International Journal of Sustainable Studies, Technologies, and Assessments

IJSSTA

Original Article

The Water Crisis in Sicily: Strategic Implications for Environment, Society, and Governance

Sala Eleonora
eleonorasala.96@outlook.com

Received: 05 September 2025 / Revised: 16 October 2025 / Accepted: 20 October 2025 / Published online: 23 October 2025

Abstract: In recent years, Sicily has faced increasing water scarcity due to the intensification of drought events, exacerbated by climate change. However, alongside climatic factors, a major cause of water shortage is rooted in systemic inefficiencies in water infrastructure management particularly poor maintenance and underutilization of reservoirs. This paper applies a Lean Management approach to the Sicilian water crisis, introducing tools such as Value Stream Mapping (VSM) to identify and mitigate structural inefficiencies. By analyzing three emblematic case studies Trinità Dam, Gibbesi Dam, and Pozzillo Dam we categorize the types of inefficiencies (active waste, potential waste, and capacity loss) and propose targeted interventions. The study suggests that Lean principles can serve as a powerful framework to shift from emergency response to proactive water governance, promoting long-term sustainability and resilience in Mediterranean water management systems.

Keywords: Water scarcity, Sicily, drought, governance, climate adaptation, infrastructure, agriculture, Lean Management.

1. Introduction

Water scarcity represents one of the most pressing challenges of the 21st century, particularly in Mediterranean regions characterized by high climate variability and growing anthropogenic pressures. Sicily, the largest island in the Mediterranean Sea, offers a particularly illustrative case: although endowed with multiple water infrastructures including 46 reservoirs and a network of river basins the island has repeatedly experienced critical water shortages, especially during the summer months. These shortages severely impact domestic use, agriculture, and tourism, resulting in economic losses and rising social tensions.

In recent years, the situation has been exacerbated by insufficient maintenance of existing infrastructure, lack of institutional coordination, and an outdated governance model. Notably, several strategic reservoirs, such as Trinità and Gibbesi, remain underutilized or completely inoperative due to structural and bureaucratic inefficiencies, while others, like Pozzillo Dam, suffer from sedimentation and degraded capacity. These failures underline a structural mismanagement problem, in which the available water is not only scarce but also poorly distributed and frequently wasted.

Addressing such inefficiencies requires more than new infrastructure, it requires a fundamental rethinking of how water systems are managed. This study applies Lean Management methodology, commonly used in industrial optimization, to the context of water governance. Specifically, it proposes the use of Value Stream Mapping (VSM) and visual process control tools to diagnose systemic dysfunctions and propose sustainable, value-driven improvements. Through three case studies Trinità, Gibbesi, and Pozzillo dams this paper aims to demonstrate how Lean tools can contribute to reducing non-value-added activities, mitigating waste, and ultimately improving water resilience in semi-arid regions.

2. Literature Survey

Understanding Drought: Definitions and Typologies

There are multiple definitions of drought, which may emphasize either its climatic causes or its hydrological and socioeconomic effects. One of the most comprehensive definitions describes drought as a temporary and accidental natural phenomenon, characterized by a significant, non-brief, and spatially extensive reduction in water availability relative to the normal values for the region under consideration.

Drought is therefore linked to the concept of a temporary water deficit, which evolves over time in contrast to aridity, a permanent climatic condition typical of areas where average precipitation is lower than average evapotranspiration, leading to a structurally negative water balance.

In some climates, seasonal drought may be a normal and recurring phenomenon, not necessarily associated with deviations from climatic norms. However, drought in the strict sense is related to medium- and long-term variations in the balance between precipitation and evapotranspiration in a given area. Its impact depends not only on quantity but also on timing (e.g., delays in the onset of the rainy season or critical rain periods overlapping with plant growth stages) and on the nature of the rainfall (e.g., intensity and frequency of events).

The following four main types of drought are commonly distinguished:

- **Meteorological drought**: defined by a significant precipitation deficit relative to the long-term “normal” or average (calculated over at least 30 years), and by the duration of the dry period.
- **Agricultural drought**: occurs when the water reserves in the root zone are insufficient to sustain the development of crops and pastures between rainfall events. Crop response to water deficit depends on species and phenological stage.
- **Hydrological drought**: caused by insufficient recharge of aquifers, rivers, and surface reservoirs. It typically develops over longer timeframes than meteorological or agricultural drought.
- **Socioeconomic drought**: associated with the imbalance between water supply and demand for water-related goods and services. During intense or prolonged drought periods, problems may arise in the allocation of water resources, affecting economic activities and civil uses.

