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MANAGERIAL PERFORMANCE OF A WATER USER ASSOCIATION UNDER GOVERNANCE REFORM AND DROUGHT: EVIDENCE FROM THE İNÖNÜ OPEN-CHANNEL IRRIGATION SCHEME (2012–2024)

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Abstract: Water scarcity and recurrent droughts are reshaping the operational and governance challenges faced by Water User Associations (WUAs). This study assesses how managerial performance evolved in the Inönü Water User Association (Eskişehir, Türkiye)—a reservoir-based open-channel system—across a major governance reform implemented in 2018. An annual operational dataset covering 2012–2024 was analyzed. Because the institutional change entered into force in April 2018, 2018 was treated as a transition year, and pre-reform (2012–2017) and post-reform (2019–2024) periods were compared using time-series analysis and period-based summaries. Managerial performance was evaluated using widely applied indicators: return on investment, maintenance costs to income ratio, management–operation–maintenance cost per irrigated area, fee collection performance, labor cost per irrigated area, and irrigated area per labor, together with water availability and irrigated area dynamics. Results indicate that post-reform management operated under markedly tighter hydrologic constraints: mean pre-season water availability declined from 12.9 million m^3 (2012–2017) to 5.4 million m^3 (2019–2024), while the mean dam water ratio decreased from 66.8% to 28.0%. Despite intensified drought pressure, service outcomes remained functional, with the mean irrigation ratio increasing from 42.9% to 52%, and fee collection becoming higher and more stable (fee collection performance between 91.2% and 97.7%). Overall, the findings suggest strengthened fee-collection discipline and continued service delivery under water scarcity, supporting the conclusion that the governance reform contributed to improved managerial performance of the irrigation scheme despite intensifying drought conditions.

Keywords: Water user associations, WUA governance reform, Water scarcity, Irrigation management, Open-channel irrigation

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1. Introduction

Water scarcity and recurrent droughts are intensifying operational and governance challenges in irrigation-dependent agricultural regions worldwide. As agriculture remains the dominant water user in many semi-arid basins, sustaining irrigated production increasingly depends not only on physical infrastructure and hydrologic supply, but also on the institutional capacity to plan, allocate, and deliver water services fairly and efficiently under scarcity. In this context, Water User Associations (WUAs) represent a widely adopted organizational model for local irrigation management, with an extensive literature assessing their performance through technical, financial, and managerial indicators and benchmarking approaches (Kazbekov et al., 2009; Akçay, 2018; Zema et al., 2018; Berihune and Moges, 2022; Arslan et al., 2023; Ayyıldız and Baran, 2024; Çakmak and Avcı, 2025; Kırmıkıl, 2025; Rawat and Kulshrestha, 2025; Vafaei et al., 2025).

Performance assessment studies consistently emphasize that WUA outcomes are shaped by multiple interacting factors, including infrastructure type (open channels versus pressurized/piped conveyance), service coverage, fee collection capacity, staffing and O&M burdens, and the degree of resource pressure faced during irrigation seasons (Zhang et al., 2013; Fernández-Pacheco et al., 2015; Vafaei et al., 2025). Under drought conditions, allocation rules and the credibility of enforcement become particularly critical, as scarcity increases the stakes of distribution decisions and may elevate risks of disputes, non-compliance, and financial instability (Goetz et al., 2017). Moreover, evidence from Türkiye indicates that climate-change–driven shifts in reservoir evaporation may alter effective storage dynamics, adding an additional layer of constraint for irrigation planning and allocation (Ahi et al., 2023). International evidence further suggests that governance arrangements and rule acceptance can strongly influence how WUAs cope with scarcity, although the direction and magnitude of these effects vary by context (Hu et al., 2014; Mustafa et al., 2016).

Türkiye has experienced several waves of irrigation management reforms since the 1990s, following large-scale management transfer processes and the establishment of WUAs to improve efficiency, cost recovery, and equity. Lessons from this experience highlight that irrigation reforms can deliver benefits when governance arrangements ensure institutional clarity, accountability, and effective coordination among stakeholders (Kibaroğlu, 2022). In Türkiye, the roles and responsibilities of WUAs are defined within a national legal and administrative framework that assigns associations duties for operating, maintaining, and managing transferred irrigation facilities. A major governance reform later restructured this framework by abolishing elected governing bodies and introducing an appointed presidency: WUA presidents began to be assigned from among public officers under a centralized appointment mechanism, alongside strengthened and regularized auditing arrangements. While such a reform can be expected to alter accountability channels, enforcement capacity, and managerial incentives, empirical evidence linking this institutional change to measurable managerial performance outcomes—especially under concurrent drought stress—remains limited.

This study addresses that gap using a 13-year (2012–2024) operational record from the irrigation scheme in Eskişehir Province, a reservoir-based open-channel system operated by Inönü Water User Association. The reform entered into force in April 2018; therefore, 2018 is treated as a transition year, while pre-reform (2012–2017) and post-reform (2019–2024) periods are compared under clearly differing hydroclimatic constraints. The study evaluates annual dynamics in water availability and irrigated area outcomes, and investigates managerial efficiency patterns using a set of widely used indicators, including return on investment (RI), maintenance costs to income ratio (MCIR), MOM cost per irrigated area (MOMI), fee collection performance (PWF), labor cost per unit irrigated area (LCIA), and irrigated area per labor (IAL). Unlike most WUA performance studies that treat governance context, this analysis quantifies how managerial-efficiency indicators and service outcomes evolved across a discrete governance transition while explicitly documenting concurrent deterioration in pre-season water availability.

