

ECONOSCITECH INTEGRATION

ISSUE
5

INTERNATIONAL SCIENTIFIC
ELECTRONIC JOURNAL



**TASHKENT STATE
UNIVERSITY OF ECONOMICS**



**American University
of Technology**

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ISSN: 3060-5075



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THE SCIENTIFIC-POPULAR
ELECTRONIC JOURNAL
"ECONOSCITECH-INTEGRATION"
HAS BEEN REGISTERED UNDER
THE NUMBER C-5669651 BY THE
AGENCY FOR INFORMATION AND
MASS COMMUNICATIONS (AOKA)
OF THE REPUBLIC OF UZBEKISTAN,
EFFECTIVE FROM OCTOBER 9, 2024.

In accordance with Resolution No. 384/6 dated April 10, 2026, issued by the Presidium of the Supreme Attestation Commission under the Ministry of Higher Education, Science and Innovation of the Republic of Uzbekistan, this journal is included in the list of recommended international scientific publications for publishing the primary research findings of doctoral dissertations in the field of Economic Sciences.

Partners: Tashkent State University of Economics / American University of Technology in Tashkent (AUT)

Electronic publication, Issue 5. 374 pages.
Approved for publication on May, 2026.

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SUSTAINABLE REGIONAL SPECIALIZATION UNDER WATER SCARCITY: GLOBAL EXPERIENCE AND PROSPECTS FOR UZBEKISTAN

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Abstract. This article investigates how regional specialization can be redesigned under conditions of chronic water scarcity. It integrates classical comparative advantage theory, location theory, new economic geography, cluster development, institutional economics, and smart specialization with water stress, water footprint, virtual water, and water productivity approaches. The study applies systemic, comparative, structural, and institutional analysis to examine international experience from Israel, Australia, the Netherlands, and Spain, and relates the findings to Uzbekistan, with particular attention to the Bukhara region. The results demonstrate that sustainable specialization in water-constrained territories should not be evaluated solely by output volume or historical production patterns. Instead, it should be guided by value added, employment, export earnings, and ecological effects per cubic metre of water. The article proposes a diversified smart specialization model for Bukhara based on water-efficient horticulture, greenhouse production, food processing, tourism, education, digital services, and water technologies. Institutional reforms, digital water accounting, differentiated incentives, research–business cooperation, and strict monitoring are identified as prerequisites for effective implementation.

Keywords: regional specialization, water scarcity, water productivity, virtual water, water footprint, smart specialization, regional development, Bukhara region.

Аннотация. В статье исследуются направления устойчивого развития территориальной специализации в условиях хронического дефицита водных ресурсов. Теоретическая основа исследования объединяет концепции сравнительных преимуществ, размещения производства, новой экономической географии, кластерного развития, институциональной экономики и умной специализации с подходами водного стресса, водного следа, виртуальной воды и продуктивности воды. На основе системного, сравнительного, структурного и институционального анализа изучен опыт Израиля, Австралии, Нидерландов и Испании, а полученные выводы адаптированы к условиям Узбекистана, особенно Бухарской области. Установлено, что при выборе отраслевых приоритетов необходимо учитывать не только объём производства, но и добавленную стоимость, занятость, экспортную выручку и экологический эффект в расчёте на один кубический метр воды. Для Бухарской области предложена диверсифицированная модель умной специализации, основанная на водосберегающем садоводстве, тепличном хозяйстве, переработке пищевой продукции, туризме, образовании, цифровых услугах и водных технологиях. Институциональные реформы, цифровой учёт воды, дифференцированные стимулы, сотрудничество науки и бизнеса, а также строгий мониторинг определены в качестве необходимых условий эффективной реализации данной модели.

Ключевые слова: территориальная специализация, дефицит воды, продуктивность воды, виртуальная вода, водный след, умная специализация, региональное развитие, Бухарская область.

INTRODUCTION

Water scarcity is a structural economic constraint. Population growth, climate variability, urbanisation, and rising food demand are increasing pressure on limited freshwater resources. Consequently, regional policy must assess not only output and employment, but also the value created per unit of water.

Regional specialization is one of the central categories of regional economics. It explains how territories concentrate resources and capabilities in activities in which they possess relative advantages. Classical interpretations emphasised natural resources, labour productivity, and market access. Contemporary interpretations add knowledge, innovation, institutional quality, connectivity, and entrepreneurial discovery. Under conditions of water scarcity, however, the concept requires an additional criterion: the amount of economic and social value generated per unit of water used. This criterion changes the ranking of sectors and products because activities with large gross output may generate relatively low value added and high ecological pressure, while service industries and technologically advanced agriculture can produce substantially higher returns with lower water intensity.