  Each of these drought categories can trigger a cascade of environmental, economic, and social impacts, depending on the duration and spatial scale of the drought event.

Monitoring Drought: SPI and Regional Trends

Drought is a complex, multi-layered phenomenon. As per the Sicilian drought reports, it is defined as a temporary and significant reduction in water availability, unlike aridity, which is a permanent climatic condition. The region identifies four types of drought: meteorological, agricultural, hydrological, and socio-economic. Sicily uses the Standardized Precipitation Index (SPI), calculated using data from over 500 stations, to monitor deficits across temporal scales (1 to 48 months). The index is produced using Ordinary Kriging interpolation, following WMO Guidance 1090. Recent SPI readings and regional data confirm that both June and July 2025 have continued a multi-year trend of above-average temperatures and below-average rainfall. Moreover, sea surface temperatures have reached exceptional levels, with the Tyrrhenian Sea peaking at 28–29°C, and the 0°C isotherm rising to 5400 meters, significantly affecting atmospheric balance and local climate stability. Cross-Mediterranean studies reveal that water stress is not unique to Sicily. Tunisia and Algeria have invested in wastewater recycling and desalination plants, while Greece has developed precision irrigation and smart metering. These comparative cases provide practical benchmarks for Sicilian policy reform.

3. Proposed Methodology: Addressing Systemic Inefficiencies Through Lean Management

One of the main factors exacerbating the water crisis in Sicily is not merely the lack of rainfall or rising average temperatures, but above all the chronic inefficiency and absence of maintenance within the island's water infrastructure, which leads to an average water loss of 52%. This structural issue has severe consequences for households, agriculture, and tourism, as seen in the city of Agrigento, where water reaches homes only once every 15 days. Unlike climatic variables which are harder to control and whose effects unfold over the medium-to-long-term improving water infrastructure management can yield immediate and measurable results. Currently, of the 46 reservoirs located in Sicily, only 23 are fully operational: the rest are either under testing, partially functional, out of service, or still under construction. Furthermore, the accumulation of sediment, caused by soil erosion, reduces storage capacity and undermines structural stability. To address these critical issues, we propose the use of innovative and operational management tools, particularly Lean Management and its technique of Value Stream Mapping (VSM). This visual tool allows for the mapping of an entire process in this case, the water cycle from source to end-user highlighting bottlenecks, waste, and systemic delays.

A. Comparative Analysis

1. Case Study Trinità Dam (Trapani):

The Trinità Dam, located in the Trapani area between Castelvetrano, Campobello di Mazara, and Mazara del Vallo, stands as a striking example of the systemic inefficiencies that plague Sicily's water infrastructure. Constructed between 1954 and 1959, the dam has never been officially certified and remains subject to severe operational limitations. Despite a total storage capacity of 18 million cubic meters, the dam is currently authorized to hold just 2.5 million cubic meters less than half of the 6 million required annually by the surrounding agricultural sector. Any excess water is routinely discharged into the sea to mitigate the risk of structural failure, representing a tragic waste of resources in a region suffering from extreme drought. These restrictions stem from long-standing safety concerns, including non-compliance with modern seismic standards and a lack of routine maintenance over the last seven decades. Since 2016, proposed interventions ranging from seismic reassessment and hydraulic studies to structural reinforcements have failed to materialize. As recently as January 2025, the Ministry of Infrastructure ordered the dam's water level be further reduced to 50 meters above sea level, and emergency operations have involved using Civil Protection water trucks to remove excess water rather than allow it to overflow. The dam's dysfunctionality has cascading effects on the regional economy. It currently irrigates only 800–1,000 hectares out of the 2,500 hectares of agricultural land it was designed to serve. Wine cooperatives and olive growers report devastating losses, with some describing this as the worst crisis in sixty years. As one farmer put it: "It is unthinkable that in a year of extreme drought, we are still wasting the water we have due to lack of maintenance."