The contribution of this paper is twofold. First, it provides a drought-contextualized, time-series assessment of managerial performance across a legally defined governance reform in a Turkish WUA. Second, by jointly presenting water availability constraints and managerial indicators, it offers evidence that supports interpretation of institutional performance under the real-world conditions in which reforms are implemented—namely, increasing scarcity and operational stress in open-channel irrigation systems. The findings are intended to inform both policy discussions on WUA governance models and practical strategies for sustaining irrigation services under drought-prone conditions.

2. Materials and Methods

2.1. Study Area and Irrigation Scheme

The study was conducted in the Inönü Water User Association located in Eskişehir Province (İnönü District), Türkiye (Figure 1), operated as an open-channel irrigation system under the jurisdiction of the DSİ 3rd Regional Directorate (31st Branch). The irrigation supply is provided by a reservoir constructed in 1977 and commissioned for operation in 1984. The dam axis is located at 39°47′37.2″N, 29°57′57.4″E (UTM: 240192, 4409338) on the Sarısu Stream, and the command area lies to the northeast of the reservoir at a distance of approximately 5.2–18.7 km, within an elevation range of 820–950 m. The scheme has a net command area of 1,850 ha, while the reservoir storage capacity is 19.21 hm^3 with an active storage of 17.4 hm^3, and a water surface area of 3.32 km^2. Long-term hydrological information reported in the DSİ planning documentation indicates a mean annual inflow estimate of 12.62 hm^3 and a mean annual natural flow of 17.16 hm^3 $year^{-1}$, with an irrigation module of 0.56 L s^{-1} ha^{-1}. The regional climate is characterized by a continental regime, and the mean annual precipitation is reported as 631 mm, with Class-A pan evaporation of 550.5 mm. Based on soil survey information summarized in the planning report, the project area is dominated by heavy-textured soils (65.47%), followed by medium-textured soils (23.62%), while light-textured soils constitute a minor share (1.61%). Irrigation water quality was assessed from a sample collected in October 2016 and classified as T2A1 (pH 8.48; EC 43.4 mS m^{-1}; SAR 0.22), indicating suitability for irrigation with moderate salinity-related considerations (DSİ, 2025a).

2.2. Governance Reform and Institutional Setting (2012–2024)

This study assesses the effects of a major institutional reform that restructured the governance and oversight model of irrigation organizations in Türkiye. Under the pre-reform system, the management and supervisory boards of the irrigation association were selected through elections among member water users. Following the reform, the election-based structure was abolished, and the association began to be managed by a public officer appointed by the DSİ regional directorate, with the former management and supervisory boards discontinued. In parallel, technical and administrative inspections have been carried out by DSİ-appointed audit teams on a regular annual basis, while financial audits have continued to be conducted by provincial treasury audit teams, complemented by Court of Accounts audits, resulting in tighter monitoring of financial and compliance processes. To capture the phased implementation of the reform, the analysis period (2012–2024) was divided into three sub-periods: 2012–2017 as the pre-reform period, 2018 as a transition year (given that the reform took effect in April 2018), and 2019–2024 as the post-reform period.

