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Conflicts of Use and Environmental Governance in the Bizerte Lagoon:

A Strategic Analysis Using the MACTOR Method

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Conflicts of Use and Environmental Governance in the Bizerte Lagoon: A Strategic Analysis Using the MACTOR Method

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Abstract
Coastal lagoons represent critical socio-ecological systems facing intense governance conflicts due to competing uses and institutional fragmentation. This study employs the MACTOR (Matrix of Alliances and Conflicts: Tactics, Objectives, and Relationships) method to analyze actor dynamics, power asymmetries, and governance conflicts in the Bizerte Lagoon (Tunisia), a Mediterranean hotspot experiencing severe ecological degradation from industrialization, fisheries, aquaculture, and agricultural pressures. Through systematic mapping of 17 actors (governmental, economic, civil society) and 9 governance objectives (economic, social, environmental, institutional), we reveal a stratified power structure characterized by: (1) Dominant actors (Ministry of Environment, industrial operators, military) wielding disproportionate influence while resisting accountability; (2) Relay actors (e.g., sanitation agencies, local authorities) trapped in high-dependence roles, exacerbating implementation gridlock; and (3) Marginalized actors (artisanal fishers, shellfish farmers) bearing ecological burdens without decision-making agency. MACTOR's quantitative matrices (MDII, Ri/Qi, 2MAO) expose irreconcilable conflicts between pro-development and pro-conservation blocs, particularly over industrial expansion (E3) versus water quality (V1) and equity (SE1). Notably, latent power potential (Qi) among resource-dependent actors and civil society remains untapped due to institutional barriers. Our findings demonstrate that environmental degradation in Bizerte stems not from resource scarcity but from governance failures rooted in power asymmetries and institutional fragmentation. We advocate for transformative governance reforms: redistributing decision-making power, integrating polycentric management, and leveraging latent actor potential (e.g., fishers' ecological knowledge, universities' technical expertise) to reconcile ecological sustainability with social equity. This study advances strategic actor analysis as a critical tool for diagnosing and resolving intractable socio-ecological conflicts in contested coastal systems worldwide

KEYWORDS
Environmental governance, MACTOR method, Stakeholder analysis, Coastal lagoon management, Use conflicts, Bizerte Lagoon, Tunisia, , Institutional fragmentation, Strategic analysis

JEL Classification Codes
Q24 , Q56 , D74 , R11, O13

1.Introduction

Coastal lagoons represent highly complex socio-ecological systems where the interpenetration of natural processes and human activities generates governance challenges that defy conventional management paradigms. These transitional environments, situated at the dynamic interface between terrestrial, freshwater, and marine realms, provide essential ecosystem services including fisheries production, nutrient cycling, shoreline stabilization, biodiversity conservation, and cultural heritage preservation (Barbier et al., 2011; Rodrigues-Filho et al., 2023). Yet, their ecological significance and economic accessibility simultaneously render them focal points of intense competing uses, transforming them into arenas of persistent governance conflicts (Adger et al., 2006). The governance of these systems transcends technical environmental management to become a profoundly political process characterized by power struggles, institutional fragmentation, and contested rationalities (Lemos & Agrawal, 2006). Within this context, conflicts of use emerge not merely as disputes over resource allocation but as manifestations of deeper structural tensions between divergent societal objectives—industrial development versus ecological sustainability, economic growth versus social equity, and state authority versus community autonomy (Ostrom, 2009; Paavola, 2007).

The Mediterranean Basin presents a particularly compelling laboratory for examining these governance dynamics. As a semi-enclosed sea with millennia of intensive human interaction, its coastal lagoons exhibit deeply entrenched conflicts shaped by historical legacies of resource exploitation, contemporary development pressures, and accelerating global change (Pérez-Ruzafa et al., 2019). The region's governance landscape is characterized by overlapping jurisdictions, weak coordination mechanisms, and persistent tensions between supranational directives (e.g., EU environmental frameworks) and national development priorities (Pérez-Ruzafa and al. (2019). These institutional deficiencies are exacerbated by the Mediterranean's status as a global biodiversity hotspot experiencing disproportionate impacts from climate change, coastal urbanization, and mass tourism, creating synergistic pressures that intensify conflicts over resource access and pollution control (Micheli et al., 2013). Within this regional context, the Bizerte Lagoon in Tunisia emerges as an archetypal case study where governance conflicts have produced severe environmental degradation while resisting resolution through conventional policy approaches.

The Bizerte Lagoon is one of Tunisia’s largest coastal lagoons and a key socio-economic hub in northern Tunisia. Its coastline and maritime areas support a wide range of human activities, including coastal fishing, shellfish farming, maritime transport, military operations, recreational fishing, and urban settlements with associated wastewater discharges, industrial installations including metallurgical, cement, textile, and boatyard sectors, and recreational or tourism uses. Yet, this very multiplicity of uses creates overlapping spatial and functional claims, generating complex socio-economic and governance conflicts. Documented confrontations between fishers and shellfish farmers, such as the destruction of shellfish farm infrastructure in 2019, illustrate how competition over productive zones, perceived pollution, and lack of transparent regulatory mediation can escalate into open conflict (Hamdaoui et al., 2022; Yahyaoui · 2018 ·, 2018). Meanwhile, industrial and municipal effluents — including heavy metals, hydrocarbons, nutrients, and microbial pollutants — exacerbate environmental degradation, affecting fisheries, aquaculture, and recreational spaces, thereby indirectly amplifying disputes over access, quality, and equity (Mahfoudhi and al., 2025; FAO/GFCM, 2023). Recreational users, tourism operators, and urban stakeholders further contribute to the complexity of competing claims on space and water quality, highlighting the multi-dimensionality of lagoon conflicts.

Institutional fragmentation compounds these pressures. Management responsibilities in Bizerte Lagoon are distributed across multiple ministries (fisheries, environment, urban planning, industry, maritime transport), local authorities, and civil society organizations, each with overlapping or unclear mandates, inconsistent enforcement, and insufficient integration of stakeholders into decision-making processes (DHV, 2011; M. El Mahrad,and , 2020). This fragmented governance landscape favors economically and politically powerful actors — industrial firms, port authorities, commercial investors — while marginalized groups, such as artisanal fishers, small-scale aquaculturists, recreational users, and local communities, lack formal representation and secure tenure.

The theoretical landscape of environmental governance scholarship has increasingly recognized that such conflicts are endemic to complex socio-ecological systems, where multiple actors with heterogeneous values, interests, and power resources interact within fragmented institutional

environments (Ostrom, 2010). These conflicts are particularly intractable because they involve "wicked problems" characterized by irreducible complexity, profound uncertainty, and the absence of unambiguous solutions (Rittel & Webber, 1973). Critical governance perspectives emphasize that environmental outcomes are co-produced through strategic interactions among actors operating within specific institutional arrangements, where power asymmetries systematically favor certain interests while marginalizing others (Robbins, 2012). The persistence of environmental degradation in many coastal systems can thus be attributed less to ecological ignorance and more to governance failures rooted in institutional designs that perpetuate inequitable power relations and exclude vulnerable stakeholders from decision-making processes (Agrawal, 2001; Marshall, 2008).

