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The Hydro-Political Economy of Jordanian Agriculture: Navigating Scarcity, Efficiency Paradoxes, and the Imperative of a Just Transition

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Abstract

This study provides an integrated hydro-political economy diagnosis based on rigorous official data from the Jordan Valley Authority and the Ministry of Water and Irrigation spanning 2019-2024. Empirical evidence confirms three critical findings: 1) Structural Imbalance: Agricultural irrigation dominates the basin, consuming 45% (210 million cubic meters) of the 2023 baseline managed water budget (totaling 462 MCM), with subsequent analysis reflecting evolving pressures through Q3 2025. 2) Operational Challenges: Key reservoirs operate at critical operational deficits, exemplified by the combined 40.1% storage efficiency for the five core dams. 3) Efficiency Paradox: The system is trapped in the Jevons Paradox, where policy focus on technical irrigation efficiency has fueled "vertical intensification" toward high-value, water-intensive crops, exacerbating basin-wide demand. The crisis is compounded by unregulated groundwater abstraction, particularly the overdraft in major basins. Findings, updated with Q3 2025 metrics, reveal that while the overall national unemployment rate declined to 16.2%, female unemployment among Jordanians remains acute at 33.9%, adding a layer of socio-economic vulnerability to the resource crisis. The causal mechanism for this depletion involves complex socio-political dynamics impacting monitoring enforcement. Escaping this situation requires a Just Transition strategy coupled with firm volumetric caps, ensuring long-term sustainability without sacrificing rural livelihoods.

Keywords

Hydro-Political Economy, Jevons Paradox, Water Scarcity, Jordan Valley, Water Budget, Systemic Losses, Non-Revenue Water, WEF Nexus, Just

Transition

1. Introduction

The Hashemite Kingdom of Jordan is in the grip of an existential water crisis. Consistently ranked as one of the most water-stressed nations globally, its annual per capita availability of renewable freshwater stands at approximately 61 cubic meters (m^3) (MWI, 2023b). This is in alarming contrast to the internationally recognized threshold of "absolute water scarcity" set at 500 m^3 per capita (Murad, 2023; MWI, 2024). The crisis is a fundamental structural constraint on Jordan's economic development. The economy faces significant structural constraints; as of December 2025, while the national unemployment rate (residents) has declined to 16.2%, internal structural challenges for Jordanian citizens remain acute. The unemployment rate for Jordanians stands at 21.4% (Q3 2025), with female unemployment reaching 33.9% (DoS, 2025). Crucially, 59.1% of all unemployed Jordanians hold a secondary education degree or higher (DoS, 2025), while PhD activity rates reach 79.7%, highlighting the urgency of reforms that strengthen competitiveness and address the interconnected challenges of water, energy, and food security (World Bank, 2025). This convergence has pushed Jordan's water system beyond its natural limits, forcing an unsustainable over-extraction of its groundwater aquifers, which are being depleted at twice their safe yield (Murad, 2023; Radaideh, 2022).

Despite the richness of existing literature on this crisis, a significant research gap exists in the lack of an integrated analysis that systematically connects technical water policies with the underlying political economy and the behavioral paradoxes that render them ineffective. For example, technical analyses of irrigation efficiency rarely account for the structural influence of large landowners, while political economy studies often fail to quantify the hydrological consequences of complex governance challenges.

This paper's unique contribution is an integrated hydro-political economy analysis. It applies two key theoretical frameworks—the Jevons Paradox and the concept of a Just Transition—to the Jordanian agricultural sector (Sears et al., 2018). By applying the Just Transition framework, the paper shifts the focus from purely technical or economic solutions to a holistic approach that prioritizes social equity and the protection of vulnerable livelihoods during the necessary transformation of the agricultural sector (ActionAid, 2019). This integrated approach aims to deconstruct the dominant narrative of "absolute scarcity" and reframe the crisis as a "management-induced reality" (Mustafa et al., 2016), where the solutions must be as much social and political as they are technical.