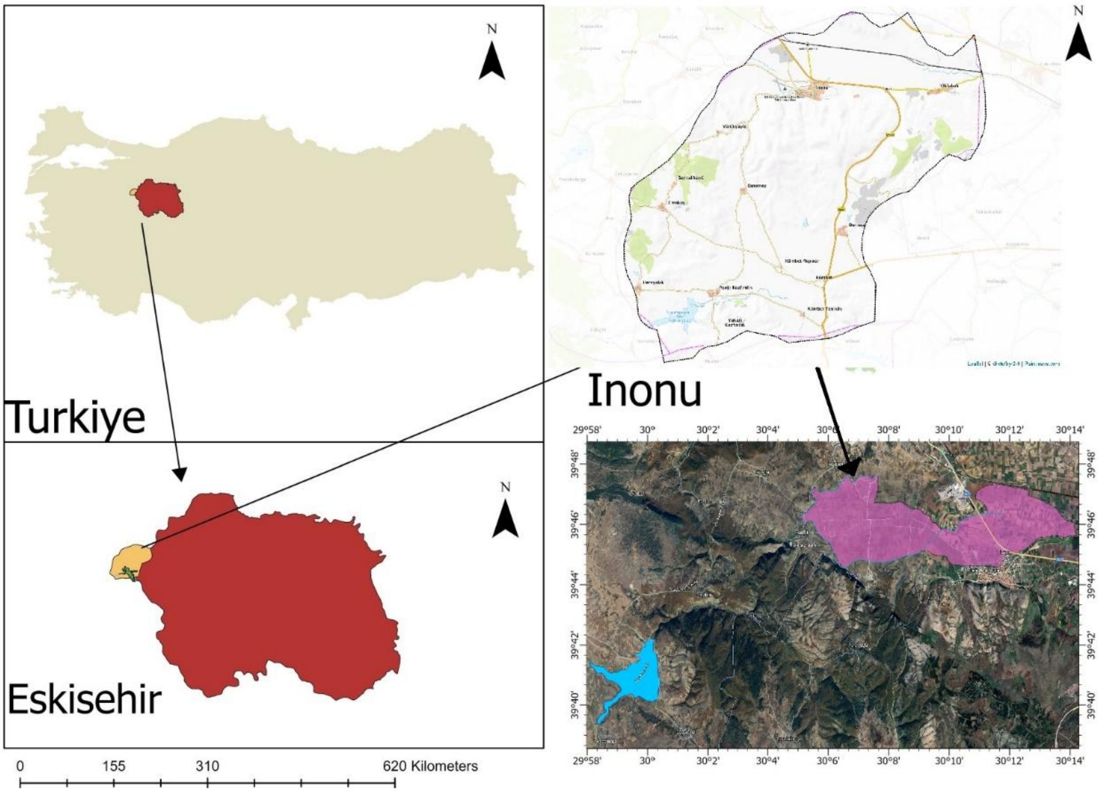

Figure 1. Location of the irrigation scheme operated by the Inönü Water User Association (WUA) in İnönü district, Eskişehir Province, Türkiye.

Table 1. Technical and water-supply dataset (2012–2024)

Year	Command area (ha)	Irrigated area (ha)	Dam volume (m^3)	Water in source before irrigation season (m^3)	Dam water ratio (%)
2012	1,850	773.0	19,210,000	15,370,000	80
2013	1,850	842.2	19,210,000	11,780,000	61
2014	1,850	814.4	19,210,000	6,680,000	35
2015	1,850	715.6	19,210,000	13,920,000	72
2016	1,850	802.1	19,210,000	17,030,000	89
2017	1,850	815.2	19,210,000	12,370,000	64
2018	1,850	799.1	19,210,000	7,730,000	40
2019	1,850	1,243.8	19,210,000	7,700,000	40
2020	1,850	830.1	19,210,000	5,474,000	28
2021	1,850	966.3	19,210,000	3,150,000	16
2022	1,850	1,012.7	19,210,000	5,870,000	31
2023	1,850	889.2	19,210,000	6,040,000	31
2024	1,850	826.4	19,210,000	4,170,000	22

2.3. Data Sources and Variables

Annual data for 2012–2024 were compiled from (i) official DSİ planning and technical documentation and (ii) the administrative and financial records of the İnönü Water User Association (WUA) (DSİ, 2025b). The dataset was organized into three components. First, the technical and water-supply dataset (Table 1) includes the scheme command area (constant at 1,850 ha), the annually irrigated area (ranging from 715.6 to 1,243.8 ha), the reservoir storage capacity (constant at 19,210,000 m^3), the available water in the source prior to the irrigation season (ranging from 3,150,000 to 17,030,000 m^3), and the corresponding dam water ratio (ranging from 16 to 89%).

Second, the organizational and financial dataset (Table 2) includes the total number of labor employed by the WUA (4–8 persons), annual labor costs, collected and assessed water fees, total management–operation–maintenance (MOM) expenditures, and maintenance costs, all reported in US$. All financial records were originally obtained in TRY from the WUA and converted to US$ using the USD/TRY exchange rate announced by the Central Bank of the Republic of Türkiye (CBRT) on the first business day of July for each corresponding year.

Following the managerial-efficiency assessment framework proposed by Malano and Burton (2001), the analysis selected a concise subset of indicators that are widely used in prior studies and can be reliably computed from routinely recorded financial and organizational data. Finally, the study derived a set of managerial-efficiency indicators from the primary financial and organizational records (Table 3), including the ratio of return on investment (RI), maintenance costs to income ratio (MCIR), MOM cost per irrigated area (MOMI), collection performance of water fee (PWF), labor cost per unit irrigated area (LCIA), and irrigated area per labor (IAL). Definitions and units for these indicators are provided in Table 3 (Burton et al., 2000; Çakmak et al., 2004; Harman and Çakmak, 2025a).

The indicator set was selected to represent core managerial dimensions widely used in irrigation-agency and WUA performance assessment frameworks. Specifically, the metrics capture (i) financial discipline and cost recovery (e.g., fee-collection performance and return on investment), (ii) operation–maintenance burden under open-channel conveyance (e.g., maintenance-cost intensity and management–operation–maintenance cost per irrigated area), and (iii) labor efficiency and managerial capacity (e.g., labor cost per irrigated area and irrigated area per labor). Together, these indicators provide a compact but comprehensive view of how managerial efficiency and service sustainability evolve under simultaneous governance reform and drought-driven resource pressure.

