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COMPARATIVE DYNAMICS OF AGRICULTURAL SUPPORT AND GREEN TRANSFORMATION: EVIDENCE FROM FOUR COUNTRIES

Abduraimov Abdunabi

PhD student

Institute for Macroeconomic and Regional Studies

Email: abduraimovabdunabi57@gmail.com

ORCID: 0009-0006-7210-6404

Abstract. Global agricultural support exceeds US\$800 billion annually, yet its environmental effect remains contested. Using a descriptive, trend-based comparison of Israel, Türkiye, the United States, and China (2008–2023), this paper traces how government support (TSE) has co-evolved with organic farmland share, irrigation water-use efficiency (IAWUE), nitrogen intensity, and water stress. Four distinct national pathways emerge, including a rebound-effect pattern in Israel and a broadly favorable trajectory in China. Implications for Uzbekistan's subsidized, un-metered irrigation system and nascent organic sector are discussed.

Keywords: comparative agricultural policy; agricultural support trends; organic farming; water-use efficiency; rebound effect; green agroecology; Uzbekistan.

INTRODUCTION

Global agricultural support exceeds US\$800 billion annually, yet its contribution to environmentally sustainable development remains contested [1]. While government support is widely used to raise productivity and stabilize incomes, financial support alone does not necessarily improve green productivity or resource efficiency [2,3,4], raising the question of when support translates into genuine green transformation rather than intensified production.

This is especially relevant for water-saving technologies. Modern irrigation such as drip fertigation improves field-level water-use efficiency [5], yet the literature on the irrigation efficiency paradox and rebound effects shows that lower irrigation costs can induce farmers to expand cultivated area or production intensity, offsetting water savings [6,7,8]. Environmental effectiveness therefore depends on the institutional and regulatory conditions accompanying support, not only on its amount.

These issues are highly relevant for Uzbekistan, where agriculture depends heavily on irrigation and both water allocation and agricultural support involve substantial state involvement [11]. Expanding subsidies for water-saving technology may generate different outcomes depending on farmers' behavioral responses and regulatory mechanisms [12,13], while organic-sector development faces certification and governance constraints [14,15].

Despite growing literature on this topic, comparative evidence accounting for the diversity of national trajectories remains limited: the same level of support may be associated with very different sustainability outcomes across countries with different structures and institutions. This study addresses this gap by examining the co-evolution of agricultural support (TSE) and sustainability indicators in four structurally distinct countries — Israel (technology-intensive, water-scarce), Türkiye (structural agricultural transition), the United States (large, market-oriented), and China (rapid, high-volume support) — using a comparative trend-based approach rather than panel regression. Tracing country-level trajectories of TSE, organic farmland share, IAWUE, nitrogen intensity, and water stress makes it possible to identify differences in the direction, timing, and consistency of change, and to build country-specific profiles of support and green transformation.



The paper is organized as follows. Section 2 reviews the literature and conceptual framework. Section 3 presents the data and method. Section 4 presents empirical trends. Section 5 synthesizes country profiles and a typology of pathways, discussing implications for Uzbekistan. Section 6 concludes.

LITERATURE REVIEW

Agricultural support and green transformation

Government support for agriculture includes subsidies, market interventions, concessional finance, and public investment. Its environmental consequences depend less on aggregate size than on the design of individual instruments [16,17]: support for productivity-enhancing technology can improve resource use, while production-linked or input-intensive support may reinforce harmful practices. Total Support Estimate (TSE) is widely used to compare support levels across countries [2], but it measures scale rather than environmental orientation — a higher TSE cannot by itself indicate stronger green transformation. Evidence confirms that financial support does not automatically raise green total factor productivity, particularly where support is associated with intensive input use [3,4], suggesting that the composition and institutional implementation of support matter more than its aggregate volume.

Water-saving technologies and the irrigation efficiency paradox

Water-use efficiency is central to sustainable agriculture, especially in water-scarce regions. Technologies such as drip irrigation and fertigation reduce water losses at the farm level [5] and have become a common target of agricultural support. However, technical efficiency gains do not necessarily reduce aggregate water consumption: the irrigation efficiency paradox describes how cheaper or more productive irrigation can lead farmers to expand production intensity or irrigated area, offsetting farm-level savings through rebound effects [6,7,8]. Effective water policy therefore requires technological support to be paired with regulatory mechanisms — extraction limits, monitoring, and appropriate pricing or allocation [9,10]. Israel illustrates heavy state investment in precision irrigation under water scarcity [18], while China shows that support can substantially raise adoption of water-saving technology, particularly among less environmentally motivated farmers [19], though the ultimate environmental effect depends on the broader institutional and behavioral context.