2. Methodology

This paper employs an integrated analytical methodology, combining the quantitative analysis of the data extracted from the primary data: Official documents (Jordan Valley Authority Annual Report 2024, Water Budget Report 2023, National Water Strategy 2023-2040; MWI, 2023a), reports from International Organizations (World Bank, UNICEF), with a comprehensive and critical review of secondary data from peer-reviewed academic literature (Yorke, 2013; ActionAid, 2019), to contextualize and interpret the results.

2.1. Study Area

The study area is the Jordan Valley Administrative Area (JVAA) shown in **Figure 1**, which stretches across the Jordanian territory from the northern border through Ghor to Wadi Arraba. This unified geographic scope reflects the overall operational authority granted to the joint entity for integrated water resources development and irrigation management throughout the region. The primary objective is to evaluate the water balance, assess the performance of key storage infrastructure, and diagnose the principal drivers of water stress, with a specific focus on System Losses (Non-Revenue Water, NRW).

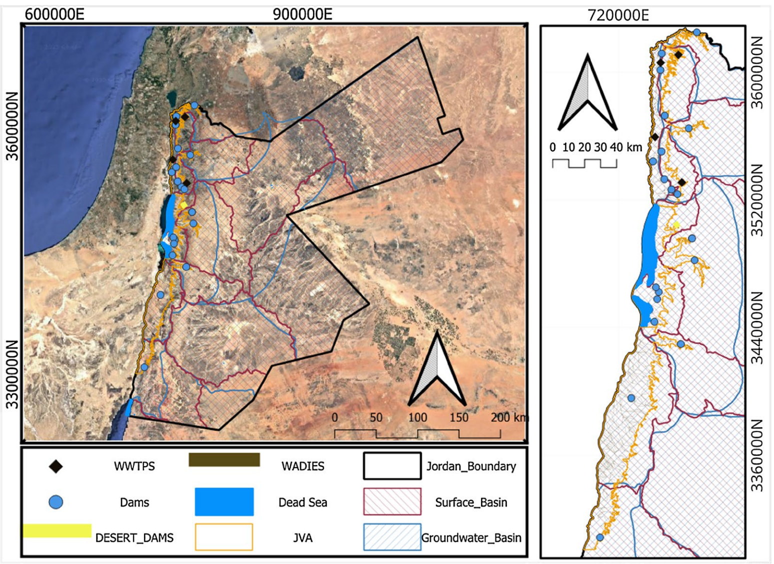

Figure 1. The Jordan Valley Administrative area of the Jordan Valley Authority (JVA).

2.2. Empirical Data and Analytical Methods

Logic and Calculation for Inflow Identification (2023) in **Table 1**, Comprehensive Water Balance Matrix (2023) in **Table 2**, The Statistical Summary of Water Managed Budget (2023) in **Table 3**, and the Operational Performance data in **Table 4** are constructed from final, verified official JVA/MWI figures (JVA, 2024; MWI, 2023a). The analysis utilizes four interconnected visualizations (**Figures 2-5**) to provide empirical proof for the policy paradoxes:

- **Figure 2:** The "Political Economy Trap" (R1). A System Dynamics Causal Loop Diagram (CLD) to establish the theoretical framework showing how scarcity is reinforced by governance choices.

- **Figure 3:** Historical Land-Use Modeling (1990-2023). Provides empirical evidence that the crisis is driven by "vertical intensification" (Al-Rkebat, **2025**). Visualization Tool: Stacked Area Chart (Python Matplotlib).
- **Figure 4:** Water Balance Sankey Diagram (2024). constructed to quantify the scale of agricultural dominance and systemic losses. Visualization Tool: SankeyMATIC (SVG).
- **Figure 5:** Dam Operational Performance. Calculates the Storage Efficiency (%), which is equal to (Actual Storage/Design Capacity) × 100 for key dams including King Talal, Karameh, Wadi Al-Arab, Kafrein, and Wadi Shuaib. Visualization Tool: Stacked Bar Chart (Python Matplotlib).