Table 2. Organizational and financial dataset (2012–2024)

Year	Total number of labor (person)	Total labor cost (US$)	Total water fee collected (US$)	Total management, operation and maintenance (MOM) (US$)	Total maintenance costs (US$)	Assessed water fee (US$)
2012	4	50,551	158,017	120,001	28,370	160,112
2013	4	49,055	170,622	117,491	29,126	172,405
2014	6	55,076	157,316	112,159	24,583	157,452
2015	6	47,622	115,913	98,106	20,555	131,645
2016	6	55,536	121,889	126,716	36,930	156,896
2017	7	51,802	135,900	163,068	91,053	164,418
2018	8	46,489	99,955	134,845	78,525	143,441
2019	6	57,780	177,635	236,528	96,810	181,532
2020	6	52,108	187,835	197,686	78,141	202,961
2021	5	48,250	162,473	109,414	59,735	163,522
2022	5	34,750	99,134	158,077	43,776	99,994
2023	4	52,433	119,441	117,838	19,934	120,954
2024	4	60,032	139,368	141,998	60,158	141,882

Table 3. Derived managerial-efficiency indicators

Indicator	Unit	Formula (computed annually)
RI – Ratio of return on investment	%	$\mathrm{RI} = \frac{\text{Total water fee collected}}{\text{Total MOM}} x\ 100$
MCIR – Maintenance costs to income ratio	%	$MCIR = \frac{\text{Total maintenance costs}}{\text{Total water fee collected}} x\ 100$
MOMI – MOM cost per irrigated area	US\$ ha^{-1}	$\mathrm{MOMI} = \frac{\text{Total MOM}}{\text{Irrigated Area}} x\ 100$
PWF – Collection performance of water fee	%	$PWF = \frac{\text{Total water fee collected}}{\text{Assessed water fee}} x\ 100$
LCIA – Labor cost per unit irrigated area	US\$ ha^{-1}	$LCIA = \frac{\text{Total labor cost}}{\text{Irrigated Area}} x\ 100$
IAL – Irrigated area per labor	ha person^{-1}	$\mathrm{RI} = \frac{\text{Irrigated area}}{\text{Total number of labor}} x\ 100$

2.4. Statistical Analysis

Statistical analyses were designed to evaluate how managerial efficiency and operational outcomes evolved during a major governance reform implemented under increasing drought pressure. All variables listed in Tables 1–3 were analyzed as annual time series (2012–2024). Because the institutional change entered into force in April 2018, 2018 was treated as a transition year and interpreted as part of the implementation phase rather than a fully representative pre- or post-reform year.

Descriptive analysis and period-based summaries. For each technical, financial, and managerial indicator, yearly time-series plots were produced, and summary statistics (mean, median, standard deviation, and range) were computed for three sub-periods: the pre-reform period (2012–2017), the transition year (2018), and the post-reform period (2019–2024). In addition, the evolution of pre-season water availability (water in source and dam water ratio; Table 1) was reported to explicitly characterize the drought-related constraint under which post-reform management was carried out.

Comparative assessment across periods. To support a structured comparison of performance patterns across periods, differences between the pre-reform (2012–2017) and post-reform (2019–2024) periods were examined using (i) Welch's t-test (Welch, 1947) where distributional assumptions were not strongly violated and (ii) the Mann–Whitney U test (Mann and Whitney, 1947) as a non-parametric alternative. These tests were interpreted as evidence of period-to-period changes in outcomes within the combined context of governance reform and hydroclimatic stress, rather than as estimates of a "pure" reform effect.

Structural change assessment (segmented trend analysis). To examine whether the reform period coincided with a change in the level and/or trend of outcomes, a segmented time-trend specification was used as a diagnostic tool for structural change. For each outcome Y_t the following model form was considered (equation 1):

$$Y_t = \beta_0 + \beta_1 t + \beta_2 \backslash\{Post\}_t + \beta_3 (t \times \{Post\}_t) + \varepsilon_t \quad (1)$$

where t is the time index (year) and $\{Post\}_t = 1$ for 2019–2024 and $\{Post\}_t = 0$ for 2012–2017. In this specification, β_2 represents an immediate level shift and β_3 represents a change in slope (trend) associated with the post-reform period. The transition year 2018 was excluded from the main estimation and was examined descriptively to avoid conflating a partial-implementation year with either regime.

Diagnostics and robustness. Residual autocorrelation and model adequacy were evaluated using standard diagnostics (e.g., residual plots and the Durbin–Watson statistic (Durbin and Watson, 1950)). When serial correlation was suggested, heteroskedasticity- and autocorrelation-consistent (HAC/Newey–West (Newey and West, 1987)) standard errors were used for inference. All statistical tests were two-tailed, and significance was assessed at α=0.05. All computations and visualizations were performed using Python.

3. Results

3.1. Water Availability and Irrigated Area Dynamics (2012–2024)

Table 1 shows a pronounced deterioration in pre-season water availability after the governance transition period, indicating that the post-reform management period coincided with substantially tighter hydrological constraints (Figure 2). The pre-season water stored in the source ranged from 6.68–17.03 million m^3 during the pre-reform period (2012–2017), peaked in 2016 (17.03 million m^3; 89%), and fell to critically low levels in the post-reform period, reaching a minimum in 2021 (3.15 million m^3; 16%).