Agricultural support and organic agriculture

Organic agriculture offers another pathway to green transformation by reducing reliance on synthetic inputs, but its expansion depends on certification systems, market access, institutional capacity, and incentives [14,15], not merely on farmers' willingness to adopt sustainable practices. Policy approaches vary substantially: European policy increasingly embeds explicit organic-land targets, while the United States relies more on market-oriented programs targeting specific outcomes [20]. This indicates that the relationship between support and organic agriculture depends on the institutional form of support rather than on aggregate support levels alone.

Country-specific policy pathways

Cross-country evidence shows substantial heterogeneity: Israel's water scarcity has driven a technology-intensive pathway centered on precision irrigation [18]; Türkiye reflects agricultural restructuring with gradual integration of environmental considerations; the United States incorporates environmental objectives through targeted programs rather than a unified green-support framework [20]; and China's large-scale intervention has accelerated water-saving technology adoption, with effects varying by farmer characteristics [19]. These cases underline the importance of national institutional and behavioral conditions in shaping the environmental consequences of support.

Research gap

Much of this literature examines individual instruments, countries, or outcomes in isolation, or uses panel regression to estimate a single average relationship between support and sustainability indicators. Such average coefficients can conceal sharply divergent national trajectories — support and outcomes may move together, in opposite directions, or independently across countries. This study contributes a complementary, trend-based approach: rather than imposing a common regression relationship, it traces the temporal co-evolution of TSE with organic farmland share, IAWUE, nitrogen intensity, and water stress across four structurally different countries, developing a comparative typology of green-transformation pathways and drawing context-sensitive implications for Uzbekistan.

RESEARCH METHODOLOGY

Theoretical Framework and Conceptual Scope

In this study, Green Agroecology is conceptualized not as a generic environmental concept, but through two specific technological and agrotechnical pillars: resource-saving irrigation technologies (primarily drip/



pressurized irrigation) and eco-friendly farming practices (organic farming). This precise scope allows for empirical measurement of how financial transfers (TSE) translate into concrete eco-technological shifts rather than abstract sustainability metrics.

Input–Output Efficiency and Environmental Load Framework

To capture the systemic impact of green agricultural transition, the variables are structured into an Input–Output Efficiency and Environmental Load framework:

- Input / Policy Leverage: Total Support Estimate (TSE, % of GDP) representing total state financial transfers.
- Technology / Adoption Rate: Organic Farmland Share (Organic, % of total agricultural land), proxying irrigation-technology and eco-practice adoption.
- Output Efficiency (Eco-Productivity): Irrigation-adjusted Water-Use Efficiency (IAWUE, agricultural output in US\$ per 1 m³ of water used), evaluating the economic return of every unit of water consumed.
- Environmental Load / Stress: Nitrogen Fertilizer Intensity (N_Intensity, kg N/ha), measuring chemical runoff risk, and Water Stress (WS, % of renewable freshwater extracted), assessing basin-level pressure.

This framework directly motivates the comparative method adopted below: rather than collapsing Input, Technology, Output, and Environmental Load indicators into a single regression coefficient, each is traced separately for each country, so that cases in which policy leverage (TSE) rises alongside output efficiency (IAWUE) without a corresponding reduction in environmental load (water stress) — the empirical signature of a rebound effect — can be identified directly.

Data Sources and Sample

The analysis covers four countries (Israel, Türkiye, the United States, China) annually from 2008 to 2023, drawing on the OECD Total Support Estimate database [25], FAOSTAT [22], FAO AQUASTAT [23], and OECD organic-agriculture land-use statistics [24]. These countries were chosen for their structurally distinct combinations of policy leverage, technology adoption, and environmental load, allowing the framework to be applied across genuinely contrasting national systems.

Descriptive Method

Rather than regression, the method is descriptive: year-by-year trends are plotted for each indicator to compare trajectories and turning points; cumulative percentage change (2008–2023) summarizes the net direction of change for each country–indicator pair; and these trends are synthesized into country profiles cross-checked against known policy history, so that patterns — including possible rebound-effect signatures — are interpreted in light of actual events rather than read mechanically off the data.