3. Results

The research asserts that the crisis is fundamentally driven by internal political economy, characterized by a Reinforcing Causal Loop (R1), visually represented in **Figure 2**. This framework establishes how scarcity is engineered and reinforced by governance choices. Involves chronic water shortages increasing socio-political pressures, which drive commitment toward large, capital-intensive supply enhancement projects. This supply-side bias leads to a chronic lack of investment in demand management, allowing water consumption to rise unsustainably.

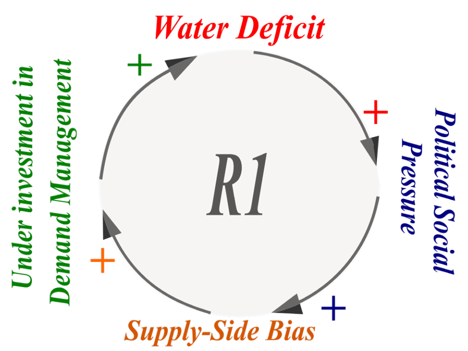

Figure 2. The "Political Economy Trap" causal loop diagram (R1).

The causal sequence of the Political Economy Trap (R1) unfolds as follows:

- Chronic water shortages increase political and social pressures, evidenced by operational challenges such as the **125** MCM in System Losses (NRW) within the JVA network (**Table 3**) and 40.1% dam efficiency gap (**Table 4**).
- This pressure drives political commitment toward large, capital-intensive supply enhancement projects, such as major dams or deep transport systems (MWI, 2023a, 2023b).
- This supply-side bias leads to a chronic lack of investment in demand management (e.g., digitalization, where a 60% funding gap exists for the IT Roadmap (MWI/JVA, 2025).
- Structural gaps allow water consumption to rise unsustainably, Regarding groundwater depletion, the **2023** Water Budget Report (MWI, 2023a) indicates that the total Aquifer Overdraft in Jordan amounted to 291.5 MCM and 41

MCM of aquifer: (Jordan Valley, Side Valleys, Northern Araba Valley, and Southern Araba Valley) that were adopted in the water balance matrix managed by JVA (2023) (**Table 3**).

- **Table 1** defines the methodological formulas used to determine the specific inflow volume for each segment before applying loss factors.
- **Table 2** presents the system equilibrium where Total Inflow matches the sum of Net Outflow and Calculated Losses.
- **Table 3** provides a summary of the percentage contribution of each source and use relative to the total managed budget.

Table 1. Logic and calculation for inflow identification (2023).

Flow Segment	Allocation Logic (Formula)	2023 Value (MCM)	Justification
Surface → Transfers	Observed Direct Abstraction	89	Fixed monitoring of King Abdullah Canal (KAC).
Surface → Drinking	Observed Municipal Intake	40	Direct intake for treatment plants from surface sources.
Surface → Irrigation	Total Surface – (Transfers + Drinking)	125	Residual surface water diverted for agricultural use.
Groundwater → Drinking	(Required $D/I/T$) – Net Surface Supply	21	Complementary groundwater to meet municipal deficits.
Groundwater → Irrigation	Total Groundwater – GW Drinking	31	Remaining groundwater utilized for local farm irrigation.
TWW → Irrigation	Total Observed TWW Supply	156	100% of treated wastewater allocated to irrigation.

Table 2. Comprehensive water balance matrix (2023).

Indicator	Inflow (MCM)	Net Outflow (MCM)	Loss Equation	Value (MCM)
Surface → Transfers	89	87	Inflow - 2	2
Surface → Drinking	40	27	Inflow - 13	13
Surface → Irrigation	125	84	Inflow - 41	41
Groundwater → Drinking	21	14	Inflow - 7	7
Groundwater → Irrigation	31	21	Inflow - 10	10
TWW → Irrigation	156	105	Inflow - 51	51
Grand Total	462	337	System Loss (NRW)	125

Table 3. Statistical summary of water managed budget (2023).