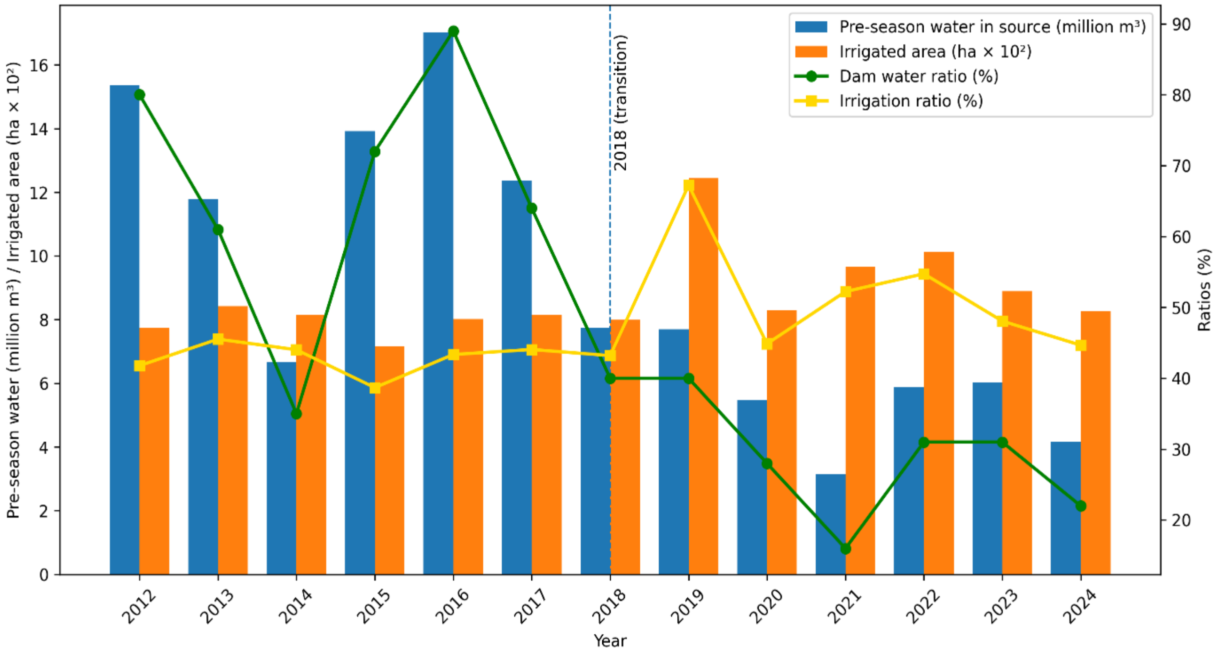

Figure 2. Joint dynamics of pre-season water availability, irrigated area, and key ratios (2012–2024).

When comparing the pre- and post-reform periods while treating 2018 as a transition year, mean pre-season water availability declined from 12.86 million m^3 (2012–2017) to 5.40 million m^3 (2019–2024) (Mann–Whitney P=0.0043; Welch P=0.0024). Consistently, the dam water ratio decreased from an average of 66.83% in 2012–2017 to 28.00% in 2019–2024 (Mann–Whitney P=0.0081; Welch P=0.0024). The transition year 2018 already reflects this tightening, with 7.73 million m^3 and 40% storage.

Despite the sharp reduction in water availability, the scheme maintained—and in some years expanded—effective irrigation service delivery. The irrigated area varied between 715.6 ha (2015) and 1,243.8 ha (2019) over the full period. The mean irrigated area increased from 793.75 ha in 2012–2017 to 961.42 ha in 2019–2024 (Mann–Whitney P=0.0087; Welch P=0.0467). In proportional terms, this corresponds to an increase in the implied irrigation ratio from approximately 43% of the command area (pre-reform mean: 793.75/1850) to approximately 52% (post-reform mean: 961.42/1850). Notably, the largest irrigated area (2019) occurred under relatively limited starting storage (7.70 million m^3; 40%), suggesting that irrigation delivery outcomes were not solely determined by initial reservoir storage and may reflect adaptation in operational allocation, scheduling, or distribution practices under drought stress.

Segmented trend diagnostics (excluding the transition year) were consistent with these patterns: the irrigated area series showed a significant post-period structural change in level and/or trend under the segmented specification (HAC inference), while the water-availability series exhibited marked period differences primarily driven by the pronounced post-2018 drought conditions (Figure 2).

3.2. Managerial Efficiency Indicators (RI, MCIR, MOMI, PWF, LCIA, IAL) (2012–2024)

Managerial-efficiency indicators (Table 4) were used to assess how the irrigation organization's revenue–cost balance, maintenance burden, cost intensity, fee collection, and labor productivity evolved across the pre-reform (2012–2017), transition (2018), and post-reform (2019–2024) periods under increasing drought pressure. Overall, the transition year (2018) stands out as a year of pronounced stress across multiple indicators, followed by a post-reform period characterized by high fee-collection consistency and improved labor productivity, albeit with continued variability in cost structure.

Fee collection performance (PWF) remained high overall and became more stable after the transition. The mean PWF increased from 91.2±9.5% in 2012–2017 to 97.7±2.3% in 2019–2024, while the lowest value occurred in 2018 (70%). Consistent with this pattern, the post-reform years typically clustered around 98–99%, indicating near-complete recovery of assessed fees in most years.