ANALYSIS AND RESULTS

Policy Leverage: Agricultural Support (TSE)

Figure 1 shows Türkiye recording by far the highest support in the early period, peaking at 4.4% of GDP in 2010 before falling to about 1% by 2022 (–58%). China's TSE rose steadily from 1.1% to a peak near 2.4% before easing to 1.6% (+44%). Israel and the United States maintained low, stable support throughout, at or below 0.6% of GDP — the United States ending with the lowest TSE-to-GDP ratio of the four (0.43% in 2023), contrary to common assumptions of heavy U.S. farm subsidization (Figure 1).

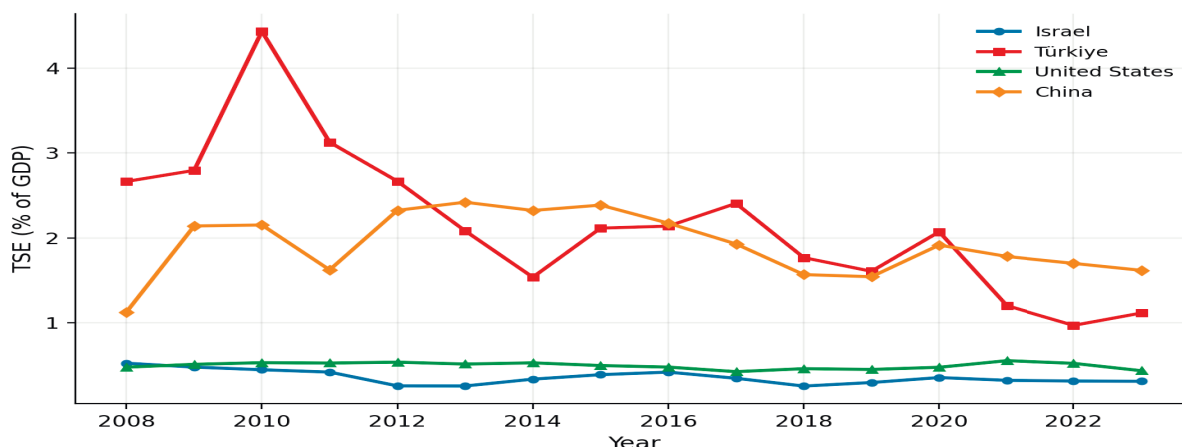


Figure 1. Total Support Estimate (TSE, % of GDP), 2008–2023, [25]



Technology Adoption: Organic farmland share

Figure 2 shows organic land expanding in three of the four countries. Türkiye records the steepest, most sustained increase (+110%), overtaking the others by the mid-2010s. China's organic share also rose sharply (+94%); the United States increased more modestly (+26%). Israel is the outlier: despite starting with the second-highest organic share, it declined 25.5%, ending with the smallest organic sector — consistent with certification and governance barriers documented elsewhere [14,15] (Figure 2).

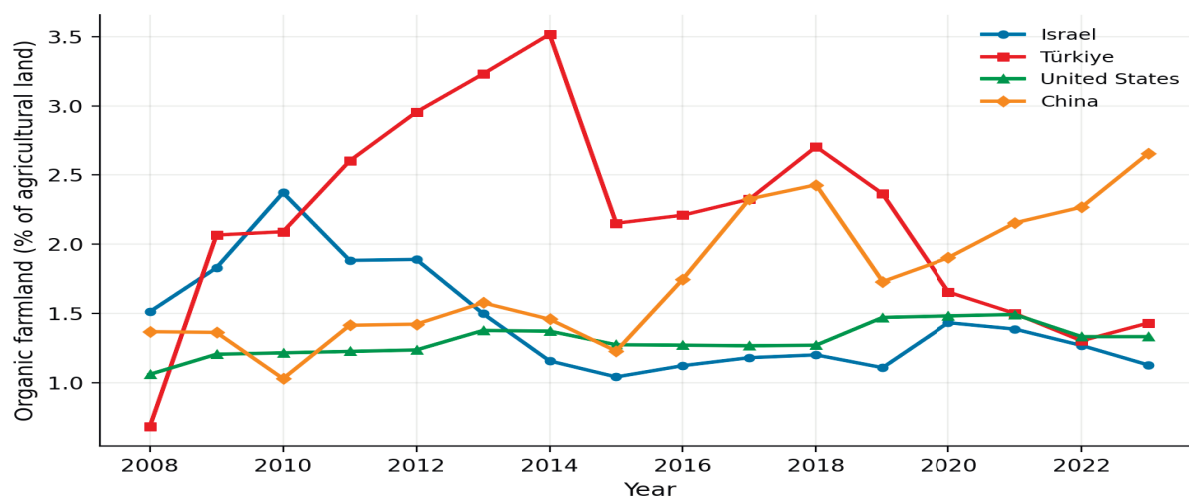


Figure 2. Organic Farmland Share
(% of agricultural land), 2008–2023, [24]