Indicator	Volume (MCM)	% of Total (462 MCM)	Primary Source
Total Inflow	462	100%	Mass Balance Check
Surface Water	254	55%	MWI, 2023a

Continued

Groundwater	52	11%	Calculated Complement
Treated Wastewater	156	34%	MWI, 2023a
Total Outflow/Uses	462	100%	Mass Balance Check
Irrigation (IRR)	210	45%	JVA, 2024
Drinking (D/I/T)	40	9%	JVA, 2024
Transfers Out	87	19%	JVA, 2024
System Losses (NRW)	125	27%	Calculated (27% rate), Jordan Times, 2025

Table 4. Critical dam operational performance (end of 2024).

Dam	Design Capacity (MCM)	Actual Storage (MCM)	Storage Efficiency (%)
King Talal	75.0	31.11	41.5
Karameh	55.0	22.61	41.1
Wadi Al-Arab	16.8	5.54	33.0
Kafrein	8.5	3.45	40.6
Wadi Shuaib	1.7	0.25	14.7
Total (Core JV Dams)	157.0	62.96	40.1

3.1. Structural Imbalance and the Jevons Paradox

The rapid transformation of land use provides strong empirical evidence for the Jevons Paradox. **Figure 3** demonstrates the mechanism of "vertical intensification": The area for lower-value, less water-intensive crops has fallen sharply, while the area for high-value, high-water-demand crops (Protected Vegetables and Fruit Trees) has surged dramatically (Al-Rkebat, 2025). This pattern confirms the Jevons Paradox Effect: Efficiency gains from micro-irrigation technologies were not translated into basin-wide conservation. Instead, economic savings were reinvested to maximize profitability by cultivating more water-intensive crops, ultimately exacerbating the basin's total water demand (Gomez & Gutierrez, 2011).

3.2. Water Balance and Systemic Losses

The structural imbalance is quantitatively confirmed by the water budget (**Figure 4**). Irrigation consumes ~210 MCM (45%) of the 2023 baseline managed water budget of ~462 MCM (JVA, 2024). A critical proxy for governance challenges is the massive aquifer overdraft. The successful integration of TWW manages ~156 MCM; however, the expansion in unregulated abstraction volumes risks neutralizing the benefits of these non-conventional sources.

In addition to groundwater challenges, the system suffers significant losses in conveyance and distribution requirements. Total System Losses (NRW) are strictly

