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Sustainable Agricultural Innovation in Uzbekistan Through the Helix Models

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Abstract

Uzbekistan is a double-landlocked country with an economy heavily reliant on agriculture, arguably one factor impeding the country's development. One possible remedy to the agricultural transformation is the Helix Innovation Ecosystem. This research investigates how the pillars of the helix- academia, industry, government, civil society, and environmentalists- can be the catalysts that arise from the groans of collaboration while strategizing theories such as international relations and political case studies. The Green Industrial Revolution will allow Uzbekistan to compete favorably, be market-oriented, and maximize its comparative advantages in agriculture: renewable resources, eco-industrial parks, and energy-efficient greenhouses. Besides building institutional fittings and bridges, improving the interaction among the helix actors will facilitate climate funds in the agricultural sector. In addition, funds from the carbon market will enable socio-economic resiliency. As library-based and secondary data research, the article further acknowledges that these eluding aspects can only be comprehended through field studies that can be compared to other landlocked countries. Finally, this paper argues that balancing the interaction between the various elements of the Helix model will enable Uzbekistan to have a sustainable economic environment and focus more on innovations in the agricultural sector. It can also serve as a guide for other low-income countries with similar development problems.

Keywords: Academia, Civil society, Government, Strategy, Tangible and intangible.

1. Introduction

The region's economic growth is progressively bound to its innovation power, postulating a transformation towards a knowledge economic system endorsed by a robust science, technology, and innovation (STI) structure (Xu & Zhang, 2024). The evolution of an innovative economy in Asia-Pacific countries requires revolutionary transformations facilitated by active state participation, including establishing national innovation strategies and formulating supportive legislative and institutional infrastructures (Konyukhov et al., 2019). For example, strategies such as China's "New Quality Productive Forces (2023)" (Li et al., 2024), South Korea's "Digital Strategy of Korea (2023)" (Ministry of Science and ICT, 2023), and Uzbekistan's "Development Strategy of New Uzbekistan 2022-2026 (2022) " (Eurasia Center, 2022), enable the various approaches taken by each country to decode their specific challenges and highlight their strengths for sustainable growth by fostering innovation, improving digital capabilities, and upgrading comprehensive development strategies especially in agriculture.

Landlocked developing countries (LLDCs), such as Uzbekistan and some other emerging countries, lack territorial access to the sea, are remote and isolated from world markets, and have high transit costs, which impose severe constraints on overall socio-economic development.[1] Uzbekistan in 2022, with 25% of GDP and about 26% of the labor force covered by agriculture (USA International Trade Administration, 2023), has a population of over 36 million (World Population Review, 2024), with refined copper, petroleum gases, polymers of ethylene, motor cars, wheat, and mineral or chemical fertilizers as its top export and import products in 2021 (Trend Economy, 2023). Innovation in the agricultural sector is essential for economic growth, technological advancement, and societal development (Dub et al., 2023). This research discusses Uzbekistan's challenges and efforts to fight for economic, social, and environmental improvements to promote qualitative development and innovation-driven growth through sustainable agriculture.

The Helix model seeks to establish a sustainable, resilient, and highly productive agricultural sector by promoting extensive collaborations among these stakeholders. This comprehensive approach reveals how practical it can be in responding to the complex problems facing modern farming while propelling the country toward sustainability. In Uzbekistan, eco-innovation within supporting industries, primarily through developing eco-industrial parks, is a tremendous breakthrough toward achieving a more sustainable future (Ortikov, 2023). They ensure efficient resource utilization, material recycling, and better energy use, changing industrial dynamics through closed-loop systems (Opitz-Stapleton et al., 2022). Besides this, Uzbekistan's greenhouse business has started incorporating energy-saving technologies into new-generation greenhouses consistent with eco-innovation principles; these include reduced energy use and resource consumption, leading to decreased manufacturing costs (Durmanov et al., 2021). However, several challenges still exist, such as missing linkages and weak institutional

[1] ITU. Landlocked Developing Countries (LLDCs). https://www.itu.int/en/ITU-D/LDCs/Pages/Landlocked-Developing-Countries.aspx

infrastructure for innovation diffusion, which points towards 'knowledge ecology' rather than strong 'innovation systems' (Weerasinghe et al., 2024). Enhancing ties in the Helix Innovation Ecosystem is necessary to accrue eco-innovation benefits in Uzbekistan.