Output Efficiency: Irrigation water-use efficiency (IAWUE)

Figure 3 shows Israel maintaining by far the highest water-use efficiency throughout, 5–12 times the other countries, even as its own level drifted down (–13.5%). China more than doubled IAWUE (+128.8%), closing much of the gap with Israel. The United States improved modestly (+27.5%). Türkiye's IAWUE fell 56.8% — the steepest decline of any indicator in this study (Figure 3).

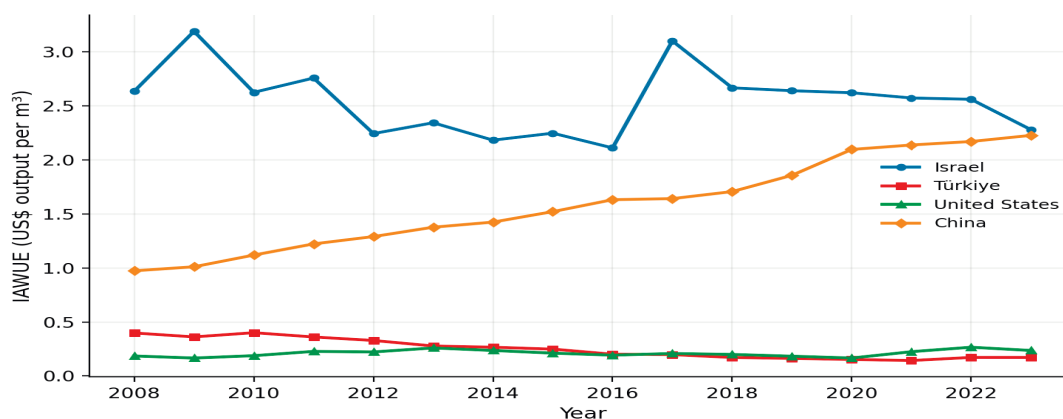


Figure 3. Irrigation Water-Use Efficiency
(US\$ output per m³), 2008–2023, [23]

Environmental Load: Nitrogen fertilizer intensity

Figure 4 shows China's nitrogen intensity far exceeding the others throughout (over 190 kg N/ha), though declining modestly (–9.5%), consistent with policy efforts to curb over-fertilization. Israel's nitrogen use fell further (–35.4%). The United States and, especially, Türkiye moved the opposite way, with Türkiye's intensity rising 75.8% alongside its organic expansion, suggesting the two trends occur in different segments of Turkish agriculture (Figure 4).

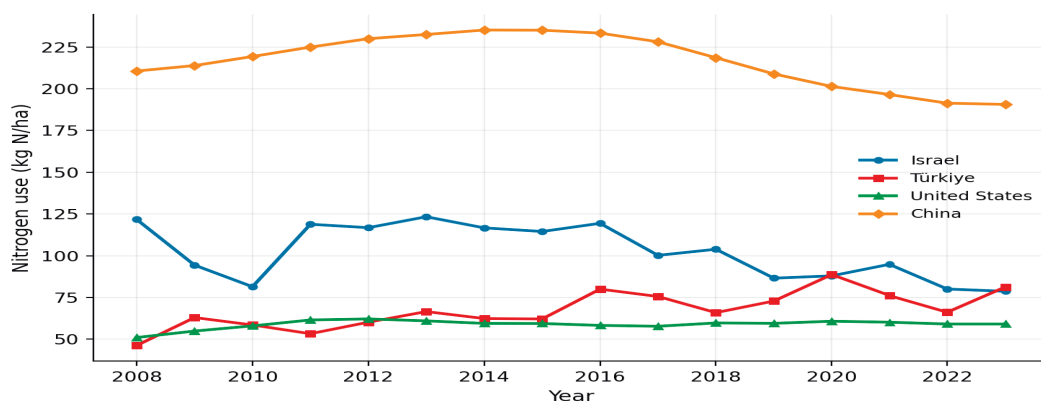


Figure 4. Nitrogen Fertilizer Intensity (kg N/ha), 2008–2023, [22]