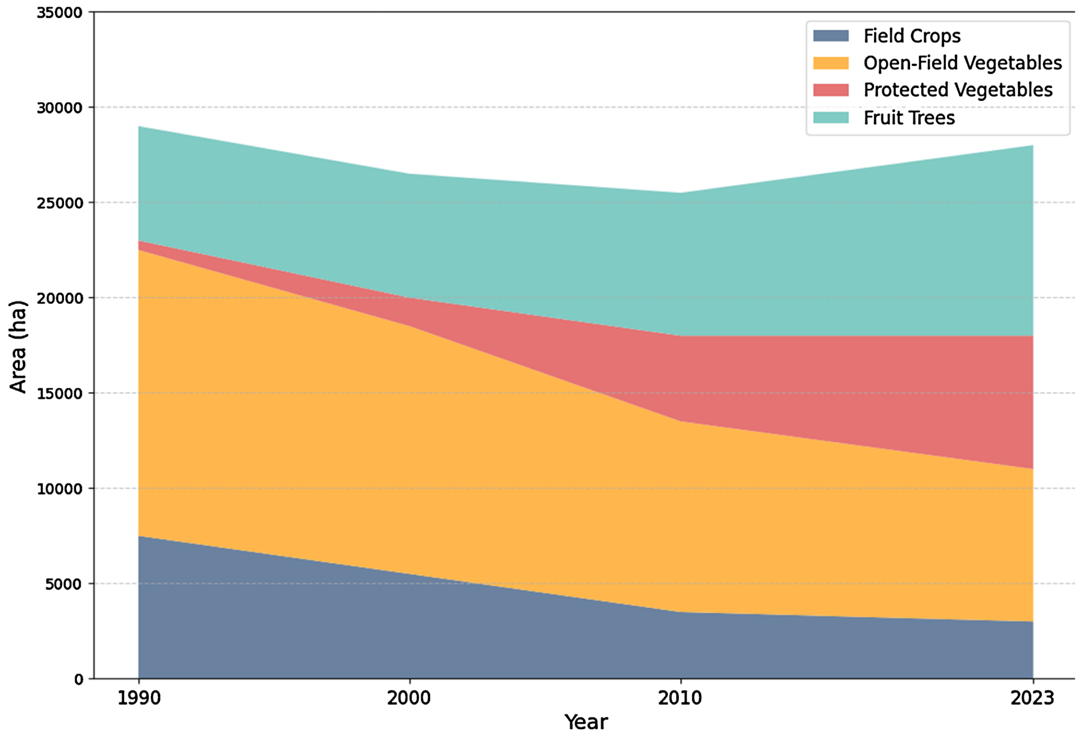

Figure 3. Transformation of agricultural land use in the Jordan Valley (1990-2023).

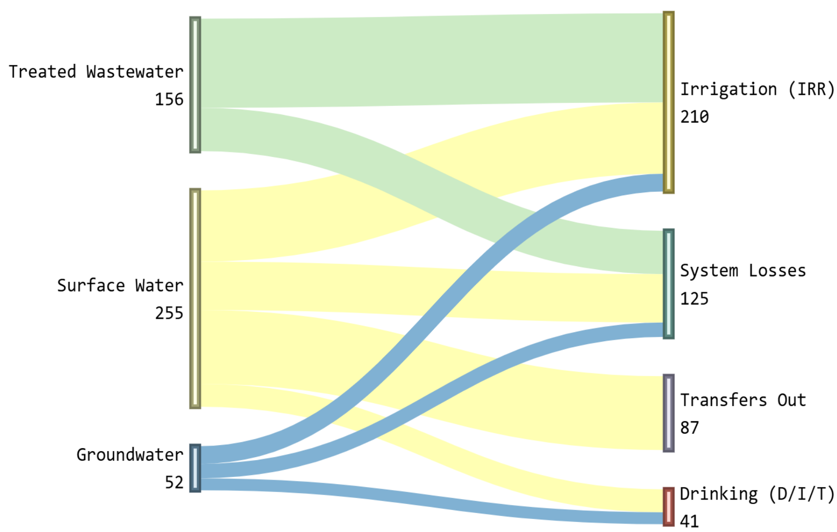

Figure 4. Water balance Sankey diagram (2024).

reported at 125 MCM, ~70% of which are administrative assaults. The Ministry of Water and Irrigation indicated that the backfilling of the violating wells contributed to saving about 62 MCM of groundwater during the years 2023/2024, in addition to saving 2.341 MCM during the month of October 2024 (Jordan Times, 2024). This volume is central to the Water-Energy-Food (WEF) Nexus crisis, as it represents not only wasted water but also wasted energy and capital, contributing directly to the fiscal unsustainability of the JVA (MWI/JVA, 2025).

3.3. Operational Capacity and Infrastructure Challenges

The analysis of the five core dams in the Jordan Valley reveals a combined operational efficiency of only 40.1% (**Figure 5**). This indicates a significant gap between the design capacity (157 MCM) and actual storage (62.96 MCM). The Karameh Dam, with a storage efficiency of 41.1%, serves as a primary case study for these challenges. Historical assessments indicate that its operational capacity has been constrained by complex geological and hydrological conditions inherent to its location (Salameh, 2004).