To operationalize these theoretical insights, the MACTOR (Matrix of Alliances and Conflicts: Tactics, Objectives, and Relationships) provides a robust analytical tool. By systematically identifying stakeholders, their objectives, strategic influence, alliances, and conflicts, MACTOR enables the simulation of governance scenarios that reflect real-world power dynamics and potential negotiation pathways (Godet, 1991; El-Fadel et al., 2013; Grenon et al., 2008).. This approach is based on successful applications in the field of natural resource management, notably the analysis by Fetoui et al. (2020) on stakeholder cooperation in the restoration of rangelands in southern Tunisia. This analysis demonstrated how strategic stakeholder analysis can identify levers for collective action. The hybrid methodology of the method—combining qualitative fieldwork and quantitative matrix modeling—preserves contextual nuances while providing the analytical rigor necessary to reveal not only the identity of actors, but also how their relationships and power dynamics shape the evolution of conflicts (Ardiyanto et al., 2024). By highlighting hidden power structures that conventional governance approaches overlook, MACTOR offers a path that goes beyond simply mapping conflicts to provide a transformative analysis capable of identifying potential alliances and strategic opportunities for institutional innovation.

Consequently, studying conflicts of use and environmental governance of a lagoon using the MACTOR method aims not only to describe tensions, but also to understand the dynamic interaction of power, interests, and negotiations between actors. Ultimately,this approach helps identify paths toward integrated and adaptive governance, where ecological sustainability, economic vitality, and social well-being can coexist. Such an analysis is particularly relevant today, as lagoons are under increasing pressure from climate change, population growth, and unsustainable exploitation. Developing a governance model that balances these competing forces is both a scientific challenge and an urgent necessity for the preservation of coastal ecosystems.

This research has three interrelated objectives: (1) to identify and characterize the key actors shaping the socio-ecological system of the Bizerte lagoon, including their objectives, strategies, and resources; (2) map the relational structures—alliances, conflicts, and power relations—that influence governance outcomes; and (3) assess the implications of these strategic dynamics for promoting integrated, equitable, and sustainable environmental governance. Through these objectives, we put forward three main arguments: first, the conflicts in the Bizerte lagoon are not, strictly speaking, conflicts over resource scarcity, but conflicts over governance, rooted in institutional structures that favor the interests of elites at the expense of collective well-being (Ostrom, 1990). Second, power asymmetries—particularly between industrial actors and regulatory bodies—create path dependencies that lock the system into unsustainable trajectories (North, 1990). Third, resolving these conflicts requires institutional innovation that redistributes decision-making power to marginalized actors and promotes negotiated solutions through structured dialogue (Ansell and Gash, 2008).

The remainder of this article is organized as follows. Section 2 details the study area, the MACTOR methodology, and data collection procedures, thereby establishing the analytical framework for examining the strategic dynamics of actors. Section 3 presents empirical results relating to stakeholder characterization, conflict matrices, and power hierarchies, revealing the structural foundations of governance conflicts in the Bizerte lagoon. It also examines the theoretical and practical implications of these results, focusing on avenues leading to conflict-sensitive co-management and reform. Section 4 concludes by summarizing the main contributions, acknowledging the limitations of the study, and outlining directions for future research on governance conflicts in complex socio-ecological systems. By highlighting conflicts of use and governance dynamics through the lens of strategic actor analysis, this study demonstrates how methodologies such as MACTOR can shed light on the political ecology of resource control and contribute to transformative approaches to environmental governance in contested coastal systems around the world.

2. MATERIALS AND METHODS

2.1 Study area

We carried out this study in Bizerte District, Tunisia, from June 2024 to June 2025. Bizerte Lagoon—one of the biggest coastal lagoons in Tunisia—spans about 128 square kilometers, with an average depth of 7 meters (Bejaoui et al., 2008). It's a rich ecosystem, home to sprawling seagrass meadows, vital fish nurseries, and internationally important bird habitats. At the same time, it fuels the local economy, supporting industries, small-scale fisheries, and aquaculture (Hamdaoui et al., 2022). Sitting in northern Tunisia (37°08' to 37°14'N, 9°46' to 9°56'E), Bizerte Lagoon stands out as Tunisia's second-largest lagoon. It's a linchpin for the Gulf of Tunis ecosystem, supporting roughly 50,000 people in the surrounding watershed. Over 120 fish species live here. Shellfish thrive, and every winter, migratory birds flock to the lagoon in huge numbers (Béjaoui et al., 2008). The lagoon isn't just a haven for wildlife—it's an economic engine. Historically, more than 3,000 artisanal fishers worked these waters, with annual catches once worth millions of dollars. Shellfish aquaculture is picking up steam, now employing about 500 people and bringing in new export revenue (Hamdaoui et al., 2022). Industry shapes the region, too. The lagoon's prime location has drawn more than 300 facilities—oil refineries, chemical plants, steel mills—all together generating about 35% of the regional GDP and creating thousands of jobs (ANPE, 2020). Ports along the shore keep trade moving and tie the region into global markets. The surrounding farmland feeds rural communities and provides jobs, even though runoff from these fields adds to water pollution. Tourism lags behind, mostly because of environmental problems, but the lagoon's beauty and cultural significance show it could attract many more visitors. All these economic activities are tangled together. When the environment suffers, jobs and livelihoods take a direct hit. Decades of unchecked development since the 1970s have seriously damaged the lagoon, leaving it one of North Africa's most polluted coastal waterways (Ben Ameur et al., 2013). Industrial growth, city populations that have tripled since 1970, and a more than 400% jump in fertilizer use have all piled on the pressure (ANPE, 2020).

1. MATERIALS AND METHODS

2.1 Study area

This study was conducted in the district of Bizerte (Figure 1), Tunisia, from June 2024 to June 2025. The Bizerte lagoon, one of the largest coastal lagoons in Tunisia, covers an area of approximately 128 km² and has an average depth of approximately 7 m (Bejaoui et al., 2008). Ecologically, it is home to seagrass beds, including essential nursery areas for fish, as well as bird habitats of international importance. Economically, it supports industrial activities, artisanal fishing, and aquaculture (Hamdaoui et al., 2022). Located in northern Tunisia (37°08' to 37°14' N, 9°46' to 9°56' E), the Bizerte lagoon is a particularly good example of these Mediterranean issues, being the second largest lagoon system in Tunisia (area of 128 km², average depth of 7 m, maximum depth of 12 m). This essential component of the Gulf of Tunis ecosystem supports approximately 50,000 people in its watershed and is home to remarkable biodiversity, with more than 120 species of fish, large shellfish populations, and crucial wintering areas for migratory birds (Béjaoui et al., 2008). Beyond its ecological importance, the lagoon is of considerable economic importance at the regional and national levels. Its fishing sector has historically supported more than 3,000 artisanal fishermen, with annual catches once valued at several million dollars, while the booming shellfish aquaculture industry employs around 500 people and represents a growing source of export revenue (Hamdaoui et al., 2022). The lagoon's strategic location has made it a hub for industrial development, hosting more than 300 facilities, including oil refineries, chemical plants, and steel mills, which collectively contribute about 35% to regional GDP and generate thousands of jobs (ANPE, 2020).

The port infrastructure along the lagoon handles significant maritime trade, thereby strengthening the region's economic integration into global markets. In addition, the surrounding agricultural land, while contributing to pollution through runoff, provides essential food production and employment for rural communities. Tourism, currently underdeveloped due to environmental degradation, holds untapped potential given the lagoon's natural beauty and cultural heritage. This multifaceted economic

dependence creates complex interdependencies where environmental degradation directly threatens livelihoods in multiple sectors, intensifying conflicts over resource use and pollution management. Indeed, decades of uncontrolled development since the 1970s have severely compromised the ecological integrity of the lagoon, transforming it into one of the most polluted coastal waterways in North Africa (Ben Ameur et al., 2013). Rapid industrialization, urban expansion that has tripled the population of neighboring cities since 1970, and agricultural intensification, which has increased fertilizer use by more than 400%, have led to complex pollution (ANPE, 2020).