Environmental Load: Water stress

Figure 5 shows Israel under persistently extreme water stress (above 110% every year), essentially unchanged (+1.4%) despite its improving IAWUE — the highest efficiency in the sample paired with stagnant environmental load, precisely the signature the rebound-effect literature predicts [6,7,8]. Türkiye's water stress rose sharply (+53.6%), moving toward growing scarcity alongside declining IAWUE — the most concerning pattern observed. The United States and China both improved mildly (−12.5%, −3.2%) (Figure 5).

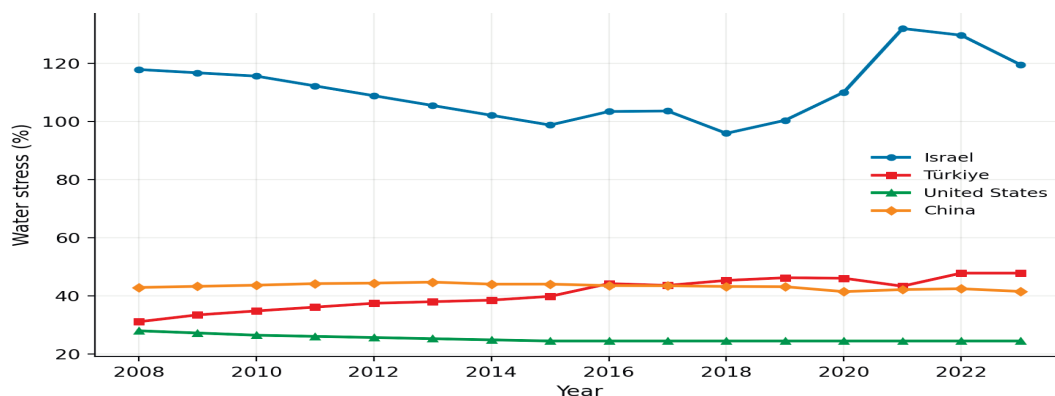


Figure 5. Water Stress (% of renewable freshwater withdrawn), 2008–2023, [23]

Synthesis: cumulative change across indicators

Figure 2 summarizes cumulative change across all five indicators. China's bars are positive across every efficiency and organic indicator while nitrogen fell — the most broadly favorable pattern. Türkiye shows the sharpest contradiction: strong organic growth alongside strongly negative efficiency and rising water stress. Israel's bars are negative across support, organic share, efficiency, and nitrogen, reflecting contracting policy intensity even as its efficiency level remains highest and its water stress remains unrelieved. The United States shows the most modest movement on every indicator (Figure 6).

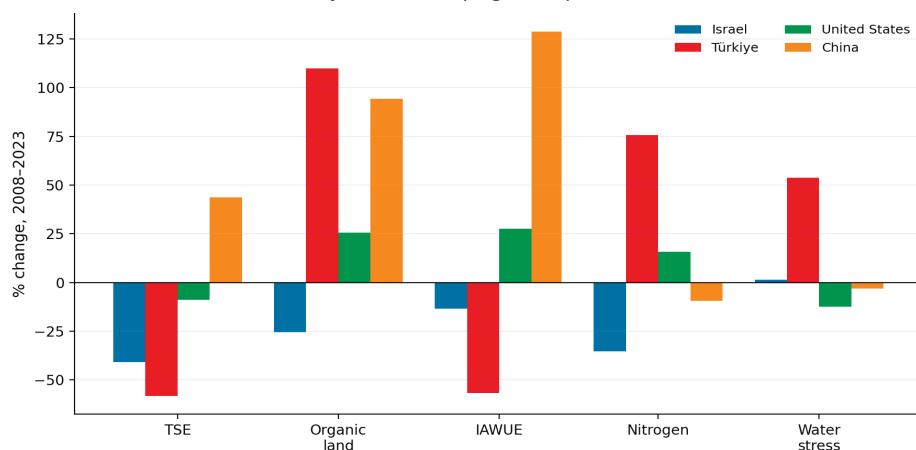


Figure 6. Cumulative Change in Key Indicators by Country, 2008–2023.