Recent developments suggest a glimmer of hope. Following coordinated action from local authorities, lawmakers, and agricultural organizations, two key proposals were presented: (1) temporarily increasing the permitted water level to alleviate immediate shortages, and (2) interconnecting the Trinità basin with the nearby Garcia reservoir via an 8–10 km pipeline a technically simple and cost-effective solution that would improve irrigation resilience. However, these solutions remain contingent on the appointment of a special commissioner and rapid project implementation. This case exemplifies not only the physical degradation of infrastructure but also a broader governance crisis, marked by overlapping responsibilities, poor planning, and decades of political inertia. Under a Lean Management lens, the Trinità Dam represents a critical point of failure in Sicily's value stream a bottleneck where non-value-added activities (such as unnecessary water discharge) could be eliminated through better system design, maintenance planning, and inter-agency coordination.

Figure 1 Trinità Dam.

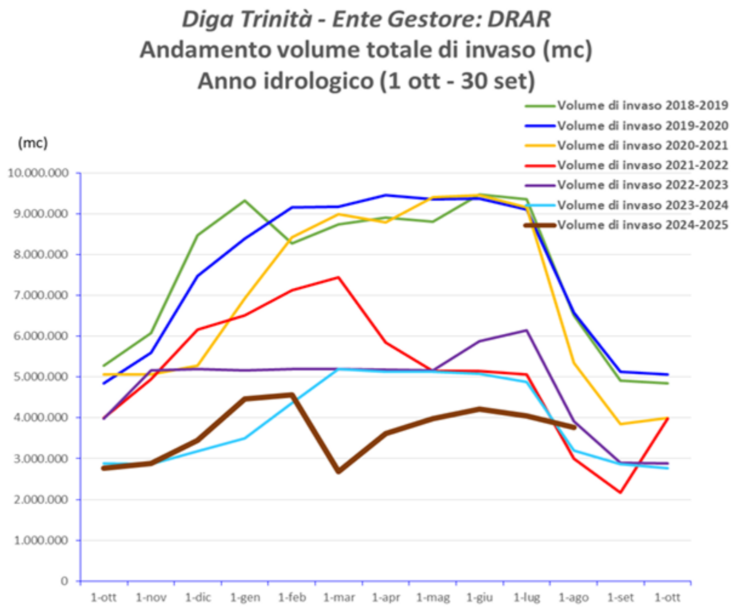

Figure 2 Trend of the reservoir's total volume. Total storage volume trend at Trinità Dam (Trapani) across hydrological years from 2018 to 2025 (data updated to July 2025). Data source: Regione Siciliana, "Prospetto volumi invasati nelle dighe – Agosto 2025" and "Grafico volumi invasati nelle dighe – Agosto 2025" (2025).

The chart highlights typical seasonal fluctuations associated with the Mediterranean rainfall pattern, while also revealing a significant decline in storage performance over the past three years. This reflects persistent structural and operational shortcomings, reinforcing the need for systemic approaches to improve regional water resilience.

2. Case Study Gibbesi Dam (Ravanusa):

The Gibbesi Dam, located near Ravanusa in the province of Agrigento, presents a different but equally critical failure in water infrastructure management. Completed in 1992 with a designed capacity of over 20 million cubic meters, the dam has never been put into operation due to the absence of final testing (collaudo) and the lack of essential water conveyance systems such as canals and pipelines. Despite being structurally intact, Gibbesi currently functions as a simple spillway: rainfall that accumulates in the reservoir is not stored or used, but rather flows directly downstream. This means that every year, millions of cubic meters of potential irrigation water are entirely wasted. The situation is emblematic of a systemic disconnect between infrastructure construction and operational planning, reflecting serious gaps in institutional coordination and long-term strategy. According to the Sicilian Water Basin Authority, the dam's non-functionality is due to bureaucratic delays, outdated engineering plans, and the absence of maintenance strategies. Moreover, the dam has never undergone proper seismic or hydraulic assessments, raising concerns about its long-term safety and feasibility. From a Lean Management perspective, Gibbesi Dam is a textbook example of “overproduction” and “non-utilized resources” two key types of waste (muda) in Lean terminology. Resources were heavily invested in building an infrastructure that has never delivered value. By integrating tools such as Value Stream Mapping, policymakers could have visualized the gaps in the operational chain, identified the lack of downstream connections, and prioritized interventions to activate the reservoir efficiently.

Figure 3 Gibbesi Dam.

3. Case Study Pozzillo Dam: From Strategic Asset to Critically Underperforming Reservoir

Figure 4 Pozzillo Dam. The Gibbesi Dam in Ravanusa, Agrigento. Gibbesi Dam (photo from Qui Licata, April 2023), illustrating the structure that remains non-operational due to lack of certification and hydraulic infrastructure.

