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# DIGITAL ECOSYSTEMS IN AGRICULTURAL SECTOR: PRINCIPLES OF CREATION AND POSSIBILITIES

# АГРАРЛЫҚ САЛАДАҒЫ САНДЫҚ ЭКОЖҮЙЕЛЕР: ҚҰРУ ПРИНЦИПТЕРІ МЕН МҮМКІНДІКТЕРІ

# ЦИФРОВЫЕ ЭКОСИСТЕМЫ В АГРАРНОЙ СФЕРЕ: ПРИНЦИПЫ СОЗДАНИЯ И ВОЗМОЖНОСТИ

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**Abstract. One of the ways to improve the efficiency of agro-industrial complex in the context of digital transformation is creation of single digital ecosystem, which implies coordination and integration of participants and results of scientific research in a single information environment. *Objective* - modern digital natural biological ecosystems are considered, oriented towards the use of innovative technologies in agriculture, increasing production volumes, and ensuring food security of the country. *Methods* - a review of scientific publications on a new model - digital biosphere as a fundamental element of digital economy; calculation of the effectiveness of the use of hydroponic units in agricultural sector and results of experimental work on growing tomatoes and lettuce; collection and analysis of quantitative data on the state and trends in the expansion of farm outlets. *Results* - the authors analyzed statistical data on the current state of city farm market in the world. It is noted that the most promising direction in the republic is distribution of hydroponic**

**devices for growing microgreens, indicators of its yield are presented, the advantages of hydroponics compared to traditional practice are shown. The profitability of producing drinks from microgreens and tarragon, cultivated in aqueous solution of nutrients, is determined. *Conclusions* - within the framework of the project, specialized experimental hydroponic installation was created to test the processes of cultivating tomato seedlings and lettuce. From the position of the authors, comprehensive digital modernization of agro-industrial complex will reduce costs of implementing digital transformation programs with significant economic effect, facilitate exchange of data and resources between farmers, suppliers, processors and retailers, increase productivity, reduce pro-duction costs, peasant (farming) households will gain broad access to domestic and foreign sales markets.**

**Аңдатпа. Сандық трансформация жағдайында АӨК тиімділігін арттыру тәсілдерінің бірі қатысушыларды және ғылыми зерттеулердің нәтижелерін бірыңғай ақпараттық ортада үйлестіруді және интеграциялауды көздейтін Бірыңғай сандық экожүйені құру болып табылады. *Мақсаты* - ауыл шаруашылығында инновациялық технологияларды пайдалануға, өнім өндіру көлемін ұлғайтуға, елдің азық-түлік қауіпсіздігін қамтамасыз етуге бағдарланған қазіргі заманғы сандық табиғи биологиялық экожүйелер қаралды. *Әдістері* - жаңа модель - цифрлық биосфера сандық экономиканың іргелі элементі ретіндегі ғылыми жарияланымдарға шолу; аграрлық секторда гидропоникалық қондырғыларды қолдану тиімділігін есептеу және қызанақ пен салат өсіру бойынша тәжірибелік жұмыстардың нәтижелерін; шаруа қожалықтарының сауда нүктелерін кеңейту жағдайы мен тенденциялары туралы сандық мәліметтерді жинау және талдау. *Нәтижелері* - авторлар әлемдегі қалалық ферма нарығының ағымдағы жағдайы туралы статистикалық деректерді талдады. Республикада ең перспективалы бағыт микрожасыл өсіруге арналған гидропоникалық құрылғыларды тарату екені атап өтіліп, оның өнімділігінің көрсеткіштері ұсынылып, дәстүрлі тәжірибемен салыстырғанда гидропониканың артықшылықтары көрсетілген. Қоректік заттардың сулы ерітіндісінде өсірілген микрожасыл және эстрагоннан сусындар өндірудің рентабельділігі анықталды. *Қорытынды* - жоба аясында қызанақ пен жапырақ салатының көшеттерін өсіру процестерін сынау үшін мамандандырылған эксперименттік гидропоникалық қондырғы құрылды. Авторлардың көзқарасы бойынша агроөнеркәсіптік кешенді кешенді сандық жаңғырту айтарлықтай экономикалық әсері бар сандық трансформация бағдарламаларын орындауға арналған шығындарды қысқартуға мүмкіндік береді, фермерлер, жеткізушілер, қайта өңдеушілер және бөлшек сауда арасында деректер мен ресурстармен алмасуды жеңілдетеді, өнімділікті арттырады, өндірістік шығындарды азайтады, шаруа (фермер) қожалықтары отандық және сыртқы өткізу нарықтарына кең қолжетімділікке ие болады.**