The ratio of return on investment (RI) showed substantial inter-annual variability and a moderate downward shift in the post-reform period. RI decreased from 119.0 ± 25.0% (2012–2017) to 96.7±29.2% (2019–2024), with a pronounced drop in 2018 (74%). Despite this reduction in the post-reform average, RI reached 148% in 2021, highlighting the sensitivity of the revenue–cost balance to year-specific operational and financial conditions.

Indicators describing the maintenance burden and cost intensity suggest that maintenance remained a critical component of the expenditure structure. The maintenance costs to income ratio (MCIR) increased from 27.7±19.9% in 2012–2017 to 39.5±12.3% in 2019–2024, peaking at 79% in the transition year. Similarly, the management, operation and maintenance cost per irrigated area (MOMI) remained within a comparable order of magnitude across periods but exhibited greater dispersion in the post-reform years, increasing from 154.6 ± 24.1 US$ ha^{-1} (2012–2017) to 167.0±44.3 US$ ha^{-1} (2019–2024), with a maximum of 238.15 US$ ha^{-1} in 2020.

Regarding labor-related performance, the labor cost per unit irrigated area (LCIA) declined on average from 65.1±3.9 US$ ha^{-1} in 2012–2017 to 54.2±13.5 US$ ha^{-1} in 2019–2024, although variability increased substantially in the post-reform period. In parallel, irrigated area per labor (IAL) increased from 151.5±40.3 ha $person^{-1}$ (2012–2017) to 195.0±29.4 ha $person^{-1}$ (2019–2024), while 2018 recorded the lowest IAL (100 ha $person^{-1}$). Taken together, these patterns indicate that the organization operated with higher labor productivity in the post-reform period, even as drought pressure intensified and maintenance demands remained elevated (Figure 3).

Table 4. Summary of managerial efficiency indicators across governance periods (2012–2017 pre-reform, 2018 transition, 2019–2024 post-reform)

Indicator (unit)	Pre (2012–2017)			Transition	Post (2019–2024)		
	Mean±SD	Median	Min–Max	(2018)	Mean±SD	Median	Min–Max
RI (%)	119.00 ± 24.95	125.00	83.00–145.00	74.00	96.67 ± 29.19	96.50	63.00–148.00
MCIR (%)	27.67 ± 19.95	18.00	16.00–67.00	79.00	39.50 ± 12.34	42.50	17.00–54.00
MOMI (US$ ha^{-1})	154.60 ± 24.06	147.37	137.10–200.03	168.75	167.00 ± 44.32	163.97	113.23–238.15
PWF (%)	91.17 ± 9.50	93.50	78.00–100.00	70.00	97.67 ± 2.34	98.50	93.00–99.00
LCIA (US$ ha^{-1})	65.10 ± 3.88	65.98	58.25–69.24	58.18	54.18 ± 13.49	54.45	34.31–72.64
IAL (ha $person^{-1}$)	151.50 ± 40.31	135.00	116.00–211.00	100.00	195.00 ± 29.44	205.00	138.00–222.00

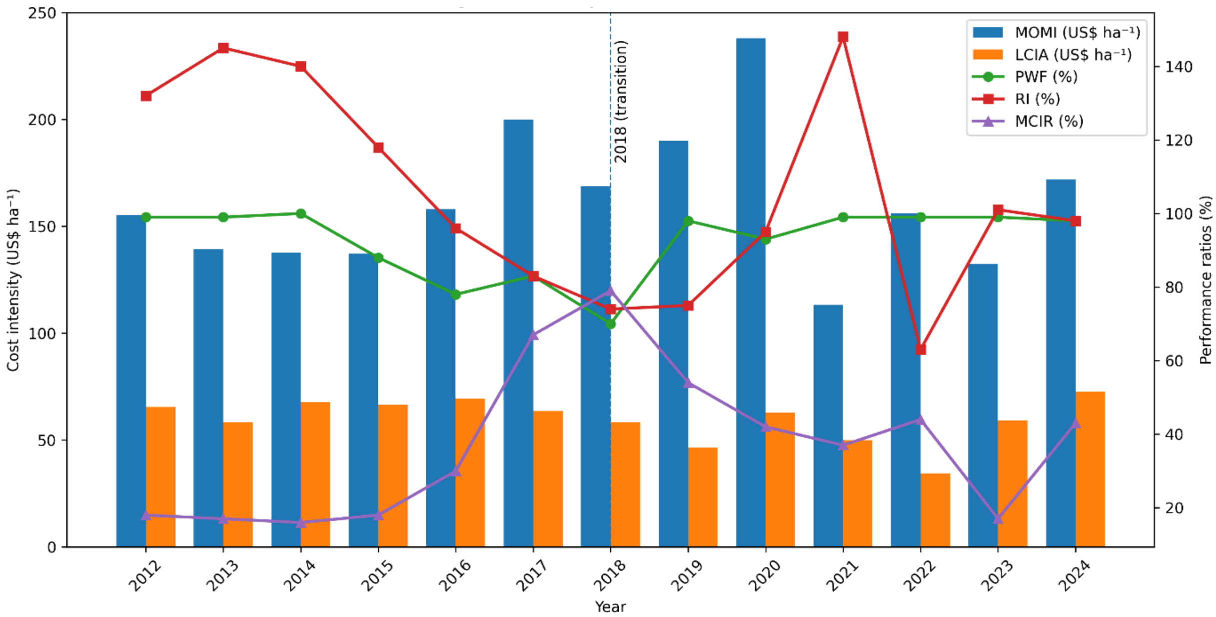

Figure 3. Temporal dynamics of key managerial efficiency indicators in the Inönü Water User Association (2012–2024), with 2018 marked as the transition year.