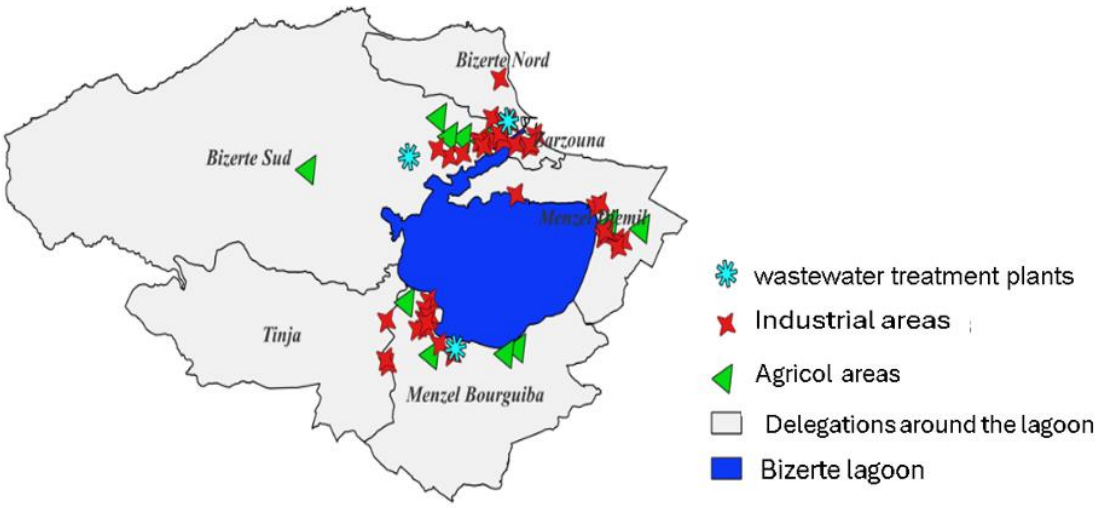


Figure 1 Spatial distribution of industrial zones agricultural areas and wastwater treatment plantes in Bizerta lagoon 2025.

2.2 The MACTOR method: Theoretical foundations and operational framework

The MACTOR method (Matrix of Alliances and Conflicts: Tactics, Objectives, and Relationships), developed by Michel Godet in the early 1990s, is a sophisticated strategic analysis tool designed to decipher the complexity of multi-stakeholder systems characterized by divergent interests, power imbalances, and dynamic interdependencies (Godet, 1991). Unlike traditional stakeholder analysis approaches, which simply identify actors and their interests, MACTOR offers a rigorous and systematic framework for quantifying influence relationships, mapping convergences and divergences in objectives, and simulating strategic scenarios that reveal the underlying power structures that shape governance outcomes (Fetoui et al., 2020). Its theoretical foundations draw on multiple disciplines, including game theory, systems analysis, and strategic management, to create a hybrid methodology combining qualitative contextual understanding and quantitative relational modeling. This makes MACTOR particularly well-suited to analyzing complex environmental governance contexts such as the Bizerte lagoon, where conflicts emerge from complex interactions between ecological processes, economic interests, institutional structures, and social dynamics.

The MACTOR method provides a comprehensive framework for analyzing stakeholder relationships through various indicators and matrices. Direct and indirect influence matrices (MDI and MDII) reveal power dynamics, while balance of power indicators (RI and QI) quantify the relative influence and dependence of actors. The matrices of relationships between actors' objectives (2MAO and 3MAO) map actors' positions on key objectives, and the convergence and divergence matrices (CAA and 3DAA) identify areas of convergence and divergence (conflict). Together, these indicators(Table1) provide valuable information for strategy development.

Table 1 MACTOR Matrices Based on Michel Godet's methodology.

	Purpose	Formula	Interpretation
1MAO	Is the **initial Actors/Objectives Matrix** I used to analyze the system.		
MDII The Matrix of Direct an Indirect Influences	determines the direct or indirect influences of order 2 between actors.	(MDII)ij = (MDI)ij + Σk Min ((MDI)ij , (MDI)ik) "(MDI)ij" the direct influence actor i has on actor j. The "Σk Min ((MDI)ij , (MDI)ik)"is the sum of all indirect influences actor i exerts on actor j, and which flow through an intermediary actor k Two indicators are calculated from the MDII: -The degree of direct and indirect influence of each actor (Ii, by summing rows). -The degree of direct and indirect dependence of each actor (Di, by summing columns)	- **Rows**: Influence exerted by an actor. **Columns**: Dependence of an actor. **Key Insight**: Actors with **high influence/low dependence** are pivotal; **high dependence/low influence** are vulnerable.
Ri	Total influence of actor *i*	Ri = [(Ii – (MDII)ii) / S] x [Ii / (Ii + Di)] Where S = Σi Ii = Σi Di	The bigger the scalar, the more competitive an actor is. High value → *i* is a dominant actor.
Qi*	the competitiveness of actor i considering its max: influences; direct and indirect dependence; and feedback.	Qi = (IMAXi / Σk IMAXk) x (IMAXi / (IMAXi + DMAXi)) Qi* = n x (Qi / Σk Qk Qi* correspond to the normalised Qi.	

2MAO **Matrix Actors/Object**	Extended MAO	The Matrix of Actors Objectives (2MAO) is in the form of Actor X Objectives. This shows for each actor: its valency on each objective (favourable, opposed to, neutral or indifferent) and the objective hierarchy	Five levels of intensity characterising the degree of priority of the objective for the actor: **4** : Objective jeopardises the actor's existence / is vital for its existence, **3** : Objective jeopardises the accomplishment of the actor's mission / is vital for its missions, **2** : Objective jeopardises the success of the actor's projects / is vital for the success of its projects, **1** : Objective jeopardises the actor's operating procedures (management, etc...) / is vital for its operating procedures, **0** : Objecive has a bleak outcome. **Strategic Insight**: Reveals coalitions and conflicts; high positive/negative sums indicate strong alliances/oppositions.
3MAO Matrix of Alliances and Oppositions	Extend MAO with **intensity** of alliances/oppositions.	$(3MAO)_{ij}=R_i*(2MAO)_{ij}$ Similar to MAO but adds weights:- **Intensity**: **+3** (strong alliance), **+1** (weak alliance), **-3** (strong opposition), **-1** (weak opposition).	- **Weighted Values**: Reflect strength of relationships. **Use Case**: Prioritizes critical alliances/oppositions; identifies fragile vs. robust coalitions.
CAA Convergence Matrix of Actors	Quantify overall convergence between actor pairs.	$CAA_{ij} = \frac{\sum_k \min(2MAO_{ik}, 2MAO_{jk})}{\sum_k \max(2MAO_{ik}, 2MAO_{jk})}$	- High value → strong convergence of objectives (cooperation potential