Figure 5 Pozzillo Lake. View of Lake Pozzillo, Sicily's largest artificial reservoir, surrounded by the hills of Enna. Pozzillo Dam (photo courtesy of Enel Green Power, PNRR project overview, 2024), showing the dam structure that faces severe sedimentation and reduced storage capacity.

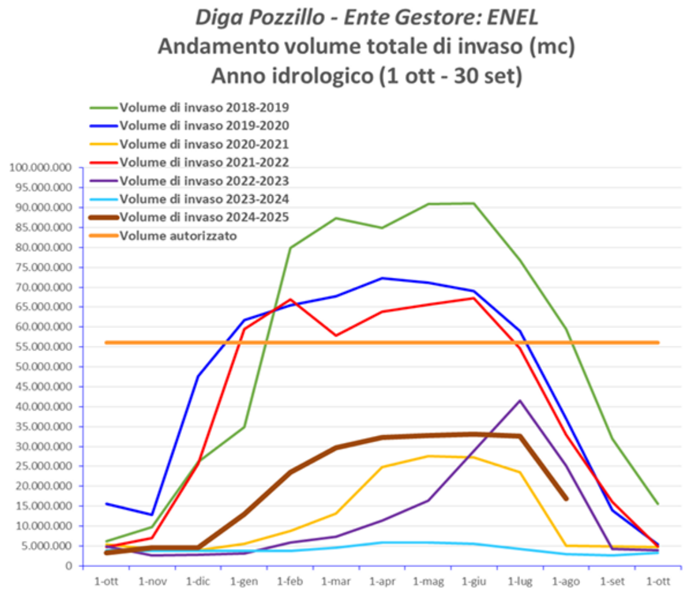

Figure 6 Trend of the reservoir's total volume. Trend of total reservoir volume at the Pozzillo Dam (managed by ENEL) across hydrological years from 2018 to 2025, compared with the authorized maximum volume (orange line). Data source: Regione Siciliana, "Prospetto volumi invasati nelle dighe – Agosto 2025" and "Grafico volumi invasati nelle dighe – Agosto 2025" (2025).

The graph highlights a significant reduction in effective storage capacity in recent years, with the 2023–2024 and 2024–2025 curves falling well below the authorized threshold (55 million m³), confirming the impact of sedimentation and structural degradation on the reservoir's performance.

Located in the municipality of Regalbuto (Enna), Pozzillo Dam is the largest artificial reservoir in Sicily, with an original capacity of 150 million cubic meters. Constructed in the 1950s through a joint effort between the Cassa del Mezzogiorno, ERAS, and the Ente Siciliano Elettricità, the dam plays a critical role in both agricultural irrigations especially for the 60,000 hectares of citrus groves in the Plain of Catania and renewable energy production, with approximately 100 GWh generated annually by Enel Green Power.

Pozzillo Dam intercepts the Salso River and forms a key node in the Salso-Simeto hydraulic system, together with Ancipa Dam. However, geological features of the catchment area and the agricultural land use mainly cereal cultivation have contributed to heavy sediment transport over time. It is estimated that approximately 30 million cubic meters of sediment have accumulated in the reservoir since its construction, leading to the progressive blockage of the bottom outlet and drastically reducing the reservoir's effective capacity. In 2006, due to safety concerns and reduced functionality, the Italian Dam Authority officially lowered the maximum authorized storage level to 60 million cubic meters, effectively halving the dam's capacity. To address this issue, a new project funded by the Italian National Recovery and Resilience Plan (PNRR) and worth €33 million was launched in 2023. It aims to restore full operational capacity by constructing a new bottom outlet at a higher elevation using an innovative barrier of O-Piles a globally unprecedented technique that allows maintenance without draining the reservoir. In addition to restoring hydraulic functionality, the project also incorporates circular economy principles. The extracted sediments will be reused as soil improvers in agriculture and as raw material for experimental geopolymer tiles (in collaboration with the CNR and the University of Catania) and for land restoration research by the University of Palermo. The project represents a rare case of long-term strategic planning in Sicilian water infrastructure. Once completed projected for March 2026 Pozzillo Dam is expected to regain its full irrigation and energy-generation capacity, providing a more resilient water management model in the face of increasing climate variability.