**Аннотация. Одним из способов повышения эффективности АПК в условиях цифровой трансформации выступает создание единой цифровой экосистемы, подразумевающей координацию и интеграцию участников и результатов научных исследований в единой информационной среде. *Цель* – рассмотрены современные цифровые природные биологические экосистемы, ориентированные использование инновационных технологий в сельском хозяйстве, наращивание объемов производства продукции, обеспечение продовольственной безопасности страны. *Методы* - обзор научных публикаций о новой модели – цифровой биосферы как фундаментального элемента цифровой экономики; расчет результативности применения гидропонных агрегатов в аграрном секторе и итоги экспериментальных работ по выращиванию томатов и салата-латука; сбор и анализ количественных данных о состоянии и тенденциях расширения фермерских торговых точек. *Результаты* – авторами проанализированы статистические данные современного состояния рынка сити ферм в мире. Отмечается, что наиболее перспективным направлением в республике становится распространение гидропонных устройств для выращивания микрозелени, представлены показатели ее урожайности, показаны преимущества гидропоники по сравнению с традиционной практикой. Определена рентабельность изготовления напитков из микрозелени и тархуна, культивированных на водном растворе питательных веществ. *Выводы* – в рамках проекта создана специализированная экспериментальная гидропонная установка для апробации процессов возделывания рассады томата и листового салата. С позиции авторов, комплексная цифровая модернизация агропромышленного комплекса позволит сократить затраты на выполнение программ цифровой трансформации со значительным экономическим эффектом, облегчит обмен данными и ресурсами между фермерами, поставщиками, переработчиками и розничной торговлей, увеличит производительность, снизит производственные издержки, крестьянские (фермерские) хозяйства получат широкий доступ к отечественным и внешним рынкам сбыта.**

**Keywords: agricultural sector, digital ecosystems, hydroponics, food, microgreens, production profitability, cost reduction, increased productivity, potential.**

**Түйінді сөздер: аграрлық сектор, сандық экожүйелер, гидропоника, азық-түлік, микрожасылдар, өндіріс рентабельділігі, шығындарды азайту, өнімділікті арттыру, әлеуетті мүмкіндіктер.**

**Ключевые слова: аграрный сектор, цифровые экосистемы, гидропоника, продукты питания, микрозелень, рентабельность производства, сокращение затрат, увеличение производительности, потенциальные возможности.**

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## Introduction

Today, with the current level of development in the world, the population is increasing significantly, which requires an increase in agricultural production, and therefore the search for non-traditional farming methods, and it is modern digital ecosystems that solve this problem. To do this, it is necessary to find ways to improve the situation in order to provide ourselves with food and develop the agricultural sector. One of the most promising areas is the use of modern digital ecosystems, which not only increase the efficiency of agricultural production, but also reduce the negative impact on the environment.

Digital ecosystems for sustainable agricultural production are an innovative and popular area of agriculture, which is often used where traditional agriculture is impossible or unprofitable. Digital ecosystems make it possible to obtain comprehensive automation solutions: from obtaining a good harvest in a smaller area and controlling almost all processes: irrigation, temperature, air, light, water quality and nutrients.

It is important to note that the idea of digital ecosystems has been explored for several decades, but is still relevant and in demand. Modern digital ecosystems have a positive impact on the environment, as they require less energy, emit fewer pollutants, and do not require heavy machinery, pesticides, or fertilizers. Growing agricultural products using digital ecosystem technologies gives real control over the resources needed by plants and makes their growth and development predictable and controllable.

