Georgian Scientists
ქართველი მეცნიერები
Vol. 7 Issue 1, 2025
https://doi.org/10.52340/gs.2025.07.01.23

Nanotechnology as a Transformer of the Agro-Sector

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Annotation

This article examines the scope of nanotechnology use in the agricultural sector and discusses the state of research in this field. The analysis is based on the study of the experience of advanced foreign countries. The authors express hope that Georgia has the opportunity to develop in this direction, and international indicators, and research substantiate this. Georgia's digitization process has been dynamic since 2012, and the country has the opportunity to carry out and develop transformations in the agricultural sector in this regard.

At the end of the article, the authors present a conclusion. The role of nanotechnology in management is considered in an interdisciplinary perspective as one of the best ways to improve the management of organizational transformations in business entities operating in the agricultural sphere.

Keywords: Nanotechnology; Agro-sector; Transformation; Digitalization.

Introduction

Today, humanity lives in the latest period of development; this is the stage that has ensured the convergence of five technological revolutions in one machine-computer[10]. The world has undergone the electronic, informational and artificial intelligence revolutions in just a century [13]. This stage of human development gave rise to the first computer, a new field of management, the Internet and many innovations, the newest of which is nanotechnology - a scientific field that implements transformations. The interdisciplinary nature of this field and the practice already implemented in the world give us hope that the world will successfully solve global challenges in many directions using nanomaterials. The introduction of nanotechnology in the Georgian agro-sector will help entities working in this direction to implement transformations, which is a prerequisite for the country's economic growth.

Main test

The main text generally reviews the concepts of organizational transformations, the agro-sector, digitalization and nanotechnology. Today, there is no uniform definition of transformation in science [15]. It is understood as a transition from one state to another, i.e. to a desired state, as a structural, corporate, etc. change. Generally, there are three groups of gradations: developmental, transitional and transformational transformations.The concept of agriculture essentially encompasses the agrosphere, which combines farming, animal husbandry, agro-production, agribusiness and significantly contributes to a particular country's economic development. The development of the agrosphere is not understood as the advancement of a single sector, agromedicine and agrotourism are subfields of medicine and tourism that simultaneously experience changes and synergistically affect each other. The development of the agrosphere should be carried out taking into account the principles of green economy and ecology. In the conditions of digitalization, innovations are a prerequisite for sustainable development. In this situation, strengthening competitiveness and efficiency is challenging for all countries. Nanotechnology, a new direction in science formed in the conditions of the digital revolution, directly impacts the transformation of the fields of the same era - business and management. Nanotechnology is used in many fields, including production, logistics, etc. As for the role of nanotechnology in organizational transformations, in our opinion it is quite important because:

1.Nano, the production of innovative products optimizes the production process.

2.Equipment created with nano materials simplifies data collection and analysis, which is important for making quick decisions.

3.Nanosensors provide automated control of enterprise management, thereby improving the management process.

4.Nanotechnology provides simplification of adaptation and effectiveness of change management.

5.Nano eco-friendly products are a prerequisite for sustainable development due to the reduction of operating costs.

Nanointegration of a business entity is a prerequisite for simplifying, improving and perfecting the management of organizational transformations. Which is expressed in the following: reducing costs, easily responding to global challenges in the direction of the principles of a green economy and effective governance. Thus, nanotechnology is an important element not only of industrial, but also of management and organizational transformations and development.

Role of Nanotechnology in Agriculture

Nanotechnology is transforming agriculture by increasing crop protection, reducing environmental effects, and optimizing resource utilization. Ineffective nutrient delivery, overuse of pesticides, and inadequate soil and crop health monitoring are common problems with traditional agricultural practices. Nanotechnology tackles these issues by offering precision-based solutions that maximize agricultural inputs, minimize waste, and boost overall productivity.