B. Tackling Systemic Inefficiencies through Lean Management

One of the main factors aggravating the water crisis in Sicily is not only the reduction in rainfall or the increase in average temperatures due to climate change, but also and above all the chronic inefficiency and lack of maintenance of the island's water infrastructure. The regional water network suffers from an average loss of 52% of its total flow due to pipeline leaks, resulting in enormous waste of a vital resource. These failures have severe consequences for households, agriculture, and tourism, as illustrated by the case of Agrigento, where water is supplied to homes only once every fifteen days.

Unlike climate-related factors which are difficult to control and whose effects manifest over the medium to long-term improving the efficiency of water infrastructure can have immediate and measurable impact. Of the 46 dams in Sicily, only 23 are fully operational: the others are either under testing, partially functional, out of service, or still under construction. Many reservoirs also suffer from sediment accumulation due to erosion, which reduces their storage capacity and compromises their structural integrity.

To address these critical inefficiencies, we propose applying Lean Management tools, particularly the Value Stream Mapping (VSM) method, to the water sector. VSM is a visual tool that maps the entire process in this case, from water collection to end-user distribution and identifies systemic bottlenecks, delays, and waste.

The comparison of three emblematic dam systems reveals three distinct types of waste, each of which can be mapped and mitigated using Lean thinking:

- Trinità Dam: built in 1959 and never fully certified due to seismic and hydrogeological concerns. For safety reasons, its maximum storage level is restricted, and excess water is periodically discharged into the sea. This represents an example of active wastewater exists but is not utilized, violating Lean principles of value preservation.
- Gibbesi Dam: completed in 1992, this structure has never stored a single cubic meter of water due to the absence of both safety certification and the necessary water conveyance infrastructure. It embodies a case of potential waste, where a functional asset has never been integrated into the value chain.
- Pozzillo Dam: the largest artificial reservoir in Sicily, originally with a capacity of 150 million cubic meters. Due to sediment buildup estimated at 30 million cubic meters its capacity was halved in 2006, reducing the available water to 60 million cubic meters. This illustrates progressive degradation a long-term erosion of value due to lack of intervention.

These three categories active, potential, and progressive waste clearly correspond to what Lean methodology defines as non-value-added activities and underscore the need for a systemic and proactive management model.

1. Lean Solutions for Water Management Optimization

Applying VSM to the management of water infrastructure would enable us to:

- Analyze and visualize inefficiencies across the entire value stream of the water system;

- Identify critical points such as pipeline leakages, lack of coordination between management entities, delays in response, absence of preventive maintenance, and resource waste;
- Design an ideal future state, including scheduled maintenance cycles, real-time monitoring, clearer lines of responsibility, and decentralized governance.

Furthermore, Lean methodology rooted in the Kaizen principle of continuous improvement calls for increased inspections, investment in technical personnel, and the digitization of monitoring systems. Recent studies emphasize how the absence of qualified young professionals in public administration hinders the implementation of innovative and sustainable solutions. One of the most illustrative examples of systemic failure is the daily discharge of over 130,000 m³ of water from Trinità Dam into the sea due to the lack of structural certification. This loss is especially paradoxical during a drought, and perfectly exemplifies Lean's concept of *avoidable waste*.

Finally, Lean thinking also supports the adoption of decentralized solutions, such as renewable-powered desalination plants for smaller islands like Lipari or Stromboli. These systems provide a cost-effective alternative: recent estimates place the cost of desalinated water at around €0.69/m³ when powered by solar or geothermal energy, compared to €16/m³ for water delivered by tanker ships. Planning and evaluating such alternatives through Lean methodology could strengthen resilience and equity in access to water across the region.

5. Steps Followed in the Proposed Solution

To apply Lean principles to the Sicilian water infrastructure, we propose a structured, replicable intervention strategy composed of the following five phases:

Step 1: System Mapping and Current State Analysis

Using VSM, the entire water delivery process from water capture at the source to end-user distribution is mapped. This highlights the flow of materials (water), information (monitoring, permits), and control points. Particular focus is placed on bottlenecks such as inter-agency coordination and delays in maintenance response. The first step in applying Lean methodology to Sicily's water infrastructure is to create a detailed Value Stream Map (VSM) of the current state. This map should trace the flow of water from source (dams, rivers, rainfall capture) to final distribution (agricultural irrigation, municipal supply), highlighting all actors, infrastructure nodes, control procedures, and information exchanges.