Moreover, digital technologies themselves can solve the problem of providing the world's growing population with enough food. More importantly, digital ecosystem data reduces agricultural production costs compared to traditional agriculture by reducing the distance between seller and buyer – logistical costs (Sasireka R., Tenzing D., Himanshu A. et al.) [1]. It is worth noting that, despite the growing popularity of organic farming and the use of digital ecosystems in agriculture, these trends have led to the development of turnkey enterprises or, in other words, "software" for farms or urban farms.

In recent years, much attention has been paid to the development of urban farms as an important element of digital ecosystems. In densely populated countries such as Singapore, Japan, and China, farms using land-based cultivation methods such as hydroponics, aquaponics, and aeroponics are being successfully introduced. These technologies make it possible to produce new, environmentally friendly food products in a limited area, which makes them in demand and promising.

The purpose of this study is to assess the current state and prospects for the development of digital ecosystems to increase agricultural production, as well as to assess the economic efficiency of using hydroponics technology in Kazakhstan. The article examines the main advantages of digital ecosystems, provides a comparative analysis of traditional and new agricultural practices, and discusses potential applications of these technologies to transform the country's agricultural sector.

## Literature Review

Modern digital ecosystems are aimed at sustainable agricultural production and providing food to the population using modern technologies and production solutions, including the use of vertical spaces (Avgoustaki D.D., Xydis G.) [2]. For example, Jacobides M.G., Cennamo C., Gawer A. in their research, they note that digital ecosystems in agriculture represent the integration of modern information technologies in order to increase the efficiency and sustainability of the agro-industrial complex, which includes: automation systems; agribusiness platforms; Big Data analysis; intelligent agriculture; internet of Things (IoT) in agriculture (Maroš K.; OECD. The Digitalisation of Science…) [3, 4].

Urban farms are one of the examples of successful use of modern digital ecosystems in agriculture and the first structures appeared in 2012. Japan was one of the countries, which actively apply the practice the concept of urban farms. A successful example of the implementation of urban farms can be seen in the example of Mirai Shokuhin, which opened its first commercial farm in 2004 in Kamakura, 50 kilometers southwest of Tokyo. An impressive example of the successful implementation of the urban farm project is the activity of the American company "AeroFarms", which organized agricultural production on an area of 6 410 square meters in the building of a former steel mill (Yukiya I.; Urban V.) [5, 6]. Urban farms are part of the digital agricultural ecosystem and use technology to create sustainable and efficient food production systems.

Currently, a urban farm is a high-quality greenhouse in which plants receive sufficient light and daylight due to optimal health and high temperatures provided by single-light LED phytolamps, hydroponics or aeroponics technology, and conditions associated with air conditioning systems (Juan G., Luis M., Jorge G. et al.) [7].

One of the most promising areas of urban farms application in Kazakhstan is hydroponics, in particular, in the field of growing microgreens, such as beetroot and tarragon microgreens. Due to their high nutritional value, compact size, and rapid growth, these plants are ideal for hydroponics (Aishvina S., Jyoti S., Sawinder K. et al.) [8]. Beetroot microgreens contain many antioxidants such as betalains, which have powerful anti-inflammatory and detoxifying effects. Tarragon is also rich in essential oils and flavonoids, which have antioxidant, antimicrobial and immunomodulatory effects (Treadwell D., Hochmuth R., Landrum L. et al.; Saldinger S.S., Rodov V., Kenigsbuch D. et al.) [9, 10].

Hydroponic technology makes it possible to use beetroot and tarragon microflora to produce new functional foods, such as fortified drinks. Beetroot juice is already known for its hemostatic and detoxifying properties, and tarragon extract can improve digestion, support the immune system, and have a calming effect on the nervous system (Sambo P., Carlo N., Giro A. et al.; Velazquez-Gonzalez R.S., Barceinas-Sanchez J.D.O., Garcia-Garcia A.L. et al.) [11, 12].