The agricultural sector sustains the economy and social welfare by offering innovation opportunities fostered through the Helix Innovation Ecosystem application. This research aims to explain how this multidimensional system involving academia, industry, government, civil society, media, and environmentalists can transform Uzbekistan's agricultural practices. This research uses a library-based research method to determine the relevance and effects of the Helix Innovation Ecosystem in Uzbekistan's agricultural sector. The first stage consisted of analyzing available literature and policies about the research question, using theories of international relations, innovation ecosystems, and comparative case studies of other countries with similar characteristics. This secondary analysis contributed to designing a model appropriate for the socio-economic and environmental circumstances that characterize Uzbekistan.

2. Literature Review and Theoretical Framework

2.1. IR Theories for Innovation

IR theories explain why and how global cooperation, power dynamics, normative structures, and international collaboration can influence innovation and technology. These insights are particularly relevant for sustainable agricultural innovation in Uzbekistan, where global partnership is critical in addressing agrarian challenges and leveraging technology for sustainable growth. For example, shifts in techno-economic trends influenced by the dynamics outlined by IR theories impact the global landscape of innovative activities such as agricultural innovation and the implications for global governance institutions (Leijten, 2019). As a nation undergoing economic and technological transformation, Uzbekistan can harness international collaboration to integrate advanced agricultural technologies and sustainable practices into its farming sector. It is associated with the principles of global governance institutions and promotes knowledge-sharing and cooperation to address cross-border issues like food security and climate change. For another example, theories like ecosystem theory and collaborative innovation theory, which can implement the broader insights provided by IR theories, address efficiency by enhancing information flow and resource sharing easier for better entrepreneurship education (Wang & Zhu, 2023). By applying the Helix Model, Uzbekistan can enhance collaboration between universities, industries, government entities, and civil society to facilitate the flow of information, improve resource-sharing, and foster entrepreneurship in agriculture.

In international relations theory, debates on realism and constructivism are essentially about constructivists' claims that realism cannot see changes in global politics, such as transformations in actors, identities, or social practices (Sterling-Folker, 2002). The evolution of realism and its intersection with constructivism suggests an attempt to harmonize traditional realism with constructive approaches (Brown, 2012). This blended theoretical perspective is crucial for understanding state behavior and international relations, mainly when applied to fostering innovation and sustainability. For Uzbekistan's sustainable agricultural innovation, these IR insights provide a framework to understand how the country interacts with global and regional actors, shaping its innovation ecosystem. At the same time, constructivism's emphasis on identities and practices underscores the importance of shared norms, collaborative behaviors, and inclusive innovation practices within Uzbekistan's agricultural sector. Nørreklit states that materialistic aspects do not contradict reality's subjective features but enhance them, thereby suggesting a pragmatic constructivist approach that resolves this dichotomy (Nørreklit, 2013).

Practically, further emphasis on government involvement and international collaboration comes from Bridge Organizations, which are established through partnerships between government, academia, and business organizations for succeeding in the technology companies' internationalization on global innovation hubs (Pietrasieński & Rokosz, 2023). These actors can form bridge organizations tailored to Uzbekistan's unique needs, ensuring the internationalization of its agricultural technology and aligning it with global standards of sustainability and innovation. With knowledge exploitation at its core, fostering the growth of industries under innovation ecosystems aims for a cooperative evolution (Cherchem & Keen, 2022). The importance of scientific collaboration is highlighted in exploring how to promote comprehensive innovation internationally (Gao et al., 2021). Uzbekistan can encourage cooperative evolution within its agricultural sector by fostering innovation ecosystems and promoting shared learning and collaborative problem-solving among stakeholders to enhance agricultural productivity, reduce environmental impact, and improve food security. However, without careful management and equitable access to the benefits of these collaborations, there is a risk that innovative efforts may primarily serve the interests of larger entities, potentially marginalizing smaller players and stifling broader, inclusive growth within the global innovation ecosystem.

Industrially, in-depth analysis such as Tianjin's manufacturing industry case study guides economic adjustments for constructing these innovative ecosystems within an industrial scope (Yan & Liu, 2023). It was found that improving the industrial chain ecosystem of the manufacturing sector, boosting the industrial competitiveness of Tianjin's manufacturing industry, and prioritizing the development of the high-tech manufacturing industry are essential. As for human-centric approaches to nurturing skilled human resources, three categories of innovation ecosystems foster high levels of talent competitiveness driven by business investment, e-government initiatives, research and development (R&D), and innovation ecosystems associated with lower talent competitiveness if neglecting general education (GE) and research and development (R&D) irrespective of increased government investment in technology infrastructure (Huang et al., 2023). Just as improving the industrial chain ecosystem and prioritizing high-tech industries boosted Tianjin's competitiveness, a similar approach can enhance Uzbekistan's agricultural innovation ecosystem. For example, Uzbekistan can focus on developing a comprehensive agricultural value chain ecosystem, integrating advanced technologies like precision farming, smart irrigation, and agri-tech solutions to improve productivity and sustainability. Uzbekistan can also prioritize high-tech agriculture, such as biotechnology, sustainable farming equipment, and climate-resilient crop development, ensuring that innovation addresses environmental and societal needs. Moreover, a human-centric approach is essential for sustainable agricultural innovation. Business investments in workforce training and government and academic farm education and research initiatives can create a pipeline of skilled agrarian professionals. While focusing on the R&D of farming technologies, Uzbekistan must build a broad knowledge base and adaptability among its workforces. This ensures equitable talent competitiveness and reduces disparities