3CAA weighted valued matrix of convergences	Enhance CAA with **weighted intensity** from 3MAO.	*If ((3MAO)$_{ik}$*(3MAO)$_{jk}$)>0* *So (3CAA)$_{ij}$=1/2*(|(3MAO)$_{ik}$ |+| (3MAO)$_{jk}$ |)* Otherwise *(3CAA)$_{ij}$=0* *The degree of convergence is related to the valued positions:* *3C = (åij (3CAA)ij) / (åij (3CAA)ij + åij (3DAA)ij)) x 100*	- **Weighted Sums**: More nuanced than CAA.- **Insight**: Highlights high-stakes convergences/divergences; identifies "swing" objectives that alter relationships.
DAA The Matrix of divergences of objectives between actor	identifies for each couple of actors the number of objectives on which these actors do not hold the same position.	$DAA_{ij} = \sum_{k=1}^{n} \frac{\lvert a_{ik} - a_{jk} \rvert}{2}$ Where: • n = total number of objectives • $\lvert \alpha^{ik} - \alpha^{jk} \rvert$ = absolute difference of positions on objective k	-. High divergence values indicate high risk of strategic conflict between actors.
3DAA The weighted valued matrix of divergences	Extend DAA with **importance weights** for objectives.	Similar to DAA but adds: **Importance Weight: 3** (critical), **2** (important), **1** (minor). $3DAA_{ij} = DAA_{ij} \times \min(P_i, P_j)$ Pi,Pj = influence/power of actors iii and jjj.	- **Weighted Priorities**: Highlights objectives critical to actors. **Strategic Use**: Identifies non-negotiable objectives; informs conflict resolution.

The MACTOR operational framework is structured around four sequential analytical phases, each building on the previous one to gradually deepen understanding of the dynamics of actor systems (Godet, 1991; Bendahan et al., 2004). The first phase consists of an exhaustive identification of actors, systematically listing all entities that exert a significant influence on the system, regardless of their formal status. This identification encompasses not only officially recognized institutions, but also informal networks, marginalized groups, and external entities whose decisions indirectly influence local outcomes. In the context of the Bizerte lagoon, this required going beyond the most obvious actors, such as government agencies and industrial operators, to include fishing cooperatives, agricultural associations, environmental NGOs, international funding agencies, and even military authorities whose spatial control has an impact on access to the lagoon. The theoretical basis for this approach is systemic thinking, which emphasizes that the behavior of a system emerges from the interactions between all its relevant components, not just the most visible ones (Meadows, 2008).

The second phase is devoted to mapping and prioritizing objectives. Researchers identify and weigh the strategic objectives of each actor. This step recognizes that actors pursue multiple objectives simultaneously—some explicit, others implicit—and that conflicts arise not only from competition for resources, but also from fundamental differences in priorities (Fetoui et al., 2020). Objectives are classified into three categories: defensive (preventing undesirable consequences), offensive (achieving positive objectives), and relational (influencing the behavior of other actors). For example, industrial operators may favor offensive objectives such as production expansion and regulatory flexibility, while artisanal fishers focus on defensive objectives such as preventing habitat destruction and maintaining access to fishing areas. The MACTOR framework requires researchers to distinguish between stated (publicly announced) objectives and revealed (inferred from behavior) objectives, as discrepancies often indicate strategic positioning or hidden intentions (Godet, 1991).

The third phase constitutes the core analytical engine of MACTOR: the construction and quantification of the matrix. This involves the development of three interdependent matrices that mathematically represent

2.3 Collection Data

The data for this study was collected between March 2024 and October 2025 from primary and secondary sources, providing a comprehensive understanding of stakeholder interactions and governance issues in the Bizerte lagoon. Primary data was collected through intensive fieldwork, including direct observations, semi-structured individual interviews, group discussions, and structured surveys. A total of 403 people participated in the survey, including 109 farmers, 138 fishermen, and 156 local residents, providing a representative overview of the main stakeholder groups. These primary interactions provided valuable qualitative information on stakeholders' perceptions, expectations, and potential sources of conflict. In addition, secondary data was collected from peer-reviewed scientific

articles, academic theses, and institutional reports, providing historical context, technical information, and evidence to triangulate and validate the field findings.
In terms of methodology, participants were invited to a dedicated multi-stakeholder workshop to assess the degree of influence each actor had on the others. Mutual influences, as well as affinities between stakeholders and predefined objectives, were assessed using the MACTOR rating system (0-4), reflecting the perceived intensity and importance of interactions or challenges (Godet, 2010; Knaggård et al., 2019).
The final analytical dataset was compiled in two parallel stages: (1) individual interviews with each stakeholder group and (2) a collective workshop bringing together all actors Integrating insights from these individual interviews with the collective reflections from the workshop made it possible to refine the system database used for the MACTOR analysis (Anggraeni et al., 2019; Newton & Elliott, 2016).
In this context, interactions between stakeholders were represented by identifying the actors and their associated objectives, which constitute the main entry points of the MACTOR method. Consequently, the configuration of the system—both the network of actors and the objective structure—is largely shaped by the perceptions of the participants (Godet, 2010).

3.RESULTS AND DISCUSSION

3.1. Actor Identification

The governance of the Bizerte lagoon involves a diverse group of stakeholders, each with distinct interests, responsibilities, and degrees of influence. The identification of actors for the MACTOR analysis of the Bizerte lagoon follows Michel Godet's (1991) rigorous methodological framework, which requires the inclusion of all entities exercising decision-making power, experiencing direct impacts on the system, or controlling critical resources. This rationale explains why each actor meets these criteria, ensuring that the inventory comprehensively captures the socio-ecological and political dynamics of the lagoon without redundancy. Based on their roles and interactions, actors can be grouped as follows:
The MACTOR method was applied according to a structured, multi-step process that included identifying stakeholders, defining objectives, and constructing the matrix. Seventeen stakeholders (n=17) were identified through documentary analysis and expert consultations. They include government agencies (Ministry of the Environment, Ministry of Agriculture and Health, Ministry of Food and Sports, Ministry of Agriculture and Sports, Ministry of Rural Affairs Development, local authorities, regional authorities), economic actors (industrialists, UTICA, UTAP, fishermen, shellfish farmers, farmers), representatives

Direct users of resources

1. Artisanal fishers: Artisanal fishers are direct users of the lagoon's fishery resources. They depend on deep-sea and coastal fishing for their livelihoods. Their role in governance involves participation in local committees, fishing associations, and consultations with authorities. They contribute local ecological knowledge about fish stocks, seasonal variations, and resource availability, thereby contributing to sustainable management. Their direct dependence on the lagoon makes them highly sensitive to environmental changes and pollution.
2. Shellfish farmers: Shellfish farmers are direct users specializing in aquaculture and shellfish production. They operate under authorized concessions and are organized into cooperatives or professional associations. Their participation in governance includes complying with licensing and water quality monitoring requirements, collaborating with environmental agencies, and negotiating land use and resource access. Their intensive use of lagoon areas makes them key players and particularly sensitive to industrial or environmental impacts.
3. Agricultural producers: Farmers living near the lagoon are indirect users, as their irrigation practices and land use decisions affect water quality, sedimentation, and nutrient inputs to the lagoon. They participate in governance through agricultural regulations, land use planning, and initiatives to reduce runoff and pollution, thereby indirectly affecting the ecological health of the lagoon.

4. Industrial and port stakeholders: Industrial facilities and port authorities are indirect users of the lagoon. They depend on access to the lagoon for navigation, industrial operations, and logistics. Their role in governance includes complying with environmental regulations, participating in planning consultations, and negotiating development priorities. Their activities have a significant impact on water quality, habitat integrity, and resource availability, creating conflicts with direct users of these resources.

