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THE TRANSFORMATION OF THE AGRICULTURAL SECTOR OF THE REPUBLIC OF UZBEKISTAN IN THE CONTEXT OF THE DIGITAL ECONOMY: INSTITUTIONAL BARRIERS AND STRATEGIC PRIORITIES OF SMART AGRICULTURE

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Abstract: This article examines the theoretical and practical aspects, as well as the institutional conditions, of the transition to smart agriculture in the Republic of Uzbekistan in the context of global demographic and environmental challenges. The methodological framework of the study is based on qualitative methods: a comparative analysis of leading international practices-case studies from the United Kingdom and Japan-and systematic content analysis. The study examined key barriers to the implementation of digital innovations in Uzbekistan's agricultural sector, including a shortage of specialized human capital, infrastructure limitations in rural areas, and the problem of operational incompatibility among platform solutions. Based on the proposed analysis, a comprehensive organizational mechanism is proposed to overcome the identified limitations through the creation of regional agrotechnological hubs, the implementation of public-private partnership models, and the standardization of open data interfaces.

Keywords: agriculture, digital economy, smart agriculture, digitalization, Uzbekistan, agrotechnologies, international experience, economic security.

Introduction

It is no secret that agriculture forms the economic foundation of any country, including Uzbekistan. The sector provides employment for millions of people and ensures the country's food security. However, the national agricultural system faces the challenges of the Malthusian trap. The essence of the concept is simple: exponential population growth inevitably creates a destructive imbalance with the arithmetic rate of increase in food production, which is limited by natural factors-the area of arable land and the natural fertility of the soil [1].

Statistical analysis confirms this risk: for instance, while the republic's population stood at 28.001 million in 2010, by 2026 this figure had reached 38.4 million [2]. Meanwhile, the country's land area remained unchanged at 448,900 square kilometers. There is no available land in the country for an extensive (through expansion of acreage) increase in arable land. Intensive soil exploitation using outdated technologies yields only short-term benefits, but in the long term leads to disastrous results-soil depletion and degradation [3].

One of the most effective solutions to this problem is the transition from traditional agricultural technologies to a data-driven ecosystem (Data-Driven Agriculture), which involves the deep integration of the Internet of Things (IoT), artificial intelligence, Earth observation systems (EOS), and unmanned aerial vehicles (UAVs). The widespread adoption of these innovations in Uzbekistan is hindered by institutional, infrastructural, and sociocultural barriers, which require in-depth and high-quality analysis and the development of scientifically grounded recommendations to overcome these barriers-this is the objective of this research article [4].

Research Methods

This study is based on a qualitative analysis methodology. This approach is necessary for examining the nature of underlying managerial and institutional issues. The following research methods were used in the preparation of this article:

1) Observation and data collection-this method involves the targeted tracking and gathering of necessary facts about an economic entity or phenomenon.

2) Deduction method – moving from general facts to specific conclusions.

3) Institutional analysis – helped assess the readiness of the regulatory framework for reforms, allowed for an examination of the so-called "rules of the game," as well as the regulatory environment itself.

4) Comparative method – was used for a deductive analysis of successful models of digital transformation in the agricultural sector in developed countries, in our case the United Kingdom and Japan, with the aim of comparing and identifying elements that could be applicable in the context of Uzbekistan.

5) Systemic content analysis was applied to study academic literature, analytical reports, and regulatory acts of the Republic of Uzbekistan to transition from general theoretical concepts to specific, adapted recommendations [5].

Results

First and foremost, it is essential to recognize the importance of agriculture itself. Agriculture is the primary source of food products, which are designed to meet one of humanity's fundamental needs-the need for food. As the population grows-not only in Uzbekistan but worldwide-the demand for food will only increase, further enhancing the value of agriculture [6]. The best description of this problem was provided by the English economist Thomas Malthus, who developed the theory of Malthusianism. As discussed earlier, according to this theory, population growth occurs significantly faster than the growth of food production, which in the long term can lead to resource shortages and food crises. The emergence of food shortages is only a matter of time if agricultural reforms are not implemented. And one of the most effective ways to solve this problem is the digitalization of rural areas, i.e., the creation of so-called smart agriculture. As the population grows, businesses are forced to work harder, which has a negative impact on the quality of land resources. Soil quality deteriorates, water bodies become depleted and polluted, and livestock suffer. Numerous problems and limited opportunities for growth in production and product quality objectively contribute to the adoption of digital technologies. This will allow for the most efficient use of natural resources, with high labor productivity and optimized utilization of various categories of personnel, which, in turn, will positively impact the liquidity of enterprises [7]. However, for the successful implementation of smart agriculture practices in Uzbekistan, it is necessary to study the best practices of developed countries regarding the successful implementation of these practices. A qualitative analysis of global development trajectories in smart agriculture allows us to identify two key models demonstrating high efficiency:

1) Robotics and Unmanned Systems Model (UK Experience): The British approach focuses on minimizing human involvement and its impact on processes, as well as soil compaction caused by heavy machinery. The development of the "Hands-Free Hectare" (fully automated cultivation and harvesting of grain by robots without human presence in the field) demonstrates that robotic systems and UAVs are capable of optimizing operational costs, applying fertilizers with precision, and continuously monitoring plant growth using multispectral cameras [8].