To contextualize these indicator-based results, Table 2 shows that the transition year (2018) combined low collections with relatively high expenditure pressure: collected fees fell to 99,955 US$ against 143,441 US$ assessed (consistent with PWF = 70%), while total MOM remained 134,845 US$ and maintenance spending was 78,525 US$. In the post-reform period (2019–2024), collected fees averaged 147,648 US$, while assessed fees averaged 151,808 US$, consistent with the high PWF values reported in Table 4. In addition, the maintenance share within MOM increased from an average of approximately 29% (2012–2017) to 37% (2019–2024), supporting the rise in MCIR and highlighting the continuing importance of maintenance expenditures under constrained conditions.

4. Discussion

This study examined how a major governance reform in a Turkish Water User Association (WUA) coincided with changes in managerial efficiency under intensifying drought constraints.

4.1. Reform Implementation under Drought Pressure: Shifting Constraints and Managerial Adaptation

The results clearly show that water availability became substantially more restrictive after the reform period (Figure 2), implying that post-2019 management had to deliver irrigation services with a smaller and more volatile resource base. Such conditions typically magnify trade-offs between service coverage, equity, and operational reliability. International evidence suggests that institutional performance in WUAs is strongly conditioned by resource pressure and rule enforcement capacity, particularly under droughts (Kazbekov et al., 2009; Zhang et al., 2013; Goetz et al., 2017; Kakuta, 2019). In this context, centralized oversight and strengthened monitoring may function as a “risk-management” mechanism, potentially improving compliance and revenue collection when scarcity increases transaction costs and conflict risks.

At the same time, Turkish experience emphasizes that sustained success of irrigation reforms depends on stakeholder participation and consensus-building across irrigation actors (Kibaroğlu, 2022). The reform introduced a more centralized governance setting with an appointed presidency and strengthened auditing practices. While this can increase administrative control and standardization, it may also reduce direct farmer representation—an issue repeatedly highlighted in international cases where administratively dominated governance structures weakened local legitimacy or acceptance (Hu et al., 2014; Mustafa et al., 2016). In İnönü, however, the post-reform period did not coincide with a collapse in service outcomes; rather, management appears to have maintained scheme operability despite drought constraints (Figures 2 and 3). This supports the view that the effectiveness of “centralization vs. participation” is context-dependent and may vary with scarcity severity, enforcement capacity, and institutional maturity.

4.2. What Improved and What Became More Challenging: Evidence From Managerial Indicators

The managerial indicator set provides a compact view of where performance improved and where costs intensified (Table 4; Figure 3). Two patterns stand out.

First, fee collection performance (PWF) became both higher and more stable in the post-reform period (Table 4; Figure 3). Cost recovery and collection capacity are repeatedly identified as core determinants of sustainable irrigation agency performance at global scale (Bayramoğlu et al., 2021; Arslan et al., 2023; Vafaei et al., 2025). From a governance perspective, stronger auditing, clearer enforcement, and standardized procedures can plausibly enhance timely collection and reduce arrears—especially when water scarcity increases the perceived value of service reliability. Similar improvements following a shift toward more centralized structures were also reported in a comparable Turkish WUA context (Ersöz and Çamoğlu, 2020; Harman and Çakmak, 2023; Bildim and Irık, 2024; Karacalr and Irık, 2024; Harman and Çakmak, 2025b), suggesting that the reform may strengthen certain managerial controls even under drought.

Second, several indicators indicate that operational sustainability became more cost-pressured. The maintenance-cost-to-income ratio (MCIR) and the per-hectare MOM burden (MOMI) show that maintaining system functionality under drought can raise maintenance and operational intensity (Table 4; Figure 3). This is consistent with broader evidence that poorly performing collective irrigation agencies often face high O&M burdens relative to service outcomes, particularly when infrastructure is aging and open-channel conveyance systems dominate (Zema et al., 2018; Vafaei et al., 2025). Under drought, conveyance and operational inefficiencies become more consequential, and additional maintenance may be required to sustain delivery reliability and mitigate losses.

Labor-related indicators also provide a meaningful signal. Post-reform irrigated area per labor (IAL) increased (Table 4), implying a more “lean” personnel structure and/or higher workforce productivity. This may reflect tighter staffing controls and formalized administrative supervision, which are common reform targets in irrigation governance (Gany et al., 2019). However, lean staffing can generate risks in open-channel systems where field-level monitoring, gate operations, and rapid maintenance response remain essential; some performance studies report that reduced staffing or underutilization can constrain operational quality and equity (Kazbekov et al., 2009; Zema et al., 2018). Therefore, increases in labor productivity should be interpreted alongside maintenance and service reliability metrics rather than as a stand-alone “success” criterion.