between technological advancements and workforce capabilities. Nevertheless, without a balanced approach, the long-term sustainability of the innovation ecosystem may lead to inequalities in talent competitiveness and industrial growth.

2.2. Theoretical Framework: Helix Models

The Triple Helix model, which explains how universities, industries, and government interact, offers a way to understand collaborative innovation dynamics (Etzkowitz & Leydesdorff, 2000). Nevertheless, according to Cai, this model was expanded to include broader societal and environmental dimensions in 2022, thus reflecting the growing complexity of innovation ecosystems (Cai, 2022). In addition, an analysis of European case studies on effective innovation ecosystems has highlighted the importance of diversity in stakeholder participation and governance models (Taratori et al., 2021). Traditional innovation models have been redefined by including non-state actors like NGOs and TNCs and technological advancements such as AI or IoT. As in the Triple Helix model, the innovation ecosystem has substantially changed. Explaining how universities, industries, and government interact has evolved into more complicated models, such as the Quadruple or Quintuple Helix models, which are positively related to future vision (Mineiro et al., 2023).

Adopting Helix Models reflects the need for structural and social elements to drive progress. For instance, realism's focus on structural determinants highlights the necessity of strong governmental policies and resource allocation. Uzbekistan tries to resolve many environmental challenges that are profoundly tangled with its economic actions and climatic situations. The mining industry, essential for the nation's economic evolution, has led to providential ecological degradation, particularly in the Free Economic Zones (FEZs) of Navoi and Angren, where decades of mining have led to substantial waste accumulation and land degradation (Mavlyanova et al., 2021). Soil erosion and salinity are persistent issues exacerbated by regional climate change, which is expected to increase droughts and high summer temperatures, further risking land degradation. Efforts to combat these challenges include science-based crop rotation, sustainable farming systems, and adopting eco-technology and biotechnology for soil conservation (Gafurova & Juliev, 2021). Water resource problems are another critical issue, mainly due to the decline of central Asian mountain glaciers and the disappearance of the Aral Sea, which create crucial challenges for agricultural water usage. The possibility of regional water conflicts also modifies the situation, especially for downstream countries like Uzbekistan (Brody & Eshchanov, 2021). The switchover to renewable energy sources, which address climate change and natural resource diminution, has prospects for increased renewable energy use (Shaydanov & Qalandarxonov, 2023). These environmental challenges require comprehensive and innovative solutions to ensure sustainable development in Uzbekistan.

3. Helix Innovation Ecosystem for Uzbekistan

In Uzbekistan, the agricultural sector sustains the economy and social welfare by offering innovation opportunities fostered through the Helix Innovation Ecosystem application. It explains how this multi-dimensional system involving academia, industry, government, civil society and media, and environmentalists can transform Uzbekistan's agricultural practices. The Helix model seeks to establish a sustainable, resilient, and highly productive agricultural sector by promoting extensive collaborations among these stakeholders.

3.1. Government

As the largest population in Central Asia, Uzbekistan has excellent potential for establishing its national advantages either following the European model of landlocked countries or some other model that facilitates its local diversities in national values, culture, economic structure, system, and history while coping with its challenges and threats (Yann, 2022). The government hopes to double farmers' incomes and ensure a minimum 5% annual growth of agriculture in 2022-2026 through intensive development programs, application of advanced scientific achievements, digitization, and adoption of new technologies with support from international institutions. [2]

Moreover, national agricultural reform strategies and detailed planning in practice are provided. However, a peaceful and sustainable comprehensive approach integrating the local, national, regional, and global factors toward its national competitive advantage in coping with climate change has not been envisioned clearly in the agricultural industry (Eshov et al., 2021).

Transitioning to a green economy necessitates achieving food security while using fewer natural resources. This can be accomplished through improved water management, significant investments, and innovations, including cultivating crops with higher nutritional efficiency per unit of water consumed (Rockström et al., 2017). In landlocked countries like Uzbekistan, adopting strategies like zero-waste farming and incorporating blockchain technology in the agricultural sector can help establish national competitive advantages is necessary.