Country Profiles and a Typology of Green Transformation Pathways

Israel — high efficiency, contracting policy intensity, and an unresolved rebound signature

Israel's profile combines water-use efficiency that is not merely highest but categorically different in scale, consistent with its reputation as a global leader in drip-irrigation and precision agriculture [18]. Yet this efficiency has not reduced environmental load: TSE, organic share, and nitrogen use are all declining, while water stress — already highest in the sample — is not improving. This is consistent with a rebound-effect mechanism: field-level efficiency gains can be offset by expanded irrigated area or cropping intensity absent binding extraction caps [6,7,8]. Israel's pathway is best described as mature-system consolidation with an unresolved rebound signature.

Türkiye — organic expansion with a widening efficiency gap

Türkiye combines the fastest organic growth with the steepest declines in TSE and water-use efficiency, and the largest rise in water stress. This is not a simple success story: organic expansion appears to occur in parallel with, rather than as part of, broader efficiency improvement, and rising nitrogen intensity suggests the two trends occur in different parts of the sector. Türkiye's pathway is best described as partial and uneven transition — progress on one margin accompanied by deterioration on another, easily overlooked if only organic-growth figures are reported.

United States — a low-intensity, gradually improving system

Contrary to the common assumption of heavy U.S. subsidization, its TSE-to-GDP ratio is the lowest of the four countries and among the most stable. Organic share, water-use efficiency, and water stress all show modest, steady improvement, while nitrogen use rose only slightly. This low-intensity gradualism plausibly reflects a support system weighted toward market-based and general-services instruments [9,10] rather than large, volatile direct payments.

China — the most broadly positive trajectory, from a high-intensity base

China combines rising support with the fastest efficiency gains, continued organic growth, and declining — though still highest — nitrogen intensity. Unlike Türkiye, China's improvements are consistent across indicators, suggesting its water-saving subsidies have been paired with sufficient regulatory constraint to avoid Israel's rebound pattern. China's pathway is best described as high-intensity convergence, consistent with its documented policy emphasis on water-saving irrigation adoption [19] and organic-sector development.

This comparison shows that government support is not uniformly associated with sustainability outcomes, and that rising output efficiency (IAWUE) does not by itself guarantee reduced environmental load: Israel's trajectory shows the two diverging for an extended period, consistent with a rebound mechanism through which efficiency-driven savings induce expanded water use elsewhere in the basin [6,7,8].

This is directly relevant for Uzbekistan, where agricultural water remains largely un-metered and heavily state-funded [11], and high transaction costs hinder market-based allocation [13]. Expanding subsidies for water-saving irrigation under these conditions risks reproducing Israel's pattern — improved field-level efficiency without reduced basin-level water stress — rather than delivering true resource savings [12]. China's and Israel's profiles are the most relevant reference points for Uzbekistan's own irrigation-subsidy program, expanded rapidly since 2017 [21]: China suggests sustained support can generate simultaneous progress when paired with adequate regulatory structure; Israel is the cautionary complement — without extraction caps and metering, efficiency subsidies alone are unlikely to relieve structural water scarcity.

Türkiye's experience further warns against treating organic growth as evidence of broad sustainability progress. Uzbekistan's own organic-cotton ambitions already face certification and governance barriers [14,15]; these should be pursued alongside — not instead of — continued attention to water metering, volume caps, and use efficiency, to avoid Türkiye's uneven pattern.

CONCLUSION AND RECOMMENDATIONS

Tracing four countries' trajectories individually, rather than estimating only an average panel relationship, reveals heterogeneity that regression coefficients alone cannot convey. The United States, often assumed heavily subsidized, shows the lowest support-to-GDP ratio; Israel's unmatched efficiency coexists with a contracting organic sector and unrelieved water stress, consistent with a rebound effect; Türkiye's rapid organic expansion accompanies the sharpest efficiency decline; and China shows the most broadly favorable trajectory. These four pathways — mature-system consolidation with an unresolved rebound signature, partial and uneven transition, low-intensity gradualism, and high-intensity convergence — offer a typology that can inform how countries such as Uzbekistan benchmark their agricultural support strategy, cautioning against expanding irrigation-efficiency subsidies without complementary metering and volume caps, and against reading organic growth alone as evidence of broad sustainability progress.



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El.Pochta: sq143235@gmail.com

Bot: @iqtisodiyot_77

Tel.: 93 718 40 07

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