fertilizing; to optimize the consumption of seeding materials and agrochemicals; to plan re-sowing the part of the areas at the appropriate time in case of serious plant damages; to optimize expenses of water on irrigated lands; to reveal and to correct the drawbacks of tillage, sowing or collecting plants. According to the evaluation of experts the usage of drones helps to reduce production costs by 30-50% and to reach the increase of yielding capacity on average by 10% [29].

Important innovative element of the activity of agricultural enterprises is satellite monitoring, which helps to monitor the state of cultivated lands, to perform operational monitoring of cultivated areas, automated formation of reports, forecasting and planning of agricultural operations, etc.

Summing up, it can be concluded that digitalization in plant production is the management of the systems of agricultural crops production based on information.

The general aim lies in the application of a proper approach in appropriate place with the account of local peculiarities of soil and cultivar. It leads to the increase of production efficiency at the expense of costs reduction and increase of obtained effects. It is important to reduce economic as well as production risks.

Main spheres of digitalization in livestock production are the regulation of microclimate in livestock buildings, registration of new-born animals, livestock inventory, feeding system and keeping animals, management of pasture, control of animal weight, automation and robotization of the most difficult activities, analysis of expenses and quality of obtained produce, etc.

Systematization of innovations in agriculture in the context of climate zones is presented in table 3.

*Organizational and economic innovations*. Development of agricultural enterprises depends on organizational and economic factors. Under the effect of climate changes these factors also require improvement and innovations particularly in the spheres of production organization, management systems and marketing. Organizational innovations imply improvement of the methods and forms of organization of enterprises, their structural subdivisions and business processes.

Introduction of innovative management implies the usage of the newest tools and methods of enterprise management, including those on the basis of digitalization.

Marketing innovations are related to the improvement of existing and introduction of new methods of marketing based on the creation of new products and assortment expansion (for example, production of ecologically safe products), branding, changes in design and presentation of products, in pricing policy, in creation of innovative logistic flows and diversification of sales channels, including e-commerce, etc.

*Social innovations*. Conducted analysis of innovative development of agricultural enterprises helps to conclude that modern society is "the age of intelligence", in which people, their knowledge, skills, and devotion to business have a decisive role. Main directions of social innovations in agricultural sector are the improvement of employee qualification, the change in the structure of labor force in the direction of mental labor, formation of the systems of motivation for innovation activity and stimulation of labor.

In the whole, this will have a positive influence on all spheres of activity of an enterprise and promote its innovative development.

**Conclusions.** Therefore, it can be concluded that in current conditions agricultural production considerably depends on climate changes that have negative as well as positive influence.

Thus, the introduction of innovations in different activity spheres will promote the innovative development of agricultural structures.

The main directions of innovative development of agriculture in the context of climate changes were defined, and can be united into 7 groups: biological, technical and technological, chemical, organizational and economic, social, alternative energetics and digitalization.

Their introduction will promote sustainable development of agriculture and its adaptation under conditions of climate change.

*Table 3*

**Systematization of innovations in agriculture in the context of climate changes**

| | | | |
|---|---|---|---|
| **Biological** | *Plant production* | New cultivars, hybrids of agricultural crops | types and varieties of plants with short vegetation period, resistant to biotic and abiotic threats, with high indexes of photosynthesis productivity in stress vegetation situations, introduction of niche and exotic crops in production;<br>application of up-to-date technologies in selection: in vitro, molecular markers, genetic modification of plants, micro-methods to evaluate the quality of plant material at the early stages of growing |
| | *Animal breeding* | New types, breeds of agricultural animals | stress-resistant types and breeds of animals, that are least dependent on the environmental factors modeling of the animal productivity and preset/ desired/set-up/ established parameters of product quality using biotechnologies, in vitro, pillar cells, etc. |
| **Technical-technological** | *Plant production* | Advanced technologies in plant production | organic production technology, No-till system, Strip-till, bio-enzyme technology, biogenic technology of arable farming, innovative systems of irrigation and drainage (dribble irrigation, sub-soil irrigation, sprinkling machines); protective afforestation |
| | *Animal breeding* | Advanced technologies in animal breeding | progressive technologies of animal feeding;<br>energy- and resource saving technologies of production and the use of wastes |
| **Chemical** | *Agriculture* | Fertilizers, plant protection agents, plant growth regulators | development and introduction of new fertilizers, plant protection agents, growth regulators in production on the principles of environmentalism and biologization |
| **Organizational and economic** | *Agriculture* | Business organization, management, marketing | improvement of organizational methods and forms, introduction of innovative management of marketing |
| **Social** | *Agriculture* | Human social development | advanced training of employees, the change of labor force structure in the direction of intellectual labor, formation of the motivation to the innovative activity and stimulation of labor, creation of proper labot conditions and social protection |
| **Alternative energy** | *Plant production* | Production of energy from renewable sources | production of energy from the biomass of agricultural crops, wood biomass |
| | *Animal production* | | production of energy from the wastes of animal breeding |
| **Digitalization** | Agriculture | Digital transformation of production processes | precise farming, smart live-stock production, dosage management, soil analysis, drone technology, satellite monitoring, meteo-monitoring, agro-scouting, big data analysis, management digitalization |

*Source: created by the authors.*

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