3.2. Academia

Uzbekistan has built a network of higher education institutions (HEIs) that are an integral part of the national innovation system, which is critical to the nation's development strategy. These institutions have a key role in developing human resources and are crucial to the socio-economic development necessary to modernize and diversify the economy (Saidov, 2024). Due to its transition phase, Uzbekistan is gradually concentrating on the productive activities performed by the HEIs, such as active international partnerships (Merrill, 2024). Modern teaching and research methods are meant to meet international standards (Arshad, 2024).

To this end, Uzbekistan seeks to shift 85% of its higher education institutions to the credit-module training system by 2030 while enhancing the scientific potential through several measures like those financed by the Ministry of Higher and Secondary Special Education (MHSSE) as well as other initiatives, including attachments to and attending advanced training courses in the leading international universities for faculty members as well as huge capital investment in capital expenditures and equipment (Aralova, 2024).

HEIs construct innovation ecosystems, as they are potent players in shaping innovative structures and institutional features for adequate research conduct. They transcend their normal educational functions when

[2] US International Trade Administration. Agricultural Sectors. Uzbekistan - Country Commercial Guide. https://www.trade.gov/country-commercial-guides/uzbekistan-agricultural-sectors

developing market-relevant experts who will contribute to achieving core objectives. HEIs contribute to the training of qualified professionals and promote innovative and effective educational systems and development changes (Zufarova, 2024). Uzbekistan is a state that seeks foreign investments in education; this partnership will assist in investments into foreign universities (Khaydarov, 2024).

Today's challenges for higher education institutions (HEIs) of the higher educational and scientific system, including their optimization, competitiveness, and ability to attract external investment, have necessitated the incorporation of cutting-edge technologies (Murodova et al., 2024). In addition, such institutions are developing new curricula to provide students with the necessary skills in response to changing labor market requirements (Urbančíková & Umarkhonov, 2024).

Meanwhile, Uzbekistani higher education institutions contribute much to the internationalization of education, first through preparation for global intercultural interaction among young people and secondly through improvements on an international level, which have increased their recognition around the globe (Ovezmyradov & Kepbanov, 2020). This is vital for creating a knowledge-based workforce that can meaningfully contribute to the nation's innovation ecosystem. Higher Education Institutions in Uzbekistan are not only centers of learning. They are also integral to the national innovation ecosystem, promoting research and development and making great efforts towards socio-economic transformation within its borders. As Uzbekistan seeks to modernize education and enhance international cooperation, its aspirations lie in building a strong, innovative economy (Nabiyev et al., 2023).

The internationalization of higher education can enhance regional competitiveness by promoting the exchange of knowledge, skills, and resources among academic institutions, industry partners, and policymakers. There are 154 members, including 25 international institutions in Uzbekistan (see Figure 1). Promoting agricultural innovation has been one of the main goals of the higher education institutions (HEIs) in Uzbekistan, which are aware of agriculture's immediate and strategic needs (Toshboev et al., 2023). Their primary function is to conduct research and employ effective farming technologies that promote productivity and sustainability (Khudoynazarovich, 2021). The participation of HEIs in agricultural innovation encompasses a variety of activities, from cultivating new agronomic techniques to making crops overcome changing climatic conditions. Universities in Uzbekistan support innovation in agriculture, such as the creation of creative procedures in Uzbekistan's agro-industry, particularly in Tashkent province, which is vital for increased production and employment, improved quality of products, and decreased costs, competition both at home and abroad, thus improving the socio-economic conditions in agriculture (Narinbaeva et al., 2021).

Collaboration between agricultural stakeholders and HEIs is essential in technology transfer and knowledge sharing. These relationships lead to sustainable farming practices which are economically viable and environmentally friendly in many instances. It should be noted that HEIs provide manpower by training graduates competent enough to drive change within the agricultural sector. Various government policies aimed at improving performance by modernizing and adopting technology and other measures have supported this educational role while demonstrating an all-inclusive approach to promoting agricultural innovation in Uzbekistan (Najjar et al., 2023).

Number of higher education institutions in the Republic of Uzbekistan.

Indicators	2019-2020 cademic year	2020-2021 academic year	2021- 2022 academic year
Number of higher education institutions	119	127	154
including the number of foreign higher education institutions	16	18	25

Figure 1. Higher Education Institutions in Uzbekistan (Lyamkina, 2024).