This issue is especially important for Central Asia, where a dry climate, irrigated agriculture, ageing infrastructure, and regional disparities interact. In Uzbekistan, water-intensive production remains economically important, yet it increases vulnerability to drought and upstream supply changes. Therefore, Bukhara needs a specialization model that combines efficient agriculture with tourism, processing industries, and knowledge-intensive services.

The purpose of this article is to develop a policy-oriented framework for sustainable regional specialization under water scarcity and to identify strategic directions for Uzbekistan and the Bukhara region. The study addresses three questions. First, how should the theory of regional specialization be modified when water becomes a binding constraint? Second, what lessons can be learned from countries that have combined water efficiency with high-value production? Third, which institutional, technological, and sectoral priorities are most relevant for Bukhara? The contribution of the article lies in integrating regional economics with water-economy indicators and formulating an adaptation model that treats water scarcity not only as a limitation, but also as a stimulus for innovation and structural change.

LITERATURE REVIEW

The intellectual foundations of regional specialization originate from the classical theory of comparative advantage. Smith and Ricardo demonstrated that territories gain from concentrating on activities in which their relative productivity is higher. Although this logic remains relevant, it is insufficient for water-constrained regions because observed productivity may ignore resource depletion, environmental impacts, and the implicit export of scarce water. A product may be commercially competitive while remaining socially inefficient when its full water cost is taken into account.

Cluster theory emphasises the geographical concentration of interconnected firms, suppliers, research organisations, and public institutions. Porter (2000) argues that clusters improve productivity, innovation, and entrepreneurship by facilitating knowledge flows and specialised services. For water-scarce regions, cluster logic suggests that isolated investment in irrigation equipment is less effective than an integrated ecosystem involving technology providers, farmers, processors, universities, financial institutions, and water authorities. Such an ecosystem can support continuous improvement in crop selection, monitoring, water reuse, and processing.

The water-stress framework of Falkenmark and Rockström (2004) classifies territories according to renewable water availability per capita. Although this indicator does not capture every local condition, it provides a clear signal of when water begins to constrain economic activity. Water-footprint analysis, developed by Hoekstra and Chapagain (2008), extends the assessment from direct withdrawals to the full volume of blue, green, and grey water embedded in products and consumption. Mekonnen and Hoekstra (2016) demonstrated the global scale of severe water scarcity and highlighted the importance of seasonal and spatial variation.

Water productivity offers an operational indicator for policy. Molden (2007) defines it in physical terms, such as kilograms per cubic metre, or in economic terms, such as value added per cubic metre. Economic water productivity is more suitable for comparing agriculture, industry, and services because it provides a common measure. Nevertheless, a complete assessment should include employment, export revenue, tax contribution, and ecological impact. This multidimensional approach avoids selecting sectors solely because they generate high monetary returns while neglecting social inclusion or environmental sustainability (Table 1).

Table 1. Main theoretical approaches to regional specialization under water scarcity

Approach	Key scholars	Core proposition	Relevance for water-scarce regions
Comparative advantage	A. Smith; D. Ricardo	Specialize according to relative resource and labour productivity	Select activities with low water intensity and high value
New economic geography	P. Krugman; M. Fujita	Market size, transport costs and agglomeration shape concentration	Assess market access jointly with water infrastructure
Cluster approach	M. Porter	Co-location of firms and institutions raises productivity and innovation	Build agro-technology, tourism and service clusters
Smart specialization	D. Foray; P. McCann	Priorities should reflect unique local capabilities and discovery	Concentrate scarce water on activities with the highest return
Institutional approach	D. Acemoglu; A. Rodríguez-Pose	Governance quality and inclusive institutions shape outcomes	Ensure transparent allocation, tariffs, monitoring and accountability

Source: Compiled by the author based on the reviewed literature.

RESEARCH METHODOLOGY

The research uses a qualitative and analytical design that combines systemic, comparative, structural, and institutional methods. The systemic method is applied to interpret regional specialization as the interaction of natural resources, production structure, infrastructure, human capital, institutions, and innovation. The comparative method is used to examine the experience of Israel, Australia, the Netherlands, and Spain. The structural method identifies the relationship between sectoral composition and water intensity. The institutional method evaluates the rules, incentives, and organisations required for effective implementation.

The principal evaluation indicator is economic water productivity, expressed conceptually as the ratio of value added generated by an activity to the volume of water consumed. For public decision-making, this indicator should be supplemented by employment per cubic metre, export revenue per cubic metre, fiscal return per cubic metre, and a qualitative environmental-risk score. Because comparable and fully disaggregated regional data are limited, this article does not present econometric estimation. Instead, it develops a policy framework based on triangulation of the academic literature, international cases, and the structural characteristics of Bukhara.