The major applications of nanotechnology in agriculture can be classified into four key areas:

Nanofertilizers: Increasing Nutrient Efficiency and Crop Yields

Due to their inefficiencies, conventional fertilizers cause nitrogen loss through runoff and leaching, raising expenses and polluting the environment [1]. By improving nutrient intake and decreasing waste

through regulated release mechanisms, nanofertilizers provide an answer [2]. These fertilizers can be divided into three groups: nanoscale coatings (fertilizers with nanolayered release control), nanoscale additives (nanomaterials combined with traditional fertilizers), and nanoscale fertilizers (encapsulated nutrients) [1]. Their large surface area ensures more effective nutrition delivery by enhancing solubility and absorption [2]. On-demand nutrient release, which reacts to changes in soil pH, moisture content, and temperature, is a significant benefit that avoids overfertilization and lessens environmental harm [3]. Additionally, they increase the bioavailability of vital micronutrients such as magnesium, iron, and zinc [2]. Research indicates that using magnesium oxide nanoparticles in nanofertilizers can enhance cotton yields by 42.2% and boost the absorption of nitrogen, phosphorus, and potassium in coffee plants by up to 67.5% [2]. These findings demonstrate how they can increase productivity with lower application rates. Although there are advantages, adoption is hampered by high production costs, small farmers' restricted access, and concerns about long-term environmental effects [1][4]. Since regulatory frameworks are continually developing, further safety and sustainability research is necessary.

Nanofertilizers can potentially increase agricultural productivity while promoting food security and environmental sustainability with further developments. Future studies should concentrate on ecological safety, large-scale application, and cost reduction [3].

Nanopesticides: Enhanced Crop Protection and Reduced Environmental Impact

Concerns about pesticide resistance, water contamination, and toxicity to non-target creatures are only a few of the health and environmental issues brought on by the overuse of conventional pesticides [5]. By increasing pesticide delivery efficiency, decreasing treatment frequency, and limiting environmental impact, nanopesticides—created via nanotechnology—offer a novel pest control method [4]. To improve the stability and targeted release of active pesticide components, nanopesticides employ nanoscale carriers. These formulations, intended to enhance solubility, adhesion, and controlled release qualities, include metal-based nanopesticides, polymer-based nanoparticles, nanoemulsions, nanosuspensions, and nanocapsules [6]. A longer-lasting effect with less pesticide loss is ensured by nanoencapsulation, which shields active chemicals from premature deterioration brought on by UV light and environmental conditions [5]. Their effectiveness stems from their improved capacity to stick to plant surfaces, withstand rainwater wash-off, and more successfully pierce insect cuticles. Certain nanopesticides containing silver nanoparticles or chitosan also have antifungal and antibacterial qualities, offering dual defense against pests and plant diseases [4]. Furthermore, studies show that nanopesticides enhance integrated pest management (IPM) by guaranteeing slow-release, regulated formulations that reduce application frequency [5]. One of their main advantages is that nanopesticides have less adverse effect on ecosystems and non-target creatures. Because of runoff and deposition, traditional pesticides can cause collateral harm to aquatic systems, beneficial insects, and soil microorganisms. Because of their tailored action and lower dosages, nanopesticides reduce negative impacts without sacrificing the effectiveness of pest control [1].

Nanotechnology in Soil and Water Management

Two of the most urgent issues facing modern agriculture are soil degradation and water scarcity, which endanger sustainability and long-term output. By tackling issues like nutrient depletion, pollution, and wasteful water use, nanotechnology provides creative ways to strengthen soil health and improve water management [7].

Nanotechnology in Soil Management

To improve soil fertility, structure, and pollution remediation, nanotechnology is essential. Nanoparticles include zero-valent iron (nZVI), nano-clays, and nano-silica to improve soil aggregation, retain more water, and immobilize dangerous pollutants [7]. By enabling the gradual and regulated release of vital nutrients, these nanomaterials guarantee that crops get a consistent supply of components like potassium, phosphorus, and nitrogen [8]. By more efficiently binding nutrients, nano-fertilizers minimize environmental losses and help prevent nutrient leakage and soil depletion [8]. Better nutrient bioavailability, for example, is offered by nano-zinc and nano-phosphorus fertilizers, which ensure efficient plant absorption and lessen the need for excessive chemical fertilizers [3]. Furthermore, nanotechnology can recover degraded lands by introducing nanoparticles that promote microbial activity and improve soil bioremediation [7].