3.3. Civil Society (The Public)

A sustainable development philosophy, state-of-the-art technologies, and effective operations would promote farmers, consumers, and ecology by creating more substantial and more profitable agriculture systems (Pretty et al., 2011). In the above-substantiated scenarios, delay, information fragmentation, fraud, and counterfeit products circulating through the network often significantly affect the supply chain (Kshetri, 2017). For instance, agricultural producers may not be able to obtain their payment after transporting goods in return for delivery; buyers may lack funds to afford transactions with farmers, while consumers may not fully trust the products they purchase and would overwhelmingly need supporting verifiable information regarding the goods' conditions and quality. By building upon the integration of data, trade, and finance flows, it would optimize the supply chain in which all the actors in the agricultural supply chain, such as farmers, buyers, storage, and consumers, will be participating in one database with a specific interface to exchange information and develop a more innovative and secure supply of goods and services.

Uzbekistan has placed a high priority on realizing its agricultural development and diversification. According to them, initiatives funded through USAID assist farmers in developing successful farming businesses that use improved methods and technology.[3] Blockchain technology could significantly support the agricultural supply chains in Uzbekistan. It enables transactions among participants without requiring a third party to facilitate them (Kamilaris et al., 2019). Data can be kept in a single distributed database rather than a centralized one, making access easier while strengthening security and data integrity instead of centralized servers. One of the potential

[3] "Agriculture and food security." *Annals of the New York Academy of Sciences* 894, no. 1 (1999): 9-17.https://www.usaid.gov/uzbekistan/agriculture-and-food-security

challenges when using digital systems is integrating physical assets into their digital identifiers; solutions like weighbridge integration and quality testing instruments can solve this. In places where such data infrastructure technologies are still awaited, a model based only on declaration and manual human data entry could be applied. However, this might also increase the chances of human error and data manipulation.

The supply chain of agriculture is made more complex by disintegrated inward and outward networks, often consisting of several levels of decision-making from farmers to intermediate silos, silos to transformation plants, and transformation plants to clients (Wilding, 1998). Preparing for potential impediments and challenges becomes paramount to addressing increased competition within the agricultural sector. As proposed by the diamond model, the value chain approach of global sustainable agricultural supply chains can assist nations and firms in enhancing their competitive edge through opportunity and process realignment (Kaplinsky & Morris, 2000).

Enhancing support for green ventures and employing circular economy principles can foster renewal and create additional jobs to improve the sustainable economy (Bocken et al., 2016). In addition, adopting sustainable agriculture combined with new technologies such as blockchain could assist in realizing the United Nations Sustainable Development Goals Agenda, which focuses on priority areas, including zero hunger, responsible consumption and production, and climate action (Sachs et al., 2019).

Moving towards sustainable agriculture, backed by innovative practices and new technologies, will significantly improve environmental management, food security, and economic and social growth. Countries such as Uzbekistan can use sustainability-based strategies to elevate the competitiveness of their agricultural sector and address some of the most pressing issues of the current times.

3.4. The Industry of Agriculture: ESG Investing

The application of the Helix Innovation Ecosystem will revitalize the agricultural industry in Uzbekistan. Integrating Environmental, Social, and Governance (ESG) principles in agricultural practices can help Uzbekistan deal with the factors affecting the country and change its image in international markets as a landlocked, low-emission economy center with strong supply chains of enhanced added value.

In agriculture, natural resources management in Uzbekistan might not be peaceful partially because of human-wildlife conflicts or dam conflicts between Uzbekistan and its neighbor nation, Kyrgyzstan, due to the historical context.[4] Even though Uzbekistan has made significant advancements in its climate change adaptation planning process to strengthen climate-sensitive sectors further and improve existing mechanisms to maintain sustainability,[5] Uzbek's agricultural sector has been dominated by the production of cotton and wheat, two highly regulated sub-sectors whose productivity and production levels remain low, with limited diversification after numerous farm and sector restructuring processes.[6]

Agricultural development in Uzbekistan is intertwined with multiple facets of environmental, social, and governance (ESG) investing. For instance, industrial agriculture can impact the country's environment, posing risks of deforestation and pesticide use (de Souza et al., 2024). Additionally, centralized power and control by unelected technocrats and private global institutions can negatively influence monetary policy, capital, and credit distribution (Pistor, 2019). Landlocked developing countries (LLDCs) like Uzbekistan face challenges, such as delays at borders, productivity constraints, and structural weaknesses, reducing their development by approximately 20% compared to countries with sea access (ESCAP, 2024).