The selection of international cases follows a most-different-systems logic. Israel represents technology-intensive water reuse and drip irrigation. Australia represents tradable water entitlements and basin-level allocation. The Netherlands represents closed greenhouse systems, advanced logistics, and high agricultural value despite limited land and water resources. Spain represents a combination of irrigation modernisation, differentiated pricing, and export-oriented Mediterranean agriculture. These cases differ in geography and governance, but they all demonstrate mechanisms relevant to water-efficient specialization.

ANALYSIS AND RESULTS

In a water-scarce economy, the shadow price of water changes comparative advantage. Activities that create more value and employment per cubic metre become preferable, while low-value water-intensive production creates opportunity costs for households, ecosystems, and higher-productivity sectors.

Israel demonstrates how technology, pricing, and institutional coordination can transform water scarcity into an innovation advantage. Drip irrigation, desalination, wastewater reuse, and precision agriculture are integrated with research institutions and export-oriented technology firms. The lesson is not that Bukhara should reproduce Israel's entire system, but that water-saving equipment should be linked to monitoring, agronomic advisory services, processing, and innovation finance.

Australia's Murray–Darling Basin experience highlights the role of clearly defined water entitlements, limits, and allocation mechanisms. Market-based instruments can help reallocate water toward higher-value users, but they require reliable measurement, enforcement, and protection of environmental flows. For Uzbekistan, the immediate lesson is the need for transparent limits and volumetric accounting before more complex allocation mechanisms are considered (Table 2).

Table 2. International mechanisms and their adaptation relevance for Bukhara

Country	Main mechanism	Priority activities	Observed strategic outcome	Lesson for Bukhara
Israel	Drip irrigation, reuse and desalination	Vegetables, flowers, agro-technology	High water productivity and technology exports	Develop a water-efficient agro-cluster and reuse systems
Australia	Water entitlements, caps and adaptive basin management	Horticulture, vineyards and high-value crops	Water shifts toward higher-value uses	Introduce reliable accounting, limits and economic incentives
Netherlands	Closed greenhouses and recirculating systems	Greenhouse vegetables and floriculture	High exports with low water use	Integrate greenhouses, science, processing and logistics
Spain	Drip irrigation, tariffs and cluster development	Olives, grapes, citrus and horticulture	Growth of export-oriented production	Restructure crops according to water productivity

Source: Compiled by the author from the comparative case analysis.

The analysis indicates that Bukhara requires diversified smart specialization. The first priority is water-efficient agriculture, including intensive horticulture, vineyards, medicinal plants, drought-resistant crops, and greenhouse production supported by drip irrigation, soil-moisture monitoring, and agronomic advisory services.

The second priority is the development of tourism and related services. Bukhara's cultural assets provide a comparative advantage that does not depend heavily on irrigation water. Sustainable tourism should include water-efficient hotels, heritage conservation, digital booking systems, local crafts, gastronomy, and professional training. A stronger link between tourism and local food processing can generate demand for high-value regional products.

Technological modernisation must be accompanied by institutional reform. District-level water-economic passports should combine water limits, land conditions, crop structure, infrastructure losses, and value-added indicators. Investment decisions should then prioritise projects that increase economic water productivity while remaining within basin limits.

Financial instruments should reward high water productivity and value added. Concessional loans, green finance, public-private partnerships, and performance-based subsidies should support metering, water reuse, efficient irrigation, cold storage, processing, and renewable energy. Support should depend on verified water savings rather than equipment purchases alone.

The overall result is a model of structural renewal rather than the abrupt abandonment of traditional sectors. Agriculture remains important, but its composition shifts from raw, water-intensive production toward efficient cultivation and processing. Industry shifts toward recycling and closed-water cycles. Services expand through tourism, education, health care, logistics, and digital exports. This combination improves resilience to drought while creating new competitive advantages.

CONCLUSION AND RECOMMENDATIONS

The study confirms that regional specialization under conditions of water scarcity must be assessed through a broader framework than historical production shares or gross output. Water becomes a binding economic factor that changes comparative advantage and requires the use of indicators such as value added, employment, export earnings, and environmental impact per cubic metre.

For the Bukhara region, the most appropriate pathway is a diversified smart specialization model based on water-efficient horticulture, vineyards, medicinal plants, greenhouse production, food processing, cultural tourism, education, digital services, and water technologies. This strategy should be implemented gradually and should preserve rural employment through training, finance, and improved market access.

Five recommendations are proposed: to introduce district-level water-economic passports; to link irrigation support to measured outcomes; to develop value-chain clusters for horticulture, processing, and tourism; to establish a regional water-technology platform involving universities and firms; and to publish annual indicators of water use, productivity, losses, and sectoral value added.

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Proofreader: Xondamir Ismoilov
Layout and Designer: Oloviddin Sobir ugli

2026. № 5

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