Government institutions and regulatory bodies

5. The Department of the Environment, together with its agencies APAL and ANPE, is responsible for environmental protection, land use planning, and scientific monitoring. APAL focuses on the conservation and management of coastal and lagoon areas, including land use regulation and habitat protection, while ANPE monitors water quality, soil conditions, and pollution control.
6. ONAS, although also under the Ministry of the Environment, has a distinct operational and technical role, managing wastewater treatment and sanitation infrastructure, with direct impacts on water quality and public health.
7. The Ministry of Agriculture sets national agricultural and fisheries policies.
8. The Regional Agricultural Development Commission (CRDA-Bizerte) implements regional development programs and supports local producers, facilitating coordination between communities and government initiatives. Their neglect of the externalities of pollution makes them responsible for degradation.
Their failures in coordination lead to institutional fragmentation.

Local authorities and economic organizations

9. Local authorities (municipalities, governorates): Retained for the issuance of land use permits and their proximity to communities. They ensure territorial coordination, security, and local planning. Their vulnerability to pressure from real estate developers leads to spatial injustices.
10. UTICA (Tunisian Union of Industry, Commerce, and Handicrafts): Represents industrial and commercial interests in decision-making. Maintained for its political influence (lobbying against regulation) and representation of industrial interests. Its power perpetuates its stranglehold on institutions .
11. UTAP (Tunisian Union of Agriculture and Fisheries): Represents farmers and fishermen and facilitates dialogue with the authorities.

Communities and civil society

12. Residents and riparian communities: As direct users and beneficiaries of the lagoon ecosystem, their involvement ensures social acceptance of governance measures.
13. NGOs and associations: Advocacy for environmental protection and implementation of conservation projects. Their role is essential in providing a counterbalance (combating pollution) and representing communities. Their role in monitoring and legal action helps to hold regulatory bodies accountable.
14. Universities and research centers: Contribution of scientific knowledge, monitoring, and evaluation of ecosystem health.

International and specialized actors

15. International community (international actors): Provides funding, technical expertise, and harmonization with international standards and conventions. Its conditional support influences national priorities.
16. Armed forces: Ensures security and protects strategic areas around the lagoon. The exclusion of civilians is at the heart of spatial injustices (Equity) and habitat loss (V2).

Tale 2 : Actor Identification and Characterization Protocol

Stakeholders	Use of resources	Feedback (caused or suffered effects)	Dependence	Main interests
Fishermen	Small-scale/artisanal fishing (fish, crustaceans)	Pollution → declining catches, economic insecurity	Very high	Resource preservation, income stability
Shellfish farmers	Mussel/oyster farming	Pollution → mortality, loss of sanitary certification	Very high	Clean water, sanitary standards, technical/logistic support
Industrial sector	Water use, port facilities, waste discharge	Major source of pollution	Medium	Productivity, limited regulatory constraints
Farmers	Irrigation, fertile soils	Eutrophication → water pollution	Medium	Access to water, soil fertility, sustainable practices
Academics & researchers	Data collection, scientific studies	Knowledge production → influences policy	Low to medium	Research funding, academic recognition, policy impact
Ministry of Environment	Regulatory tools, pollution control	Implements international conventions	Institutional	Biodiversity protection, compliance with global commitments
Ministry of Agriculture & Fisheries	Quota regulation, technical support	Balancing exploitation vs. conservation → internal tensions	Institutional	Productivity, employment, modernization of sectors
Local authorities	Urban planning, waste management, infrastructure	Poor management → domestic waste, urban sprawl	Medium	Local development, attractiveness, social cohesion
Local population	Fish/seafood consumption, leisure, quality of life	Health risks, environmental degradation	Medium to high	Jobs, public health, better living conditions
Military	Secured coastal areas, naval base facilities	Mainly security role, limited exploitation	Low	Maritime security, sovereignty, surveillance

International actors	Funding, technical expertise, pilot projects	Provide solutions but with conditionalities	Low	Ecosystem protection, regional cooperation, global commitments

3.2 Strategic issues and associated objectives in the governance of the Bizerte lagoon

Identifying strategic issues and their associated objectives is the foundational phase of the MACTOR method, as described by Michel Godet (1991) in « De l'anticipation à l'action : Manuel de prospective et stratégie » (From Anticipation to Action: A Handbook of Forecasting and Strategy). This phase goes beyond simply mapping stakeholders and aims to diagnose systemic conflicts and governance challenges by linking observable problems to concrete objectives.
These objectives are structured around four interdependent pillars: Economic (supporting small-scale fishing – E1, developing shellfish farming – E2, promoting industrial and port development – E3), Socio-economic (ensuring equitable access to resources – SE1, ensuring public health and quality of life – SE2), Environmental (improve water quality – V1, preserve biodiversity and habitats – V2) and Governance (strengthen stakeholder participation – Gov.Part, effectively enforce environmental regulations – Gov.Reg).

Strategic Issue	Associated Objectives
1. Economic-Environmental Trade-offs	• E1 E2, E3, V2, Gov.Reg
2. Spatial Injustice & Social Exclusion	• SE1, Gov.Part
3. Institutional Fragmentation & Regulatory Capture	• Gov.Part , Gov.Reg
4. Pollution-Health-Environment Nexus	• V1, V2, SE2, Gov.Reg
5. Legitimacy Deficit	• Gov.Part, Gov.Reg, SE1
6. Socioeconomic Vulnerability & Livelihood Dependence	• E1, E2, SE1, Gov.Part, SE2, V2

The first strategic challenge, the *economic-environmental trade-offs*, , arises from the dual role of the lagoon as both an economic driver and an ecological sanctuary. Industrial development, fishing, and aquaculture generate jobs and income, but also lead to habitat loss and pollution, creating a paradox of "growth at all costs" (Mejjade et al., 2023; Hailue et al., 2023; Nobi & Islam, 2021). Five objectives aim to remedy this: support for artisanal fishing (E1), development of shellfish farming (E2), industrial and port development (E3), preservation of biodiversity and habitats (V2), and effective enforcement of environmental regulations (Gov.Reg). E1 supports more than 3,000 households and represents cultural heritage, while E2 reconciles economic growth and ecological sustainability. E3 stimulates GDP and employment, but requires rigorous management to prevent habitat destruction, pollution, and eutrophication. V2 increases functional habitats and biological productivity, thereby reducing competition between fishermen, aquaculturists, and industrialists. Together with Gov.Reg, these objectives reconcile short-term economic gains with long-term ecological resilience.

The strategic issue of *spatial injustice and social exclusion* in the Bizerte lagoon arises from the overlapping and competing uses, including artisanal fishing, shellfish farming, port activities, industrial activities and military zones. These pressures have reduced access to resources for smallholder farmers, degraded the ecosystem and led to conflicts over space and resource distribution (Hamdaoui et al., 2022; Allouche et al., 2024). In response, the SE1 strategic objective – ensuring equitable access to resources and lagoon areas – directly addresses this problem by optimizing legally and physically available areas

for fishing, aquaculture and navigation. By prioritizing access to these areas, SE1 reduces exclusion and promotes an equitable distribution of lagoon resources between traditional users and marginalized groups. At the same time, the Gov.Part objective – to strengthen participatory governance – makes social inclusion a reality by involving local communities, fishermen and shellfish farmers in decision-making, co-management and negotiation of user rights. This dual approach links the strategic issue to concrete objectives: SE1 guarantees spatial equity, while Gov.Part guarantees procedural fairness, thus promoting redistributive justice, conflict reduction and sustainable lagoon management. (Hamdaoui et al., 2022).