Incorporating ESG principles into investment strategies can transform LLDCs into land-linked, low-carbon nations with resilient and value-added supply chains (Kronenberg et al., 2020). Enhanced investments in clean water and sanitation services can lead to faster and more sustainable progress, facilitating the transition to a green economy in landlocked nations (Gurung, 2016). ESG Country Ratings can complement traditional financial ratings by analyzing countries' sustainability performance and risks, benefiting developed and emerging markets (Ng et al., 2020). Emerging-market (EM) countries, accounting for over 60% of global carbon emissions, face significant climate change impacts that could push millions into poverty by 2030 (Garzón-Jiménez & Zorio-Grima, 2021). The United Nations' sustainability goals urge EM countries, including Uzbekistan, to make considerable progress in addressing ESG and economic challenges by 2030.[7]

ESG reporting has become indispensable for supervisory bodies, ensuring stakeholder confidence, engaging with clients, and integrating ESG into business practices. This is crucial for developing Uzbekistan and other LLDC regions into land-linked, low-emission countries with strong value-added supply chains based on ESG principles. The edge of ESG investing is that it can encourage small companies by making these SMEs attractive to public companies and consumers.[8] Nevertheless, acquiring ESG credentials for investing in portfolio firms may be complex and cumbersome because of the requirements for comprehensive information on the underlying assets (Sarda, 2024). For the owners of small enterprises in Uzbekistan's agricultural sector, the environmental ESG dimensions include using recycled material and implementing more internal recycling processes. On the social side, ESG aims to promote diversity, equity, and inclusion for employees, vendors, customers, and investors. Regarding governance, ESG incorporates appointing qualified board members with training to ensure transparency.[9]

For landlocked countries such as Uzbekistan, the agricultural development and investment strategy using ESG principles and best practices has many benefits and prospects. By applying these principles, such countries move to land-linked, low-carbon countries with strong value-added supply chains (Huan & Zhao, 2020). Achieving sustainable agriculture developments, building local industrial clusters, and integrating into global markets will enable a remarkable transformation of the farming sector in Uzbekistan (Rahmetov & Rakhmetova, 2022). Similarly, fostering social involvement, providing capacity building for farmers, and working transboundary will improve sustainability, enhance product traceability, and increase value addition within agricultural supply chains (Ghosh et al., 2021).

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[4] Uzbekistan: Sustainable Natural Resource Use. https://globalsnowleopard.org/gef-undp-projects/uzbekistan-sustainable-natural-resource-use/#:~:text=Uzbekistan%3A%20Sustainable%20Natural%20Resource%20Use%20MINIMIZING%20HUMAN-WILDLIFE%20CONFLICT,humans%20and%20wildlife%2C%20co-existence%20is%20not%20always%20easy.

[5] Change adaptation planning. UNDP. 2020. https://www.undp.org/uzbekistan/press-releases/uzbekistan-advances-its-climate-change-adaptation-planning.

[6] EU assistance for Uzbekistan Agri-Food Development Strategy 2020-2030. https://dt-global.com/projects/agriculture-uzbekistan

[7] United Nations. Transforming Our World: The 2030 Agenda for Sustainable Development. 2015. Retrieved from https://sdgs.un.org/2030agenda

[8] Landmark. ESG for Small Businesses. 2022. Retrieved from https://www.landmarkcpas.com/esg-for-small-businesses/

[9] Monica Singhania, and Neha Saini. "Systems approach to environment, social and governance (ESG): Case of Reliance industries." *Sustainable Operations and Computers* 3 (2022): 103-117. https://doi.org/10.1016/j.susoc.2021.11.003

By integrating ESG principles into their operations, small businesses in Uzbekistan's agricultural industry can attract ESG-conscious investors, consumers, and business partners while promoting environmental, social, and governance best practices. Ultimately, implementing ESG principles in agricultural development can improve environmental, social, and governance outcomes for landlocked countries like Uzbekistan. This can lead to more robust, more resilient economies and a higher quality of life for their citizens while addressing global challenges such as climate change and resource scarcity.