2) A Model of the Sensor-Analytical Internet of Things (The Japanese Experience): Faced with a severe shortage of land resources, limited arable land and soil, and an aging rural population,

Japan has focused on precision livestock farming and the Internet of Things (IoT). A prime example is the integration of smart biosensor bracelets and collars into livestock farming. These devices continuously monitor the animals' biometric parameters (temperature, physical activity, feeding cycles), transmitting the data to AI-based cloud platforms. This allows for the early mitigation of epidemiological risks, maximization of milk yields, and optimization of feed rations, significantly increasing the liquidity and profits of agricultural enterprises [9].

Comparison Parameter	**Robotic model (United Kingdom)**	**Sensor-biometric model (Japan)**
Dominant Technologies	Autonomous robots, UAVs, computer vision algorithms.	IoT sensors, biometric trackers, cloud-based AI platforms.
Key Economic Impact	Reduced soil degradation, optimized seed and fuel consumption, round-the-clock monitoring.	Minimizing livestock mortality, precision quality control, and feed cost savings.
Institutional Support	Grants for tech startups, synergy between university research and farmers' associations.	Direct government subsidies for the purchase of IoT equipment, support programs for young farmers.
Achieved Results	Winter wheat yield with fully autonomous machinery reached 6.5 tons per hectare. Errors and omissions during automated sowing decreased from 2.82% to 0.35%. The accuracy of autonomous machinery's movement along a specified trajectory reached 5 centimeters. Economic modeling confirmed the competitiveness of small autonomous robots against traditional heavy machinery due to reduced labor costs for operators.	With the introduction of smart collars (Farmnote Color system), cattle mortality from injuries dropped to minimal levels thanks to the feature that detects when an animal has fallen. The time required for mandatory daily livestock headcounts was reduced by 36%. Livestock-related IT field management systems (Kubota KSAS interface) recorded a 15% increase in forage and rice yields while simultaneously reducing grain drying costs.

Table 1. Comparative Analysis of International Smart Farming Models [10], [11].

In the agricultural sector of the Republic of Uzbekistan, there are currently three main barriers that are hindering a large-scale transition from traditional agriculture to smart agriculture:

- A shortage of specialized human capital and low awareness of innovation. Innovations in smart agriculture require end users-whether farmers or agronomists-to possess certain digital competencies, such as skills in working with big data technologies, operating UAV interfaces, and understanding the algorithms behind automated fertilizer application. Currently, many smallholder farms in Uzbekistan operate using traditional methods and conventional farming practices, lacking knowledge of the long-term economic benefits of smart agriculture practices. [12].
- The infrastructure gap in rural areas. The foundation for the successful operation of distributed networks of IoT sensors, precision agriculture systems, and other technologies is a reliable, high-speed telecommunications infrastructure. The lack of reliable broadband coverage in remote rural areas of the country makes it impossible to collect and transmit data from fields in real time [13].
- The problem of technological fragmentation and operational incompatibility. The Uzbek market is seeing a chaotic influx of disparate imported technologies, such as software from Western, Chinese, and Russian manufacturers. The lack of unified national data exchange standards means that a humidity sensor from one manufacturer cannot be integrated with another's smart irrigation system, which undermines the concept of comprehensive digitalization [14].

Discussion

To overcome the "Malthusian trap" and minimize human-induced damage to land and water resources, the author proposes an organizational framework for the sustainable development of Smart Agriculture, comprising three strategic components:

1) Establishment of regional agricultural technology centers. The government, in collaboration with relevant academic institutions, must establish a network of agricultural hubs. These centers should compile the best IT solutions, make them freely available to farmers under the "Demo Farms Ed" concept, and provide free consultations and short-term training in basic digital skills for farmers..

2) The widespread adoption of public-private partnership (PPP) models in infrastructure. It is impossible to overcome infrastructure challenges solely through budgetary funds. It is necessary to launch PPP mechanisms under which telecommunications operators will be granted tax incentives (for example, on property tax or water usage fees during construction) or tax holidays in exchange for a commitment to provide 100% coverage of agricultural land with 4G/5G connectivity.

3) Creation of the Unified National Digital Platform for the Agro-Industrial Complex (UNDP AIC). To address issues such as software incompatibility, the Ministry of Agriculture, in collaboration with the Ministry of Digital Technologies, must develop regulatory standards for open application programming interfaces (Open API). All information collected from satellites, drones, and sensors must be aggregated into a unified cloud ecosystem, access to which (in terms of basic climate and soil data) must be free for domestic agricultural producers.

Conclusion

The findings confirm that, given the severe demographic constraints and the exhaustion of the potential for extensive growth in Uzbekistan's agricultural sector, the transition to "smart agriculture" is one of the key pathways to ensuring the country's economic development, growth, and security. However, this process cannot be implemented haphazardly; a targeted and systematic approach to implementation is needed. The main contribution of this work is a shift in focus from simply noting technological trends to the need for systematic institutional preparation of the foundation, the so-called "fundamentals." Overcoming the human capital deficit through a network

of hubs, eliminating infrastructure gaps through public-private partnerships (PPPs), and overcoming platform fragmentation through unified Open API standards will unlock the innovative potential of Uzbekistan's agricultural sector, ensuring food security and the country's sustainable development in the long term.

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