In the Sicilian context, the VSM should include:

- Storage nodes: operational status and limitations of key reservoirs such as Trinità, Gibbesi, and Pozzillo dams. For example, Trinità operates below safety thresholds due to the lack of seismic certification; Gibbesi is structurally complete but disconnected from the hydraulic system; Pozzillo suffers from capacity loss due to sedimentation.
- Governance structure: overlapping competences among institutions (e.g., Region, Reclamation Consortia, Civil Protection, Ministry of Infrastructure) that often result in delayed or duplicated decision-making. For instance, the Lentini Dam requires dual authorization from the managing authority and the user entity, generating time lags.
- Distribution infrastructure: degraded or incomplete canal networks, frequent leakages, and absence of water transport between dams (e.g., no connection between Trinità and Garcia dams despite geographic proximity).

- Maintenance and monitoring: absence of preventive maintenance plans, reliance on emergency measures (e.g., water trucking), and lack of real-time monitoring systems or SCADA networks. For example, Trinità discharges water to the sea not due to excess rainfall, but because paratie must remain open due to structural risk, and there's no real-time adaptation mechanism in place.
- Environmental and operational losses: high evaporation due to shallow reservoirs, uncontrolled sediment inflow, and direct discharge of unused water into the sea. At Pozzillo, for example, sediment buildup has reduced capacity from 150 to 60 million m^3.

The current-state VSM allows for a systemic visualization of how time, resources, and water are lost at each step of the process. This is not merely a technical exercise it provides the basis for identifying critical inefficiencies, assigning accountability, and defining the "future state" map, in which those losses are either minimized or eliminated. Moreover, this mapping phase can be supported by GIS tools, digital twin models, or hydrological simulation software, allowing real-time comparison between infrastructure potential and actual performance. The integration of such tools enhances visibility across the value chain and supports evidence-based decision-making for both emergency and strategic planning.

Step 2: Identification of Value-Adding and Non-Value-Adding Activities

Activities are classified into three categories: value-adding (e.g., preventive maintenance), necessary but non-value-adding (e.g., regulatory reporting), and pure waste (e.g., idle infrastructure, emergency water trucking). This classification enables prioritization of improvement efforts. In Lean methodology, the identification of value-adding (VA) and non-value-adding (NVA) activities is a fundamental step in optimizing any process. Applied to water resource management in Sicily, this step allows for a clear distinction between operations that directly contribute to the effective supply and conservation of water, and those that generate delays, losses, or inefficiencies without producing tangible benefits. A preliminary analysis of the Sicilian hydraulic infrastructure reveals numerous NVA activities, many of which are systemic:

- Trinità Dam: The routine discharge of usable water into the sea due to lack of structural certification and outdated safety regulations is a clear NVA activity. Rather than contributing to irrigation, this action represents an *active waste* of a scarce resource.
- Gibbesi Dam: This dam has never entered into operation since its completion in 1992, due to the absence of the necessary collaudo (certification) and supporting infrastructure. This represents a *passive waste*, where investment and potential capacity are entirely unused an extreme case of a non-value-adding asset.
- Pozzillo Dam: Despite being the largest artificial reservoir in Sicily, the dam operates at less than half its capacity due to sediment accumulation. The lack of maintenance and delayed recovery projects reflect a *progressive degradation* of infrastructure value over time.

Conversely, value-adding activities are those that ensure the safe, timely, and sustainable delivery of water resources. These include:

- Scheduled maintenance of reservoirs and conduits.
- Real-time digital monitoring of water levels and structural integrity.
- Clear governance mechanisms to reduce inter-agency delays (e.g., overlapping competences between regional departments and consortia).
- Strategic planning for emergency scenarios (e.g., droughts, seismic risks).

The Value Stream Mapping (VSM) tool helps to systematically map both VA and NVA activities, visualize bottlenecks and losses, and prioritize corrective actions. In the Sicilian case, VSM could reveal delays in decision-making, inefficiencies in authorization chains, and a lack of preventive planning offering a concrete roadmap for restructuring water governance based on value creation and waste minimization.