4.3. Implications for Open-Channel Schemes: Modernization, Rule Compliance, and Adaptive Management

The İnönü case is an open-channel irrigation scheme, which makes drought management intrinsically more challenging due to conveyance losses, higher monitoring needs, and the importance of timely field operations. Multiple studies in Türkiye and abroad indicate that modernization—especially conversion toward pressurized/piped conveyance and enhanced control/automation—can improve efficiency and reduce management burdens, though investment costs and institutional capacity remain important constraints (Batt and Merkley, 2010; Fernández-Pacheco et al., 2015; Değirmenci and Arslan, 2018; Arslan and Zema, 2024; Vafaei et al., 2025). Thus, the post-reform period improvements in collection and managerial control in İnönü may represent necessary conditions for sustainability, but not sufficient conditions for long-term drought resilience unless infrastructure constraints are also addressed.

In addition, drought-period allocation rules and their acceptance are increasingly central to irrigation governance. Evidence from Southern Europe shows that the effectiveness of new allocation rules depends not only on allocative efficiency but also on user acceptance and distributional perceptions (Goetz et al., 2017). Although this study did not include farmer perception data, it highlights the need to complement "administrative performance" indicators with legitimacy and compliance metrics—particularly when governance becomes more centralized. Future work could incorporate user surveys or qualitative interviews to assess whether improved collection and auditing translate into perceived fairness, transparency, and cooperative behavior, which are increasingly recognized as determinants of collective action in WUAs (Hu et al., 2014; Mustafa et al., 2016; Cooper et al., 2023; Bopp et al., 2026).

4.4. Scope and Interpretation

This case-study evidence should be interpreted as reflecting the combined influence of the governance reform and intensifying drought conditions, rather than providing a purely causal estimate of the reform effect.

4. 5. Policy Implications and Recommendations

- Preserve financial discipline under water scarcity. Strengthened oversight and regular auditing mechanisms appear to support more stable fee collection under drought, which is critical for sustaining O&M capacity and preventing service deterioration during low-water years.
- Adopt drought-triggered operational rules. Formalize transparent rotation schedules and enforcement procedures that are explicitly linked to pre-season storage levels, so seasonal irrigated area decisions and delivery plans remain predictable and equitable when water is limited.
- Prioritize technically qualified leadership. Give priority to appointing professionally trained agricultural engineers (Agricultural Structures and Irrigation graduates) as WUA presidents to strengthen technical decision-making capacity in seasonal planning, O&M prioritization, and drought-time allocation.
- Reduce conveyance losses through modernization. Where feasible, prioritize a phased transition from open channels to closed (piped) irrigation networks and/or targeted canal rehabilitation and measurement/control structures, to lower conveyance losses and the long-run O&M burden

5. Conclusion

This study evaluated a 13-year record (2012–2024) from the Inönü Water User Association to examine how managerial performance evolved across a major governance reform in Türkiye's Water User Associations (WUAs). The results show that post-reform management operated under markedly tighter hydrologic constraints, with substantially reduced pre-season water availability and dam water ratios compared with the pre-reform period. Despite this intensified drought pressure, service outcomes remained functional, with the mean irrigation ratio increasing and fee-collection performance becoming higher and more stable in the post-reform period. These findings should be interpreted as the joint outcome of the governance reform and intensifying drought conditions rather than as a purely causal estimate of the reform effect.

Beyond the quantitative indicators, the reform also appears to have reshaped the governance environment in which managerial decisions were made. Under the earlier elected structure, managerial behavior may be influenced by electoral incentives, potentially creating pressures for preferential treatment, short-term decisions, or uneven enforcement. In contrast, the post-2018 appointed presidency—implemented through centrally assigned public officers—may support a more standardized, duty-oriented, and rule-based approach, as public officers operate under formal accountability and legal compliance rather than election dynamics. This institutional setting can facilitate more equal treatment across users and a more technical administration style, particularly when paired with strengthened and regularized audits; moreover, the assignment mechanism, which often prioritizes professional qualifications (e.g., agricultural engineering backgrounds and tertiary education), may further reinforce managerial capacity to sustain irrigation services under drought conditions.

Author Contributions

The percentages of the authors' contributions are presented below. All authors reviewed and approved the final version of the manuscript.

	E.H.
C	100
D	100
S	100
DCP	100
DAI	100
L	100
W	100
CR	100
SR	100
PM	100

C= concept, D= design, S= supervision, DCP= data collection and/or processing, DAI= data analysis and/or interpretation, L= literature search, W= writing, CR= critical review, SR= submission and revision, PM= project management.

Conflict of Interest

The author is employed by the State Hydraulic Works (Devlet Su İşleri, DSİ), Türkiye, which is responsible for the planning and implementation of the irrigation scheme analyzed in this study. The author has no other relevant financial or non-financial interests to disclose.

Ethical Consideration

Ethics committee approval was not required for this study because of there was no study on animals or humans.

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The datasets generated and/or analyzed during the current study are based on internal records of DSİ and the Water User Association and are not publicly available due to institutional restrictions, but aggregated values are included in the article.

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