The third strategic challenge, institutional fragmentation and regulatory capture, is the result of overlapping mandates between elve agencies (e.g. ANPE, APAL, ONAS), leading to coordination gaps. Industrial actors exploit these gaps, while communities face penalties for minor violations. The objectives to address this problem are participatory governance (Gov.Part) and effective enforcement of environmental regulations (Gov.Reg). Gov.Part ensures co-management and community participation, while Gov.Reg harmonizes fragmented regulation and applies credible sanctions.

The fourth strategic issue – the pollution-health-environment nexus – is evident when considering the multiple pressures that affect the Bizerte lagoon. Studies have shown that sediments in the lagoon contain high levels of trace metals (Cd, Pb, Ni, Zn, etc.), particularly near urban and industrial discharge points (Allouche, Trabelsi and Ben Halima, 2024). In addition, organic pollutants, including hydrocarbons, polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs) and pesticides, have been detected in sediments and tributary rivers, indicating widespread chemical contamination (Allouche et al., 2024). These contaminations are associated with significant alterations of benthic communities, including foraminifera and bacterial assemblages, demonstrating concrete ecological impacts on lagoon habitats, although their severity varies spatially (Allouche et al., 2024). In addition, some fish caught commercially in the lagoon had high concentrations of heavy metals (Pb, As, Cd, Zn), posing a potential food safety risk to local consumers (Mejjad et al., 2023).

Based on these observations, the strategic objectives to address this problem are the improvement of water quality (V1), the preservation of biodiversity and habitats (V2), public health and quality of life (SE2), and the effective enforcement of environmental regulations (Gov.Reg). This set illustrates MACTOR's causal logic: pollution causes health crises, requiring the application of regulations to resolve systemic impacts.

The fifth strategic issue, the *legitimacy deficit*, stems from a widespread mistrust of local communities towards decision-making institutions. Opaque and vertical processes prioritize industrial and political interests over environmental sustainability and social equity. Objectives to address this include Gov.Part, aimed at empowering stakeholders in inclusive decision-making; Gov.Reg, to ensure equitable enforcement of regulations; and SE1, to codify equitable distribution of resources and recognize traditional rights. Together, these measures restore institutional credibility, transforming governance from a source of conflict into a catalyst for sustainable development.

The sixth strategic issue, *socio-economic vulnerability and livelihood dependence*, recognizes the strong dependence of local communities on lagoon resources for their income, food security and cultural practices. Declining fish stocks, environmental degradation and limited access to resources are exacerbating poverty, gender inequalities and social vulnerability, intensifying conflicts over their use. Objectives addressing this challenge include E1 and E2, to strengthen livelihoods; SE1 and Gov.Part, to ensure equitable access to resources and participatory governance; SE2, to manage health risks; and V2, to preserve ecosystem services essential to livelihoods. Integrating environmental sustainability with socio-economic resilience reduces conflict, improves community well-being and ensures the long-term sustainability of lagoon resources.

Validation of objectives within MACTOR ensures their operability, systemic integration and non-redundancy (Godet, 1991). Coherence ensures that each objective directly addresses at least one strategic issue, thus avoiding « orphan objectives ». Exclusivity eliminates functional overlaps, for example differentiating V1 (pollution control) from V2 (habitat restoration), and Gov.Part (legitimacy of decision-making) from Gov.Reg (responsibility for implementation). Feasibility anchors objectives in technical, political and resource realities: Gov.Reg relies on inter-agency capacity and EU-supported monitoring, while SE1 uses GIS mapping and a legal framework to enable progressive implementation. Unattainable objectives, such as the prohibition of all industrial activity, were rejected in favor of concrete and negotiable objectives.

Together, these six strategic challenges and nine objectives form a coherent, conflict-sensitive and pragmatically viable framework for the governance of the Bizerte lagoon, integrating ecological preservation, socio-economic resilience and participatory and binding management. This portfolio forms the basis for the subsequent phases of MACTOR, including stakeholder positioning and scenario simulation, ensuring that the governance overhaul is evidence-based and operationally robust.

4.3. Direct and indirect influence between actors

Once the actors of lagoon governance and their objectives have been identified, the next step is to analyze their relationships by building the Direct and Indirect Influences Matrix (MIDI) (Table 1). From MIDI, we extracted two key indicators:
(1) The influence indicator (Ii), calculated as the sum of the lines, quantifies the total direct and indirect influence capacity of each actor. (2) The dependency indicator (Di), calculated as the sum of the columns, measures the sensitivity of each actor to the influence of others. These two indicators will be used to categorize the actors on the influence/dependence map.

MDII	Fishermen	Shellfish	Industrial	Farmers	ME	MAWRF	ONAS	CRDA.B	Local Auth	UTICA	UTAP	Local Comm	NGO	University	INTERN	Military	Ii
Fishermen	9	8	5	7	5	10	7	10	12	1	8	8	7	6	2	3	99
Shellfish	9	8	5	5	5	9	6	9	11	1	7	7	6	6	2	3	91
Industrial	17	17	10	11	6	16	11	14	21	6	13	17	9	7	3	4	172
Farmers	11	10	4	7	5	10	6	9	10	1	8	7	4	5	2	3	95
ME	19	18	11	15	11	24	16	19	25	6	13	18	12	9	6	4	215
MAWRF	17	16	9	15	9	21	14	18	21	4	14	14	12	9	7	4	183
ONAS	12	13	8	8	8	14	13	13	18	4	11	13	8	7	4	4	145
CRDA.B	13	12	3	10	5	13	7	10	11	2	11	8	5	7	4	4	115
Local Auth	15	14	7	12	10	15	13	15	18	4	10	14	11	8	6	4	158
UTICA	8	9	8	6	4	8	8	8	12	5	6	12	7	3	1	3	103
UTAP	5	5	1	6	2	5	3	4	4	1	5	3	1	2	1	2	45
Local Comm	7	7	5	4	6	8	8	7	10	1	4	7	5	4	2	2	80
NGO	4	4	5	4	5	7	5	5	5	2	3	5	5	4	3	2	63
University	3	3	3	3	4	3	3	3	4	1	3	2	3	2	2	3	43
INTERN	3	3	3	3	4	4	3	4	6	2	3	3	7	4	5	2	54
Military	12	13	9	8	10	16	12	14	18	3	11	11	10	9	6	4	162
Di	155	152	86	117	88	162	122	152	188	39	125	142	107	90	51	47	1823

Values represent direct and indirect influences between actors:
The higher the value, the more influence the actor has on the other.

Mapping of influences and dependencies between actors

The MDII matrix reveals a stratified governance structure where four distinct groups of actors – dominant, relay-dominated and autonomous – interact through quantifiable power asymmetries. Based on this matrix, actors are positioned as follows on an influence/dependence map:
The first group, the **dominant actors** (high Ii, low Di), located in the upper left quadrant, includes actors with strong influence but low dependence, such as the Ministry of the Environment, industrial operators and the military. These actors can be seen as the strategic drivers of the system. They possess the structural capacity to set rules, impose constraints, and shape long-term trajectories of lagoon governance, while remaining relatively insulated from external pressures. For example, industrial actors (Ii = 172, Di = 86) use their economic power to influence the policies of local authorities (21) and MAWRF (17), resisting regulatory pressures (Di = 86) and perpetuating pollution externalities on vulnerable groups. Similarly, the Ministry of Environment retains regulatory power, imposing standards on local authorities (25) and MAWRF (24), and can mobilize legal frameworks and enforcement mechanisms without being significantly constrained by other actors. The army (Ii=162, Di=47) acts as an autonomous enforcement body, influencing local authorities (18) with almost no dependence (Di=47), and putting the imperatives of security over environmental concerns.
The second category, **the relay actors** (High Ii, High Di) in the upper right quadrant, comprises actors characterized by both high influence and high dependence. This includes the Ministry of Agriculture,

Water Resources and Fisheries (MAWRF :Ii=183, Di=162) , the National Sanitation Office (ONAS : Ii=145, Di=122), and local authorities (Local Auth : Ii=158, Di=188). These stakeholders occupy a pivotal position because they are simultaneously able to shape outcomes and compelled to react to pressures from other actors. Their involvement in water management, waste treatment, and local planning situates them at the crossroads of ecological imperatives and socioeconomic demands. As such, they function as mediators and negotiators, absorbing contradictions between conservation and development. However, their dual position makes them vulnerable to conflicts of interest: while they must enforce environmental regulations, they are also expected to sustain livelihoods and economic activities dependent on the lagoon. This tension often leads to fragmented or inconsistent policies, reflecting the lack of an integrated governance framework.