**Materials and methods**

The research was carried out with the financial support of the Committee of Science of the Ministry of Science and Higher Education of the Republic of Kazakhstan within the framework of the Scientific Research Foundation BR24992852 on the topic "Development of intelligent models and methods of the Smart City digital ecosystem for sustainable development of the city and improving the quality of life of citizens."

When writing the article, the following methods were used:

- a review of literature and scientific articles on the complexity of digital ecosystems to increase agricultural productivity. Special attention was paid to approaches to sustainable agricultural production, the use of modern technologies and digital ecosystems;
- calculation of the effectiveness of using hydroponic systems in comparison with traditional agriculture;
- collection and analysis of quantitative data on the current state and development trends of the urban farm market;
- experimental studies of a hydroponic plant for growing tomatoes and lettuce-lettuce.

These methods provided a scientific basis for the results and made it possible to compare the strength and effectiveness of the modern digital ecosystem in agriculture.

**Results**

The use of digital technologies in agriculture in Kazakhstan includes farm management Information systems (FMIS), IoT monitoring and urban farms. Table 1 provides an overview of digital ecosystems and urban farming technologies, highlighting their key technological features.

Table 1 - Comparison of digital ecosystems and urban farming technologies

| Category | Definition | Key features |
|---|---|---|
| Digital ecosystems in agriculture | Integration of modern technologies to enhance efficiency and sustainability of agriculture | Robots and automated systems for crop production, harvesting, and protection |
| | | Agribusiness platforms to connect farmers, retailers, and consumers for service automation |
| | | Processes data to predict characteristics, optimize resources, and support decisionmaking |
| | | Intelligent agriculture, including sensors, GPS, and data analysis to optimize crops, fertilizers, and irrigation |
| | | IoT in agriculture including devices collect data on soil, weather, and plant health for quick response to changes |

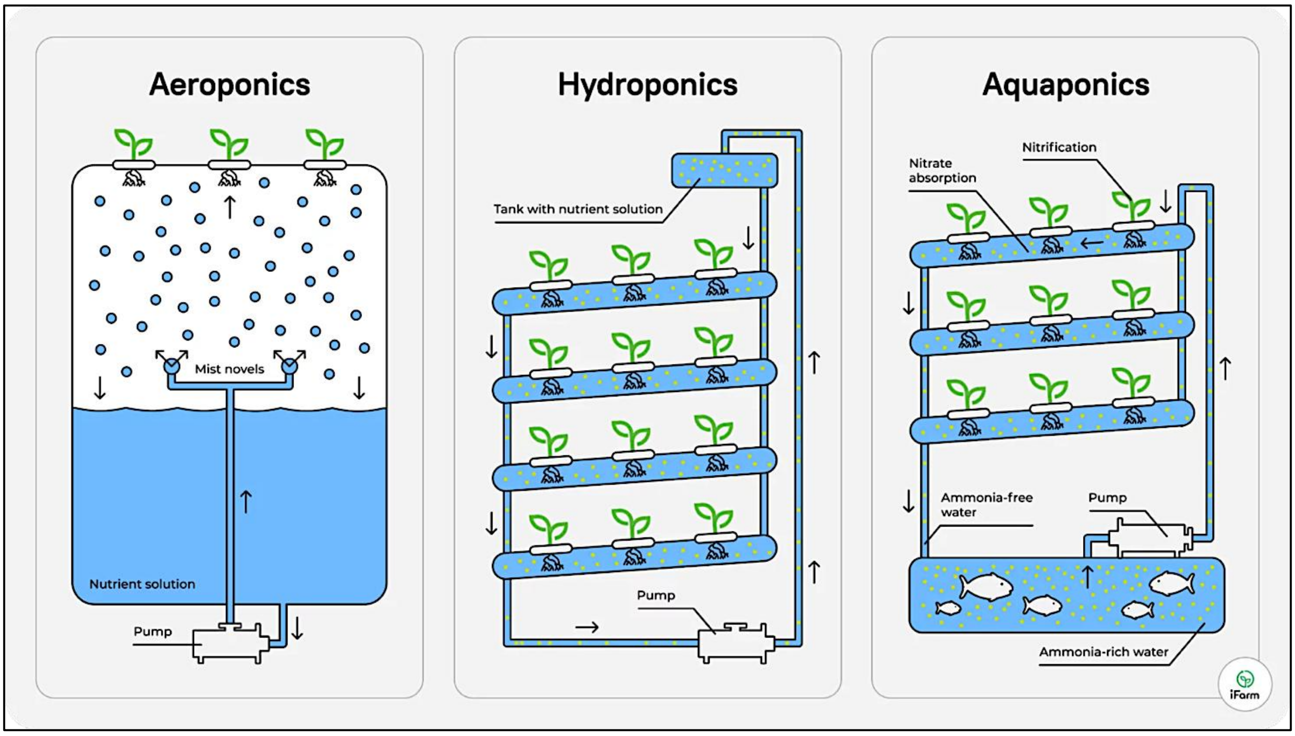
| | | |
|---|---|---|
| Urban farms | Agricultural spaces located within cities and urban areas where food and other agricultural products are cultivated, processed, and distributed | Automation to regulates lighting, watering, temperature, and humidity to optimize plant growth |
| | | IoT including sensors, collecting environmental and plant data for higher yields |
| | | AI to handle big data sets to predict product performance, optimize resources, and reduce costs |
| Note: made by the author based on sources (Maroš K.; OECD. The Digitalization of Science…) [3, 4]. | | |