3.5. Environment: Carbon Markets and Climate Finance

Uzbekistan is particularly vulnerable to climate change since it is already the site of the world's worst human catastrophe: the drying up of the Aral Sea. Things will worsen in the coming decades as temperatures rise considerably more than the global average.[10] Threats from water shortages, soil salinity, and erosion are severe, affecting 20 percent of the population through water salinization.[11] Climate warming has reduced snow cover and increased evaporation. An increase in the frequency and intensity of droughts may lead to instability in agricultural production and threaten the country's food security. [12]

3.5.1. Carbon Markets

From an international macroeconomic perspective, linking standalone national carbon markets across Asia and beyond can provide numerous benefits and challenges for the participating countries. The linkage between the carbon markets of the EU and China resulted in improved total social welfare, better economic performance, amplified expansionary effects, and mitigation of adverse cross-border spillover effects (Xiao et al., 2022). Moreover, linked carbon markets functioned as automatic stabilizers of the economy and reduced economic fluctuations in the face of supply-side shocks. Expanding the linkage of Emissions Trading Systems (ETSs) to additional regions is crucial for policymakers considering the design and implementation of international ETS. For instance, when the U.S. and China cooperated on climate action through linked ETSs, both countries benefited from additional support for domestic decarbonization and increased GDP (Li et al., 2023). By extending the linkage strategy to the broader Asian region, including Northeast Asian countries such as China, Japan, and Korea, internationally based capacity-building efforts can help support the development of linked carbon markets that are more valuable economically, environmentally, and strategically. Potential benefits of a regional carbon market linkage in Asia include:[13]

- Reducing costs by expanding the number of market participants, leading to greater efficiency and less volatility.
- Removing incentives for companies to relocate their emitting activities to areas with weaker regulations.
- Providing a confidence-building measure for broader Asian relationships and demonstrating global climate change leadership.

Linkage can reduce costs and encourage countries to set more ambitious climate change targets, promoting regional and global climate action. Uzbekistan can play a significant role in the linkage strategy for carbon markets in Asia by participating in regional cooperation and contributing to establishing an integrated carbon market. By engaging in regional collaboration, developing a domestic ETS, sharing best practices, and exploring opportunities for carbon market integration, Uzbekistan can play a crucial role in the linkage strategy for carbon markets in Asia (Kamolov et al., 2024). Uzbekistan can also adopt a combination of climate finance instruments tailored to its specific context and priorities and play an active role in developing Asian carbon markets.

The linkage between Uzbekistan's participation in carbon markets networking across Asia and elsewhere globally represents typical examples related to the Helix Innovation Ecosystem approach to climate mitigation. It underscores the importance of collaborative initiatives that drive policy-making processes to address environmental concerns while encouraging economic advancement and social welfare enhancement.

3.5.2. Climate Finance

Uzbekistan can contribute to climate change issues and sustainable development by supplying the necessary financial capital and motivating people to adopt and implement sustainable resources, practices, technologies, and innovations.

Climate Finance can help adopt climate-smart agriculture practices, conservation agriculture, agroforestry, and organic farming, promoting healthy soils, improved water management systems, and increased biodiversity through sustainable agriculture (Arabov et al., 2024). Access to climate finance increases farmers' ability to adopt cutting-edge technologies and new practices, such as precision farming, drought-tolerant crops, and efficient irrigation practices, which improve productivity while minimizing the environmental impact. Climate finance could also help establish businesses focused on biodiversity-based sectors such as ecotourism, sustainable timber harvesting, the collection of non-timber forest products, and the responsible use of genetic resources (Murodilloevna, 2024). Through biodiversity entrepreneurship, financing, and incentivizing these businesses, climate funding could help manage and rehabilitate ecosystems, conserve threatened species and provide potential new livelihoods for local people. The financing facilities made available for climate adaptation initiatives could help deepen the scholarship, research, and entrepreneurial activities to promote adopting sustainable agriculture and biodiversity technologies. This, in turn, would help cultivate an innovative and business-oriented culture in Uzbekistan, which will translate into the generation of new green products, services, and business solutions through capacity building and innovation (Pauw et al., 2024).

Therefore, climate finance can positively impact Uzbekistan's agricultural entrepreneurship by supporting various aspects of these sectors. Climate finance's vital impact in Uzbekistan enhances the Helix Innovation Ecosystem. Climate finance is a key feature of Helix Innovation Ecosystems, emphasizing that sustainable

[10] Clare Nuttall in Tashkent. Uzbekistan grapples with urgent climate change problems. 2021. https://intellinews.com/uzbekistan-grapples-with-urgent-climate-change-problems-217031/

[11] Uzbekistan advances its climate change adaptation planning. 2020. https://www.undp.org/uzbekistan/press-releases/uzbekistan-advances-its-climate-change-adaptation-planning.

[12] Zoï Environment Network. Climate change in Uzbekistan: Illustrated summary. 2020. https://www.preventionweb.net/publication/climate-change-uzbekistan-illustrated-summary

[13] Jackson Ewing. *Roadmap to a northeast Asian carbon market.* Asia Society, 2022. https://asiasociety.org/files/RoadmapNortheastern-final-online+.pdf

development will only be achieved through multilateral approaches towards addressing climate change through innovation, collaboration, and strategic investments.