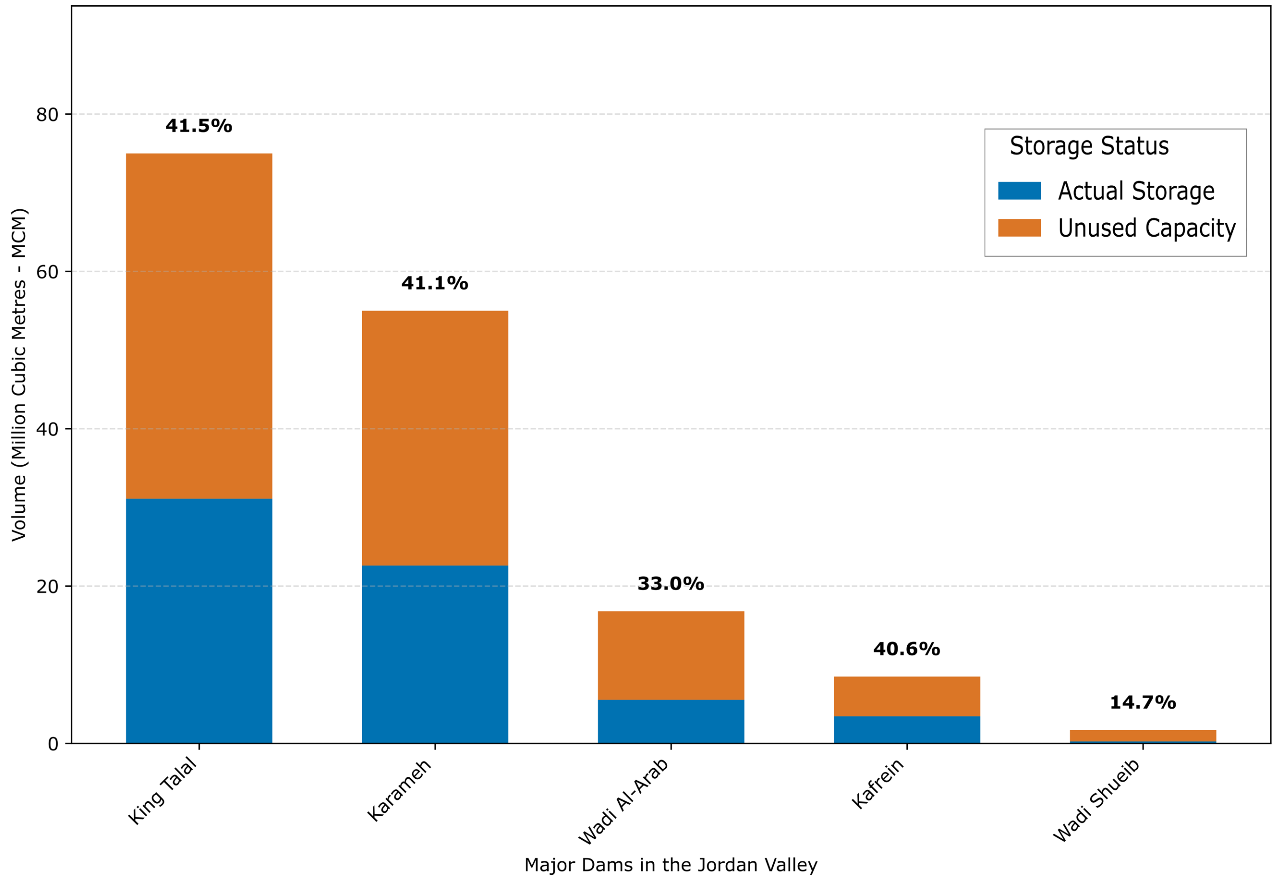

Figure 5. Major dams in the Jordan Valley: actual storage vs. capacity deficit (MCM).

4. Discussion

4.1. The Political Economy Trap (R1) in Practice

The water crisis is structurally reinforced by the R1 Causal Loop (**Figure 2**), The combined challenges of the 40.1% dams storage efficiency (infrastructure operational gap) and the documented aquifer overdraft directly constitute the Water Deficit phase, generating socio-political pressure. This pressure historically reinforces a Supply-Side Bias by making large, visible capital projects—such as the National Conveyance Project—politically and strategically paramount. This focus, while essential for security, can inadvertently lead to a funding gap in Demand Management and maintenance. This is evidenced by the 125 MCM in NRW losses (**Table 2**). The utility's fiscal dependency (64% subsidy) reinforces the trap, as structurally complex demand management reforms are constantly inhibited by the risk of institutional and operational disruption that could jeopardize essential funding (OECD, 2014).