Urban farms often use groundless farming methods such as aquaponics, hydroponics, and aeroponics, which require only 10% of the water used by traditional outdoor farms. These technologies make it possible to process and/or sell agricultural products regardless of the climate of the region in which the farm is located, providing fresh products without pesticides and herbicides (figure 1). Today, it is possible to identify groundless farming methods in urban farms for growing agricultural products:

* hydroponics - in such farms, plants are grown in a mineral solution;

* aquaponics is a "fusion" of hydroponics and aquaculture: the water used in aquaponic systems consists of fish waste - it is rich in nutrients and creates a natural environment in which farmers do not need to use other "chemicals";

* container type - shipping containers in which air and water monitoring sensors, LED lamps, hydroponic or drip irrigation systems are installed; growing units - demonstrate examples of green mass in the last stages of maturation (Avgoustaki D.D., Xydis G.) [2].




Note: based on sources (Avgoustaki D.D., Xydis G.) [2]

Figure 1 – Soilless farming methods in vertical farming for growing crops in urban environments

These digital ecosystem technologies often involve the use of advanced solutions such as cameras, sensors, automated systems, artificial intelligence, hydroponics, aquaponics or aeroponics.

It should be noted that today the global urban farming market is estimated at 14.23 billion US dollars in 2024 and is expected to reach 23.23 billion US dollars by 2029, with an average annual growth of 10.30% during 2024-2029 (Projected vertical farming market…) [13].

The global urban farm market is undergoing growth and significant growth is planned in the near future. For example, in 2022, the urban farms market amounted to 5.6 billion tenge and in 2023 increased by 1.2 billion tenge.

It should be noted that by 2032, the urban farms market will grow to 35.3 billion tenge with the largest share of the urban farms market is in North America - 40%, followed by Europe – 30%, the Asia-Pacific region – 24% and the smallest market share is occupied by the

Middle East and Africa – 2%. As a result, the urban farm market is growing in the world, since at the present stage of development, in conditions of limited resources, these systems are becoming particularly relevant and important.

According to the US Department of Agriculture, farmers in America have voluntarily excluded land from crop production due to poor growing conditions or limited water supplies for irrigation. At the same time, a decrease in yield levels will significantly affect farmers' profits, as today there is an active increase in demand for organic and environmentally friendly products. It is worth noting that today there is a gradual decrease in acreage, and forest pastures are rapidly declining. For example, according to a report by the US Department of Agriculture, agricultural land is declining every year: in 2017 it was 364.36 million hectares, and in 2021 it decreased to 362.31 million hectares.