4. Sustainable Agricultural Innovation in the Helix Ecosystem

A combination of tangible and intangible factors determines the success metrics and results of the Helix Innovation Ecosystem for sustainable agriculture in Uzbekistan. These factors constitute innovation conditions and determine the ecosystem's capacity to enhance collaboration, innovation, and sustainable social and economic growth.

Tangible factors provide the measurable and concrete infrastructure that forms the backbone of the ecosystem (Neto et al., 2024). This includes *digital infrastructure* like high-speed internet and mobile networks, essential for seamless communication and collaboration among stakeholders, and physical *infrastructure*, such as transportation networks and specialized facilities, which support the efficient movement of resources and interaction among various entities in the agricultural sector. *Financial resources*, including funding availability and public-private investments, are vital for enabling startups and research projects for sustainable agriculture, ensuring that innovative ideas can be transformed into marketable products. A skilled workforce and continuous learning opportunities (i.e., human capital) are also pivotal for driving research and technological advancements in rural areas through clear government policies that foster a conducive environment for innovation.

On the other hand, intangible factors shape the ecosystem's cultural and social dynamics, which are crucial for sustaining innovation in the long term (Moro-Visconti, 2024). A culture that promotes *risk-taking, creativity, and open-mindedness* is essential for encouraging entrepreneurship and new ideas. *Trust and social capital* among stakeholders in the agricultural industry facilitate effective collaboration, while *networking* ensures the flow of information and resources necessary for innovation. The ecosystem's success relies on c*ollaboration and partnership dynamics*, with effective inter-organizational collaboration and public-private partnerships being vital to leveraging strengths and resources from various sectors. Social responsibility, ethics, and sustainability considerations are critical in ensuring that innovation can foster economic growth while addressing social needs and environmental protection, which earns public trust and support.

This systematic support of these material and immaterial elements within the Helix system allows for persistent joint cooperative performance while contributing to the qualitative transformation of agriculture to improve the region's economy and society. Since each stakeholder brings unique strengths to the equation - policy leverage, research, commercial savvy, social and environmental concerns, and reputation, the Helix model transforms into a stable and integrated filum that restructures the agricultural sector of Uzbekistan at local and global levels. The key to sustainable economic prosperity lies in political stability and the foundation upon which that stability is built (Lee, 2024). Stability grounded in fairness, inclusivity, and adaptability fosters confidence among economic actors and creates conditions for enduring growth.

5. Discussion and Conclusion

The view of the fourth industrial revolution has integrated the strategy of innovation with new rising technologies and their influences on the economy and societies, which promote information exchanges and applications, encouraging data-navigated transformation through digital technologies by using tangible and intangible resources (Enzmann & Moesli, 2022). Emerging technologies that are creating innovation, such as artificial intelligence (AI), robotics, the Internet of Things (IoT), blockchain, and other technologies, affect human lives through products and services. These technologies are transforming the agricultural sector, offering new opportunities for innovation, improving system efficiency and security, and benefiting human lives through advanced products and services (Aruna et al., 2023). Adopting new technologies such as AI, IoT, robotics, and blockchain can uphold agriculture with new ideas and approaches, improving the already existing agricultural systems, economies, and societies.

An essential requirement for developing countries such as Uzbekistan to join the Fourth or Fifth Industrial Revolution (4IR) is to speed up the invention and aggregation of organizational-level technological capabilities necessary for digital transformation accounting for the clarified set of human and organizational activities and resources, better revealing the new certainty of the revolution (Peerally et al., 2022). For organizations entering the fourth industrial revolution, ambidexterity, balancing innovation and exploitation, is essential for their agricultural capabilities to be more efficient in Uzbekistan (Mahmoo & Mubarik, 2020). The Helix Innovation Ecosystem also assists in advancing agriculture in Uzbekistan through a balanced integration of tangible and intangible elements. It possesses the required cultural and infrastructural baselines to promote effective changes and solve different economic, social, and environmental issues. By nurturing tangible and intangible elements, the Helix model can achieve a holistic and sustainable approach to innovation, fostering an environment that drives economic growth and addresses social and environmental challenges for Uzbekistan.

This research primarily depends on secondary data sources and broad policy perspectives, which are significant limitations as they do not reflect the realities of the finer agricultural sector in Uzbekistan. Additionally, the relationships between helix stakeholders, especially at the bottom level, need further investigation as they require extensive qualitative fieldwork. Investigations should concentrate on cross-sectional studies, in-depth studies of pilot projects, and comparisons with landlocked countries to develop the model and enhance its applicability in sustainable development policies.

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