Conversely, the lower right quadrant is occupied by actors with low influence but high dependence, such as fishermen, shellfish farmers, local communities and the Tunisian Union of Agriculture and Fisheries (UTAP). These actors are extremely vulnerable to decisions made by others, as their livelihoods depend directly on the ecological integrity of the lagoon. Pollution, overexploitation and restrictive policies imposed by higher authorities directly affect their economic survival, yet they lack the political or institutional capacity to counteract these pressures. Their structural marginalization explains why conflicts of use often emerge at this level, as these groups suffer the brunt of environmental degradation without having a say in decision-making processes. Fishermen (Ii=99, Di=155) and shellfish farmers (Ii=91, Di=152) are asymmetrically dependent on government and institutional actors, such as MAWRF (10→9) and local authorities (12→11), exposing them to industrial pressures (Industry → Fishermen = 8) and competition for resources. Farmers (Ii=95, Di=117) are subject to MAWRF control over regulations (15→10), their water needs being systematically subordinated to industrial and environmental priorities. The CRDA.B (Ii=115, Di=152) illustrates this institutionalized weakness: despite a moderate technical influence, its extreme dependence on MAWRF (13) and local authorities (5) prevents it from defending the interests of agricultural communities. The UTAP (Ii=45, Di=125) symbolizes a failure of representation, unable to counter the domination of the MAWRF (14→5) or protect resource-dependent sectors. These groups bear disproportionate environmental costs (water scarcity, pollution, etc.) with no real power to act. The map thus reveals a clear governance deficit: those who depend most on the lagoon's sustainability are those who have the least influence over its future.

Finally, the lower left quadrant identifies autonomous actors (Low Ii, Low Di) , such as universities, NGOs, international organizations, and UTICA (employers' union). These actors exhibit both weak influence and weak dependence in the present system UTICA (Ii=103, Di=39). Nonetheless, their potential role as sources of expertise, advocacy, and external legitimacy should not be underestimated. Universities and research institutions(Ii=43, Di=90) contribute critical scientific knowledge for environmental management, while NGOs (Ii=63, Di=107) can raise awareness, mobilize communities, and pressure authorities for more participatory approaches. International organizations(Ii=54, Di=51), though currently peripheral, may leverage external funding and global environmental commitments to strengthen local governance capacities. Enhancing the involvement of these actors could provide an entry point for rebalancing governance in favor of sustainability and inclusiveness. These actors represent underutilized facilitators for collaborative governance—particularly Universities, whose low dependence (Di=90) could position them as honest brokers in MAWRF-Fishermen water conflicts

The MACTOR map demonstrates that the governance of the Bizerte Lagoon is marked by a pronounced asymmetry: decision-making power is concentrated among a few institutional and industrial actors, while resource-dependent communities remain marginalized. This imbalance creates fertile ground for use conflicts and undermines the legitimacy of environmental governance. Addressing these challenges requires shifting from a top-down, asymmetrical configuration to a more participatory and polycentric model, where local stakeholders, peripheral actors, and scientific expertise are more effectively integrated. Such a reconfiguration would not only mitigate existing conflicts of use but also foster the co-construction of governance mechanisms that reconcile ecological preservation with social equity and economic viability.

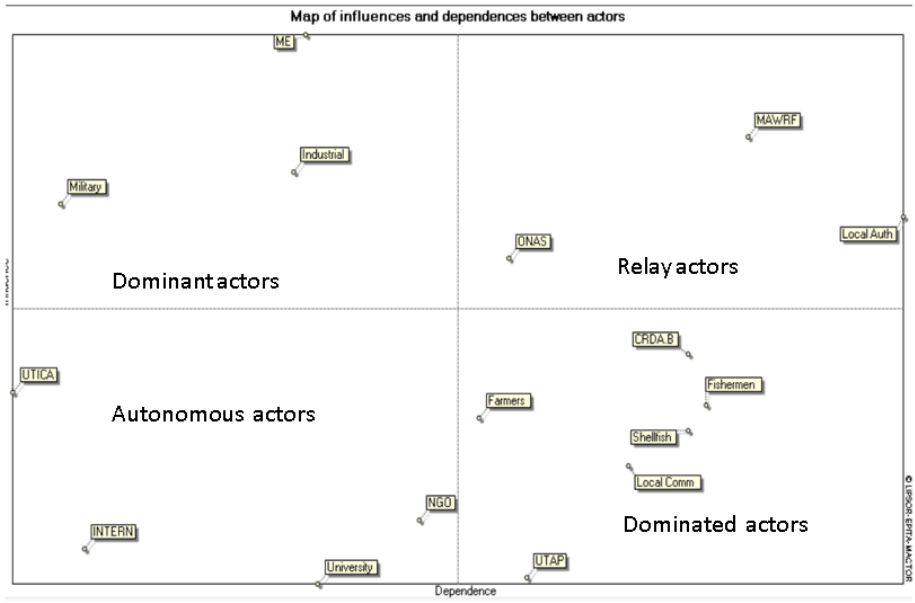


Figure 1 Map of influences and dependence s between actors

Balance of power between actors

The Ri indicator, which summarizes the maximum influence, direct and indirect dependence and effectiveness of feedback from each actor, reflects its ability to influence governance outcomes. High Ri values indicate greater strategic capacity and a stronger positioning to defend one's interests (Fetoui et al., 2021). Conversely, actors with low Ri values occupy weaker positions and have less latitude to assert their priorities within the system.

The governance of the lagoon is carried out according to a stratified power structure where four groups of actors, defined by their competitiveness Ri and the dynamic influence-dependence MDII, shape the ecological and social results. The dominant actors (ME/Ri=2.53, Industry/Ri=1.89, Military/Ri=2.14) unilaterally control the lagoon resources – setting environmental standards, allowing industrial discharges and favoring safety – with minimum liability (Di≤88). Intermediate actors (MAWRF/Ri=1.50, Local Authorities/Ri=1.12, ONAS/Ri=1.25) implement these top-down directives in a situation of extreme dependence (Di≥122), which leads to a grip on the regulations and a blockage of their implementation: the MAWRF fails to equitably balance fishing quotas and the water needs of agriculture, while local authorities issue coastal development permits under industrial pressure, thus aggravating habitat loss. Vulnerable actors (Fishermen/Ri=0.61, Shellfish/Ri=0.54, Farmers/Ri=0.69) are disproportionately affected by the impacts of lagoon degradation – pollution, resource scarcity and loss of livelihoods – due to their low competitiveness. (Ri ≤ 0.69) and a strong dependence (Di ≥ 117), the UTAP (Ri = 0.19) failing to defend its interests against the domination of the MAWRF. Autonomous actors (University/Ri = 0.23, NGO/Ri = 0.38, INTERN/Ri = 0.44) remain excluded from central governance. The University produces critical ecological data, while NGOs focus on advocacy and the INTERN provides transactional funding; their expertise is disconnected from decision-making due to negligible feedback loops (University → ME = 3). This system stratified according to the Ri perpetuates environmental injustice: high-Ri actors (ME/Ri = 2.53, Industry/Ri = 1.89) impose management of the lagoon without suffering the consequences, while low-Ri communities (Fishermen/Ri = 0.61, Farmers/Ri = 0.69) suffer ecological and economic damage without recourse. This system stratified according to the Ri perpetuates environmental injustice. High-risk actors (HRIs) impose management of lagoons without consequences, while low-risk communities suffer ecological and economic harm without recourse, requiring reforms that empower stakeholders, reduce relay dependencies, and integrate scientific knowledge to achieve equitable and sustainable lagoon governance.