In the case of China, according to the FAO, the area of agricultural land between 2017 and 2020 did not increase, but decreased slightly and amounted to 119.47 million hectares. Demographic growth in China has also led to an increase in demand for food, which encourages farmers to adopt more rational farming methods – modern digital ecosystems, for example, in the form of urban farms. Thanks to new technologies, farmers are getting higher yields using fewer resources and involving greater use of technology and automation to improve land use, is an example of solutions to improve future food production (Farming Market Size and Share Analysis…) [14].

Urban farming has become an important agricultural technology in Sweden, with multiple startups developing urban and indoor farming solutions. Urban Oasis operates Sweden’s first commercial urban farm, located in underground caves in Stockholm, where vegetables are grown using LED lights and hydroponic systems. Grönska has developed urban farming technology and inaugurated one of Europe's largest vertical farms on the outskirts of Stockholm in 2018. In early 2019, Ikea set up two container farms near its stores in Helsingborg and Malmö, Sweden, to cultivate lettuce for its restaurants (Butturini M., Marcelis L.F.M.) [15]. Greenfood in collaboration with Agtira to develop urban farming systems at ten strategic locations across Sweden, with the aim of providing sustainable, locally grown food all year round. SweGreen has developed urban farms inside supermarkets, using hydroponic methods to grow up to 100 different crop species. In such way, they can produce the equivalent of food from 3 hectares of agricultural land.

In Sweden, where 70% of fresh fruit and vegetables are imported, hydroponic farming might offer several benefits in term of higher crop yields, reduced water consumption, and year-round production capabilities (Gentry M.) [16]. The study found that urban farming can significantly reduce CO2 emissions (by approximately 44%) compared to conventional mixed salad bag production, but it may have higher environmental impacts in other categories, particularly resource use, with the farm's location playing a crucial role in its overall sustainability due to factors like electricity mix and transportation distances (Stanghellini C., Katzin D.) [17]. However, it also faces challenges, primarily related to high energy costs for lighting, heating, and cooling, which can make it less sustainable than traditional farming methods in some aspects. Additionally, Swedish consumers, however, perceived urban farmed lettuce as less natural and were less inclined to purchase it compared to other options.

Aquaponics is another emerging food production technology gaining attention in Sweden as a sustainable method for cultivating aquatic animals and plants. This innovative system combines aquaculture (fish farming) with hydroponics (soilless plant cultivation) in a symbiotic environment. This might offer attractive solutions to food security issues and environmental concerns.

Currently, the development of modern digital ecosystems in Kazakhstan plays an important role in the transformation of the agro-industrial sector, in particular agriculture. For example, the use of hydroponics makes it possible to efficiently grow more than 250 plant species. This technology significantly speeds up the production process: companies engaged in hydroponics can successfully reduce the time of growing crops, which in traditional agriculture takes about 30 days.

Moreover, the use of digital ecosystems, such as hydroponic installations, can significantly reduce resource consumption. In these systems, plants receive the necessary nutrients and water. Being part of digital ecosystems, the company's network provides environmental benefits, for example, 50% less fertilizers are required, and the use of pesticides, herbicides and fungicides can be completely eliminated, making production more environmentally friendly.

The entire control system of hydroponic installations is automated and is carried out remotely using computer technology. Artificial intelligence embedded in these digital ecosystems collects data to analyze crop conditions, predict yield levels, and develop risk mitigation strategies. These new processes contribute not only to an increase in production capacity, but also to the sustainable development of Kazakhstan's agro-industrial complex.

As part of the ongoing research on the project, the authors calculated the profitability of growing microgreens year-round in a hydroponic installation compared to traditional agriculture. It is worth noting that microgreens are now popular in large cities and are a highly valuable product that can be profitably grown in city conditions (table 2). It should also be borne in mind that calculations are focused on year-round production of microgreens.