Nanotechnology in Water Management

Water must be managed effectively as a vital resource for agriculture to support sustainable crop production. Desalination, conservation, and water purification methods have all been transformed by nanotechnology. Iron oxide, titanium dioxide, and carbon-based nanomaterials are examples of nanoparticles that are frequently employed in water filtration and decontamination processes to eliminate organic contaminants, pesticides, and heavy metals. By purifying saline water, nano-enabled desalination technologies—like nanomembranes and nano-enhanced reverse osmosis—make it suitable for irrigation in arid and semi-arid areas. Furthermore, nano-absorbent materials lessen water loss from runoff and evaporation by increasing soil water retention. For instance, soil can be treated with nanoscale water-absorbent polymers to improve moisture retention and decrease the need for frequent watering [9]. Nanosensors also monitor pollution, water quality, and soil moisture levels. By identifying contaminants before reaching crops, these sensors aid in safe irrigation, water resource conservation, and optimization of irrigation [9].

In the process of preparing the Constitution, the state of digitization/digitalization of Georgia in general and the current situation in the agricultural sector in this direction were studied. Digitization is actively underway all over the world. In this regard, the digitization process of Georgia has been dynamic since 2012 and is being implemented by government organizations. According to UN data, the EGDI index in 2022 was 0.75, and with this data, Georgia firmly established itself in the VHEGDI, i.e. very high group. The data of international indicators and the country's place in the rating lists confirm that digitalization has covered all areas and according to the Human Development Index, Georgia is a country of very high development, the trajectory of the process is positive, and state support is a prerequisite for development in this direction. As already mentioned, a study was also conducted to fix the state of studying the use of modern technologies. A cluster-based study of Georgian agro-sector companies found that the progress of digital transformation in terms of the use of computers, mobile phones, and e-mail is on average satisfactory, while the overall use of drones and nanotechnologies is not even 1-2 percent and is unsatisfactory [14] .Business entities in the agro-sector (mainly small entrepreneurs) are unable to purchase digital tools and they lack sectoral knowledge in this area. State support is important to overcome the problem. Through funding of scientific units and economic entities, subsidies, free training programs, and the provision of equipment at preferential prices.

Conclusion

The figures fixed in international indices confirm that Georgia is not only a leader in the South Caucasus, but is also ready to take bigger and bolder steps in the direction of digitalization, which is obviously impossible without the introduction of nanotechnology, because today this small technology is completely changing the world - nanotechnology is rightly considered a transformer of industries. The use of nanomaterials in the agro-sector is especially important, because world practice (the example of India) shows a positive trajectory in this direction. In general, the agrosphere and its adjacent sectors (agromedicine, agrotourism, ecology, etc.) show high receptivity to this new field. As for the experimental terms and results, as we have already mentioned, five years of scientific observation are probably sufficient in this regard. The implementation of transformations in this direction depends on the activity of the agro-sector and state support.