Step 3: Definition of an Ideal Future State

A lean-optimized model is proposed for each dam or basin. This model incorporates decentralized management, predictive maintenance schedules, digital monitoring systems, and fast-track regulatory pathways for high-risk infrastructure. The goal is to redesign the flow of operations in a way that minimizes waste and maximizes reliability, focusing on:

- Process standardization: defining clear maintenance protocols and intervention procedures.
- Responsibility alignment: eliminating overlaps between agencies to enable faster decision-making.
- Technology integration: implementing real-time monitoring systems for early detection of critical issues (e.g., sediment buildup, seismic risk).
- Risk prevention logic: establishing threshold-based actions to avoid emergency situations (e.g., water discharge, drought-induced shortages).

Rather than focusing on isolated technical fixes, the Future State Map promotes a coordinated, data-driven management model, in which each dam operates under optimal and predictable conditions. For example, sediment removal in Pozzillo, structural certification for Trinità, and infrastructure activation for Gibbesi would no longer be reactive actions but part of a scheduled improvement cycle.

This phase also includes the definition of key performance indicators (KPIs) to monitor progress, such as:

- Percentage of infrastructure functionality restored
- Time reduction in authorization and repair processes
- Increase in reservoir usability rate

Designing the Future State Map allows institutions to prioritize investments, reduce dependency on emergency solutions, and foster long-term resilience core objectives in any lean transformation.

Step 4: Gap Analysis and Root Cause Investigation

This step focuses on identifying the discrepancies between the current operational state of Sicily's water infrastructure and an ideal, lean-optimized scenario. Once the Value Stream Mapping (VSM) highlights inefficiencies such as low reservoir utilization, delays in maintenance, or overlapping responsibilities between entities a gap analysis is conducted to quantify and qualify the performance shortfalls.

To go beyond surface symptoms, Lean root cause analysis tools are deployed. The 5 Whys method is applied to dig deeper into each issue for example, if preventive maintenance is not carried out, we ask: *Why?* → "Because resources are lacking." *Why?* → "Because funding is delayed." *Why?* → "Because of bureaucratic inefficiencies," and so on, until reaching the true underlying cause. In addition, a Fishbone Diagram (Ishikawa) is used to categorize contributing factors into key areas such as:

- Manpower: shortage of skilled personnel in public water authorities;
- Methods: lack of standardized inspection and maintenance protocols;
- Materials: aging infrastructure and obsolete equipment;

- Management: fragmented governance and lack of strategic planning.

This structured approach transforms anecdotal evidence into a clear picture of systemic dysfunctions. By exposing the interconnections between technical, administrative, and organizational factors, it provides a solid foundation for the development of targeted and high-impact interventions, fully aligned with the Lean principle of continuous improvement.

Step 5: Implementation Plan and Continuous Improvement (Kaizen)

The final step in the proposed Lean approach involves establishing a continuous feedback loop for performance monitoring and adaptive improvement. This includes real-time data collection on key performance indicators (KPIs) such as storage capacity utilization, leakage rates, maintenance response times, and inter-agency coordination metrics. By integrating these data into a centralized dashboard accessible to all relevant authorities, decision-makers can identify emerging inefficiencies early and act promptly. This continuous monitoring phase reflects the core Lean principle of Kaizen continuous, incremental improvement and is essential to ensure that system-wide optimizations are sustained over time and adapted to evolving climatic, infrastructural, and governance challenges.

6. Analysis and Results

The application of a Lean framework to the management of Sicilian water infrastructures reveals that inefficiencies are not merely technical but often systemic and preventable. Through a comparative analysis of three representative dams Trinità, Gibbesi, and Pozzillo we observed recurring patterns of neglect, poor coordination, and structural obsolescence that have significantly impaired the ability of these reservoirs to serve their intended purpose.

Each dam exemplifies a distinct form of inefficiency that aligns with specific categories of waste identified in Lean methodology. Trinità Dam, although technically operational, is constrained by unresolved structural and safety concerns, which force continuous water discharge into the sea. Gibbesi Dam, completed in 1992, has never entered service due to the absence of certification and vital conveyance systems an extreme case of infrastructural underutilization. Pozzillo Dam, while historically strategic, has seen its storage capacity halved due to decades of sediment accumulation and delayed maintenance interventions.

To evaluate the potential of Lean tools like Value Stream Mapping (VSM) in diagnosing these failures, we considered a set of qualitative indicators: presence of real-time monitoring, availability of preventive maintenance programs, and clarity of institutional governance. None of the three dams currently meets the minimum threshold for coordinated, proactive management. Only Pozzillo has recently entered a recovery path, thanks to a €33 million project financed through Italy's National Recovery and Resilience Plan (PNRR), which includes sediment removal and the installation of a new spillway intake.