Table 2 - Profitability of growing microgreens year-round in a hydroponic installation compared to traditional agriculture

| Hydroponic plant for the production of microgreens** (100 m²): | Traditional agriculture** (1 ha or 10 000 m²) |
|---|---|
| Initial data | |
| - Yield: 1 kg of microgreens per 1 m² per week<br>- Total yield for the year: 100 m² × 1 kg/m² × 52 weeks = 5 200 kg<br>- Selling price: 3 000 tenge per kg<br>(microgreens are sold at a higher price) | - Productivity: 1.5 tons (1 500 kg) of microgreens per year (for example, basil, arugula)<br>- Selling price: 2 500 tenge per kg<br><br>(regular price of microgreens) |
| Estimated capital investment | |
| 30 000 000 tenge:<br>for 100 m², including equipment, lighting and control systems | 10 000 000 tenge per 1 ha:<br>cost of land rent, seeds, equipment |
| Operating costs | |
| - Electricity and lighting: 1 000 000 tenge per year<br>- Water and fertilizers: 200 000 tenge per year<br>- Staff: 1 200 000 tenge per year (one full-time person)<br>- Equipment maintenance: 300 000 tenge per year<br>Total operating costs: 2 700 000 tenge per year | - Fuel and equipment: 500 000 tenge per year<br>- Water and fertilizers: 250 000 tenge per year<br>- Salary: 1 000 000 tenge per year (per season)<br>- Equipment maintenance: 200 000 tenge per year<br><br>Total operating costs: 1 950 000 tenge per year |
| Calculation of profit | |
| - Annual revenue:<br>5 200 kg × 3 000 tenge = 15 600 000 tenge<br>- Annual operating cost: 2 700 000 tenge<br>- Net profit: 15 600 000 – 2 700 000 = 12 900 000 tenge<br>- Payback of capital expenditures: 30 000 000 ÷ 12 900 000 ≈ 2 years | - Annual revenue:<br>1 500 kg × 2 500 tenge = 3 750 000 tenge<br>- Annual operating costs: 1 950 000 tenge<br>- Net profit: 3 750 000 – 1 950 000 = 1 800 000 tenge<br>- Payback period of capital expenditures: 10 000 000 ÷ 1 800 000 ≈ 6 years |
| Note: calculated by the authors | |

Thus, the hydroponic installation provides a profit of 12 900 000 tenge per year with a high selling price and year-round production of microgreens. The payback period for capital expenditures is about 2 years. And the year-round production of microgreens in traditional agriculture provides a profit of 1 800 000 tenge per year and a payback on capital expenditures for much longer, about 6 years. As a result, it is worth noting that in the conditions of a year-round production process, using the example of microgreening, a hydroponic plant for the production of microgreening shows higher profitability and a short payback period compared to traditional agriculture. This makes modern digital ecosystems an attractive business for the population, given the increasing demand for healthy food and organic products.

It is worth noting that in the conditions of a year-round production process, using the example of the production of microgreens by means of hydroponics, higher profitability and a short payback period are shown compared to traditional agriculture. It is worth noting that the production of functional beverages through hydroponic plants has great potential for development in Kazakhstan. The use of this technology makes it possible to reduce costs, improve the environment and meet the growing demand for natural and functional products.

To calculate the efficiency of producing beverages based on microgreens and tarragon using hydroponics, we take into account the market price of natural tarragon, which is $7.18 per liter. Table 3 shows the efficiency of the production of beverages based on microgreens and tarragon in hydroponic plants.