4.2. Resource Consolidation Dynamics and the Mechanism of Aquifer Overdraft

The persistence of the crisis is directly linked to the systemic governance challenges. The 40.1% operational gap in core dams is a symptom of the immense pressure on existing infrastructure. The mechanism of aquifer overdraft (estimated at 41 MCM of core aquifers that were adopted in the water balance matrix managed by JVA (2023)) reflects the complexity of managing unregulated abstraction. This occurs through two primary avenues: (1) Institutional Weakness and Regulatory Deficit, where the JVA operates with structural deficits due to deep fiscal dependency; and (2) Enforcement Resistance by commercially dominant actors. The combination of structurally mediated resistance and institutional weakness leads to the non-deployment of digital governance tools. The sustainability of Jordan's primary water supply is fundamentally threatened by over-exploitation, which has led to a significant loss of saturated thickness in aquifers and the widespread drying of natural springs (Radaideh, 2022).

4.3. The WEF Nexus Crisis

The 125 MCM NRW loss is central to the Water-Energy-Food (WEF) Nexus crisis. Water insecurity is intrinsically linked to energy and fiscal stability. Modernizing water networks and integrating renewable energy into desalination are critical to avoiding socio-economic consequences (Belhaj, 2025). This physical loss corresponds to significant Avoided Operational Costs (O&M) for the water utility. The basis for this is that the high energy intensity of Jordan's water sector consumes ~15% of national electricity, reducing NRW is not merely a water-saving measure but a fiscal necessity infrastructure rehabilitation and breaking the cycle of fiscal dependency (OECD, 2014).

5. Conclusion and the Just Transition Pathway

5.1. Defining the Just Transition for Jordan Valley Agriculture

To address these systemic challenges, policy must embrace a Just Transition pathway for the agricultural sector (ActionAid, 2019). This framework is essential for achieving hydrological sustainability while mitigating socioeconomic impacts.

A Just Transition strategy should include: 1) Volumetric Management: Implementing transparent volumetric monitoring tied to agronomic requirements (ETc) to ensure equitable distribution; 2) Productivity-Based Incentives: Transitioning toward economic support models that maximizing Water Productivity (crop value per drop) rather than just consumption volume (World Bank, 2022); and 3) Social Safety Mechanisms: Enhancing micro-financing and technical retraining initiatives for small and marginalized farmers (ActionAid, 2019) to maintain rural livelihoods and prevent further socioeconomic inequality.

5.2. Governance and Digital Integration Imperatives

The acceleration of digital integration is a strategic necessity. Mandatory implementation of the National Water Information System (NWIS), Enterprise Resource Planning (ERP), and Geographic Information Systems (GIS) is essential for real-time monitoring and data-driven decision-making. Furthermore, expanding renewable energy investment in water pumping infrastructure is critical. This mitigates high operational energy overheads and reduces the sector's fiscal liabilities, contributing to the long-term financial sustainability of the JVA.

5.3. Safety, Quality, and Long-Term Compliance

The successful integration of TWW into the water budget is a landmark achievement for Jordan's water security. Continuous commitment to the Jordanian Standard (JS 893/2021) and international WHO/FAO guidelines is vital to guarantee microbial and chemical safety (Abu-Awwad, 2021). Maintaining these high standards ensures that water reuse remains a safe, sustainable, and strategic pillar for food security and public health.

In synthesis, while the Jordan Valley faces profound hydrological challenges, the crisis is manageable through coordinated political and technical commitment. By addressing structural governance constraints and implementing a Just Transition strategy, Jordan can secure a resilient and sustainable water future for its agricultural heartland.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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