This analysis confirms that the most critical bottlenecks are not rooted in water scarcity per se, but in misaligned governance and a chronic absence of operational oversight. As a result, reservoirs operate well below capacity, interventions are delayed by months if not years, and preventable water losses are routine. To address this, we propose the adoption of key Lean indicators to support future monitoring efforts: for example, increasing certified dam infrastructure from 43% to 80%, reducing average intervention time from 12 to under 4 weeks, and minimizing avoidable water discharge from millions to a few hundred thousand cubic meters annually.

The integration of Lean tools into water management strategies through systemic mapping, real-time data collection, and cross-agency coordination offers a scalable pathway to restore efficiency, reduce waste, and build long-term resilience in Sicily's hydraulic infrastructure.

7. Conclusion

The current water crisis in Sicily is not solely the result of shifting climatic patterns, but also a consequence of long-standing structural inefficiencies, poor governance, and the absence of preventive maintenance across the island's water infrastructure. Our comparative analysis of three major dams Trinità, Gibbesi, and Pozzillo reveals a pattern of systemic mismanagement ranging from operational underutilization to capacity degradation and bureaucratic stagnation. These inefficiencies, viewed through the lens of Lean Management, represent clear cases of non-value-adding activities, including unnecessary delays, duplicated responsibilities, and waste of both physical resources and economic investments.

By introducing Lean tools such as Value Stream Mapping and 5 Whys Analysis, we propose a pragmatic and replicable framework to expose critical bottlenecks and reorient Sicily's water governance toward performance, sustainability, and transparency. These tools offer more than operational diagnostics, they provide decision-makers with actionable pathways for change.

This research encourages a shift from reactive crisis management to proactive system optimization. It highlights the urgent need to adopt lean thinking in public water resource management not only to conserve a vital resource under increasing climatic stress, but also to restore public trust and build resilient infrastructures that can adapt to future challenges.

In this context, Sicily can serve as both a cautionary tale and a testing ground for innovative governance models. Through targeted interventions, cross-agency coordination, and investment in digital monitoring, the island has the potential to transform its vulnerability into resilience. The tools and methodology outlined in this study are a starting point what remains is the political will to implement them.

References

[1] Peres, D. J., Modica, R. & Cancelliere, A. (2019). *Assessing Future Impacts of Climate Change on Water Supply System Performance: Application to the Pozzillo Reservoir in Sicily, Italy*. *Water*, 11(12), 2531.

[2] Aschale, T. M. et al. (2024). *Analysis of Spatiotemporal Trends of Standardized Precipitation and Evapotranspiration Indexes Across Sicily (1950–2023)*.

[3] Viles, E. (2021). *Lean–Green Improvement Opportunities for Sustainable Water Consumption in the Agri-Food Industry*. *Sustainability*, 13(4), 2240.

[4] World Weather Attribution (2024). *Climate Change as Key Driver of Extreme Drought in Sicily and Sardinia.*

[5] Autorità di Bacino del Distretto Idrografico della Sicilia. (2025). *Volumi totali (al lordo di interrimenti e volumi indisponibili) presso i principali invasi siciliani: Anno idrologico ottobre 2024–settembre 2025*. Regione Siciliana – Presidenza, Servizio 1 – Tutela delle Risorse Idriche. Disponibile online: https://www.regione.sicilia.it/sites/default/files/2025-08/2025.08.01_C_Grafici_volumi_invasi.pdf.

[6] Enel Green Power. (2023). *Pozzillo Dam Project – PNRR Sustainability Intervention*. Retrieved from https://www.enelgreenpower.com.

[7] Protezione Civile – Ministero delle Infrastrutture. (2024). *Relazione tecnica sulla diga Trinità e piano di svuotamento controllato*. Internal communication.

[8] Womack, J.P., & Jones, D.T. (2003). *Lean Thinking: Banish Waste and Create Wealth in Your Corporation*. New York: Free Press.

[9] Picone, M. (2024). *La crisi idrica in Sicilia: cause strutturali e soluzioni sistemiche*. *Geopolitica.info*, 12(3), 45–59.

[10] Liker, J.K. (2004). *The Toyota Way: 14 Management Principles from the World's Greatest Manufacturer*. McGraw-Hill.