Table 3 - Efficiency of production of beverages based on microgreens and tarragon

| Basic data and parameters | Data |
|---|---|
| Initial data | |
| yields of microgreens and tarragon on a vertical farm | 2.5 kg/m 2 per month |
| production costs per 1 m$^2$ | $60 per month (29 265 tons) |
| the market value of the drink (tarragon) in restaurants | $7.18 per liter |
| is the output of the drink | 1 kg of microgreens / tarragon gives 5 liters of ready-made drink |
| Calculation of income and expenses | |
| Income from the production of tarragon drink, based on a yield of 2.5 kg per 1 m$^2$ | the volume of beverage production will be: |
| | 2.5 kg=5L/kg=12.5 liters of beverage per 1 m$^2$ per month |
| production costs | the income from 1 m$^2$ of city farm at the market price of tarragon will be: |
| profitability = (Income-costs) / costs × 100% | 12.5 liters=7.18 USD/liter=89.75 USD per month |
| Note: calculated by the authors | |

It is also worth noting that the process of integrating the cultivation of basic crops in hydroponic plants is fraught with certain difficulties, but significant progress is expected in the coming years. Although the timing may vary depending on achievements in scientific research and investments. All of the above advantages are one of the main factors in the development of modern digital ecosystems. However, it should also be noted that the sustainable development of this agricultural sector is influenced by global population growth.

**Discussions**

Modern digital innovations in agriculture are a very innovative and promising area for sustainable rural development. The main focus is on the application of technologies such as hydroponics, aquaponics and aeroponics, which can increase production, reduce resource consumption and mitigate negative environmental impacts.

The use of hydroponics has great economic potential, especially for the year-round production of microgreens. The article provides mathematical calculations showing that hydroponic systems provide a significantly shorter payback period (about 2 years) compared to traditional agriculture. This makes the technology attractive to entrepreneurs, especially given the growing demand for environmentally friendly products.

Another important factor is the possibility of optimizing the production process using digital technologies. For example, automation, IoT sensors, and artificial intelligence allow you to monitor product status, predict performance, and develop risk mitigation strategies. This not only increases efficiency, but also reduces production costs.

This article also highlights Kazakhstan's potential in creating a digital ecosystem. The introduction of such technologies will help meet the country's demand for agricultural products and at the same time strengthen its position in the global market. Hydroponics and vertical farming can play a key role in these changes, enabling production even in resource-poor and hard-to-reach areas.

The discussion also touched upon the environmental benefits of the technology. By reducing the use of pesticides, reducing air pollution, and saving water, digital ecosystems are becoming more resilient.

Thus, digital ecosystems are not only a solution for improving food security, but also a tool for transforming the agricultural sector into an environmentally and economically sustainable industry. The development of such technologies can be a key factor in achieving global development goals in the future.

**Conclusion**

1. In general, modern digital ecosystems represent a promising area that attracts attention funds both in agriculture and in business. At the current stage of development, the development and optimization of hydroponic installations within the framework of the development of digital ecosystems is aimed at improving agricultural production.

2. Modern digital technologies are opening up new horizons for agriculture and combining sustainable development with innovative technologies. The main advantages are reducing the environmental impact and optimizing the use of resources, which makes them important in the context of human development. Examples of the use of hydroponic systems show high profits and short payback periods, especially in the production of functional drinks.

3. Digital ecosystems will change the world of agriculture in the future, as they have serious advantages: the most important advantage is to reduce the harm and impact of production on the environment while presserving huge areas for other purposes. Digital ecosystems in the form of urban farms and hydroponic installations solve two main problems: the difficulty of supplying remote areas with agricultural products and maintaining high-quality food with fewer pesticides and special fertilizers.

4. It is important to note that agricultural products produced as a result of hydroponic plants are in no way inferior to food products produced in traditional agriculture, and even better. Hydroponic installations have a number of advantages, including an increase in the number of crops grown, year-round production of agricultural products and the possibility of use in urban environments. Due to technological progress, demand is growing and the volume of the urban farm market is increasing. As the market develops significantly, this agricultural sector becomes profitable for companies, especially in densely populated urban areas.

5. The use of such technologies can solve many problems, including the shortage of agricultural land, limited resources and the need to produce environmentally friendly products. Kazakhstan has great opportunities to develop a digital ecosystem that will not only meet national needs, but also strengthen its position in the global market. Further development of these technologies will contribute to the transformation of the agro-industrial complex in the future, increasing its competitiveness and sustainability.

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