Bibliography

1. Nandini,, B., Mawale, K. S., & Giridhar, P. (2023). *Nanomaterials in Agriculture for Plant Health and Food Safety: A Comprehensive Review on the Current State of Agro-Nanoscience.* 3 Biotech, 13:73. DOI: 10.1007/s13205-023-03470-w.
2. Liu, C., Zhou, H., & Zhou, J. (2021). *The Applications of Nanotechnology in Crop Production.* Molecules, 26, 7070. DOI: 10.3390/molecules26237070.
3. Javaid, A., Hameed, S., Li, L., Zhang, Z., & Zhang, B. (2024). *Can Nanotechnology and Genomics Innovations Trigger Agricultural Revolution and Sustainable Development?* Functional & Integrative Genomics, 24, 216. DOI: 10.1007/s10142-024-01485-x.
4. Tripathi, S., Mahra, S., J, V., Tiwari, K., Rana, S., & Tripathi, D. K. (2023). *Recent Advances and Perspectives of Nanomaterials in Agricultural Management and Associated Environmental Risk: A Review.* Nanomaterials, 13, 1604. DOI: 10.3390/nano13101604.
5. Gupta, P., Sharma, M., & Sharma, S. (2023). Emerging Advances in Nanopesticides for Sustainable Agriculture. Emer Life Sci Res, 9(1), 164-176.
6. Chhipa, H. (2017). Nanofertilizers and Nanopesticides for Agriculture. Environmental Chemistry Letters, 15, 15-22. DOI: 10.1007/s10311-016-0600-4.
7. Dhanapal, A., et al. (2024). Nanotechnology Approaches for the Remediation of Agricultural Polluted Soils. DOI: 10.1007/s42452-024-06265-7.
8. Rana, L., et al. (2024). Nanotechnology for Water Management in Agriculture. Discover Applied Sciences, 6:555. DOI: 10.1007/s42452-024-06265-7.
9. Hakim, A., et al. (2023). Application of Nanoparticles in Soil and Water Treatment. Materials Research Foundations 148, 229-251. DOI: 10.21741/9781644902554-8.
10. . Paliani S., Analysis and Assessment of the Digitalization Process of Georgia, Georgian Scientists, 2025.
11. http://www.nanoarchive.org
12. **ჯიშიაშვილი დ.** , ნანოტექნოლოგიის შესავალი. თბ., 2007.
13. **ღურწკაია თ., ფალიანი ს.,** ეკონომიკის ციფრული ტრანსფორმაცია (დიჯიტალიზაცია), როგორც გლობალური გარდაქმნა, ჟ. „ეკონომიკა“, თბ., 2023.

14. **ფალიანი ს.,** საქართველოს ბიზნესის ციფრული გარდაქმნა, ჟ.“მოამბე“, 2024.
15. **ფალიანი ს.,** გარდაქმნების და ცვლილებების თანამედროვე გამოწვევები ბიზნესში. ჟ. „ეკონომიკა“. ტ. 105, თბ., 2023.

ნანოტექნოლოგია, როგორც აგროსექტორის ტრანსფორმატორი

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ანოტაცია

წინამდებარე სტატიაში შესწავლილია ნანოტექნოლოგიების გამოყენების მასშტაბი აგროსექტორში და განხილულია ამ მიმართულებით დარგის შესწავლის მდგომარეობა. ანალიზი ჩატარებულია უცხოეთის მოწინავე ქვეყნების გამოცდილების შესწავლის საფუძველზე. ავტორები გამოთქვამენ იმედს, რომ ამ მიმართულებით საქართველოს აქვს განვითარების შესაძლებლობა, აღნიშნული კი დასაბუთებულია საერთაშორისო ინდიკატორების მაჩვენებლებით და კვლევებით. საქართველოს გაციფრების პროცესი დინამიურია 2012 წლიდან და ქვეყანას აქვს ამ კუთხით აგროსექტორში გარდაქმნების ჩატარებისა და განვითარების შესაძლებლობა.

სტატიის ბოლოს წარმოდგენილია დასკვნა. მენეჯმენტში ნანოტექნოლოგიის როლს მოიაზრებენ ინტერდისციპლინარულ ჭრილში, როგორც აგროსფეროში მომუშავე ბიზნეს სუბიექტებში ორგანიზაციული გარდაქმნების მართვის სრულყოფის ერთ-ერთ საუკეთესო საშუალებას.

საკვანძო სიტყვები: ნანოტექნოლოგია; აგროსექტორი; ტრანსფორმაცია; დიგიტალიზაცია.