	Ri
Fishermen	0,61
Shellfish	0,54
Industrial	1,89
Farmers	0,69
ME	2,53
MAWRF	1,50
ONAS	1,25
CRDA.B	0,79
Local Auth	1,12
UTICA	1,24
UTAP	0,19
Local Comm	0,46
NGO	0,38
University	0,23
INTERN	0,44
Military	2,14

	Qi
Fishermen	1,0
Shellfish	0,8
Industrial	1,6
Farmers	0,7
ME	1,5
MAWRF	1,2
ONAS	1,2
CRDA.B	0,9
Local Auth	0,9
UTICA	1,5
UTAP	0,4
Local Comm	0,7
NGO	0,6
University	0,3
INTERN	0,8
Military	1,7

Beyond the current balance of power represented by the Ri indicator, the potential balance of power, noted Qi, offers an innovative analytical framework for understanding the latent dynamics of lagoon governance, as conceptualized by Fetoui et al. (2021) and Godet (2010). This multidimensional calculation reveals deep disparities between current competitiveness (Ri) and untapped strategic potential, highlighting systemic inefficiencies and opportunities for governance readjustment. Qi-Ri gaps for key lagoon actors illuminate critical vulnerabilities and strategic opportunities. The EM (Ri = 2.53, Qi = 1.5) has the largest negative gap (-1.03), indicating that its current dominance is based on coercive regulatory power rather than sustainable leverage. This outperformance relative to potential suggests precarious legitimacy, as its top-down environmental standards (for example, fishing bans, pollution controls) stir resistance among resource users without creating collaborative feedback loops. The military sector (Ri=2.14, Qi=1.7) has a moderate negative gap (-0.44), indicating that it is making maximum use of its theoretical capabilities by instrumentalizing security imperatives (e.g. land expropriation for base construction) but lacks the adaptive capacity to manage ecological compromises. The industrial sector (Ri=1.89, Qi=1.6), with a minor negative gap (-0.29), demonstrates near-optimal exploitation of economic power (e.g. influence on local authorities' permits) but faces declining yields as ecological degradation threatens its social acceptability. Conversely, resource-dependent actors show significant positive Qi-Ri gaps, highlighting untapped potential: fishermen (Ri=0.61, Qi=1) and shellfish farmers (Ri=0.54, Qi=0.8) have latent power thanks to their local ecological knowledge, territorial presence and community networks that remain untapped due to structural dependencies (Di=155 and 152), while farmers (Ri=0.69, Qi=0.7) could convert their agricultural expertise into greater influence if they were freed from the regulatory subordination of MAWRF (MAWRF→Farmers=15 vs Farmers→MAWRF=10). Institutional actors also have untapped capacities: CRDA.B (Ri=0.79, Qi=0.9) could transform its agricultural technical expertise into systemic influence if it were freed from MAWRF domination (CRDA.B receives 13 MAWRF influence points, but exercises only 3 in return). UTAP (Ri=0.19, Qi=0.4), although apparently the weakest actor in terms of Ri, has a latent potential thanks to its representational role, a potential that could be amplified by formalized co-management structures. Civil society actors also have positive gaps: INTERN (Ri=0.44, Qi=0.8) and NGOs (Ri=0.38, Qi=0.6) have latent international networks, funding capacity and advocacy power that remain disconnected from central decision-making bodies due to negligible feedback mechanisms (e.g. NGO→Local Authority=5). This pattern of positive Qi-Ri gaps between resource users, institutional actors and civil society reveals a governance system where transformational potential is concentrated in the hands of marginalized actors, which requires institutional reforms to convert latent resources — local ecological knowledge, community networks, technical expertise and advocacy capacity — into concrete influence through feedback mechanisms that link evidence to policy and empower vulnerable stakeholders, thereby enabling a transition from the current stratified power structure to a more equitable, resilient and sustainable lagoon governance model.

4.4 Relationship between actors' objectives

Direct Influence Dynamics (1MAO Analysis)

The 1MAO matrix, which maps the direct positioning of stakeholders in the Bizerte lagoon with respect to a set of strategic objectives, provides a fundamental insight into the diversity of interests and conflicts that characterize the governance of this socio-ecological system. The results reveal the deep fault lines and potential areas of convergence between the different actors.

The 1MAO matrix reveals a polarized governance landscape, characterized by three main blocks: (1) pro-development actors (industrialists, UTICA, farmers, MARHP) favoring objectives E1 to E3; (2) pro-conservation actors (ME, NGOs, universities, INTERN) favoring objectives V1 and V2 and government regulation; (3) intermediate actors (residents, CRDA.B, ONAS) with variable positions and explicit conflicts (Table 1).

Fishermen appear to be one of the most committed actors, strongly supporting small-scale fisheries (E1), equitable access to resources and lagoon areas (SE1), public health and quality of life (SE2), improvement of water quality (V1), preservation of biodiversity and habitats (V2), participatory governance (Gov.Part.) and effective enforcement of environmental regulations (Gov.Reg.), while explicitly rejecting the expansion of industrial and port activities (E3), which they perceive as a direct threat to their livelihoods and to the ecological foundation of their activities. This position underlines the role of fishermen as defenders of ecological integrity and social justice in the lagoon, combining livelihood concerns with broader public interest objectives. Shellfish farmers largely share this orientation, with a particularly strong alignment with the development of shellfish farming (E2), which directly corresponds to their sectoral interests, while also supporting the objectives of water quality, biodiversity and governance, and, like fishermen, opposing industrial expansion; their approach differs only in the fact that their sector depends on the application of regulations and health standards, which makes them slightly more pragmatic than fishermen about the role of state institutions.

Industrial actors, on the other hand, have the most divergent positions: they strongly support industrial and port development (E3), which they consider essential for regional economic growth and their own survival, but oppose or neglect almost all other objectives, including equity, health, water quality, biodiversity and governance. Their position within the 1MAO represents the classic developmentalist posture that favors economic expansion over social and environmental considerations, thus placing them in structural opposition with most other actors. Farmers take an intermediate position: they oppose unbridled industrial expansion, which threatens soil and water quality, but simultaneously display ambivalence about environmental regulations, sometimes resisting strict enforcement that could limit agricultural practices, while recognizing the importance of fairness and fundamental ecological preservation. On the institutional side, the Ministry of the Environment, the Ministry of Agriculture, Water Resources and Fisheries (MARHP), ONAS and CRDA-Bizerte tend to prioritize objectives related to water quality (V1), biodiversity (V2) and regulation (Gov.Reg.), in accordance with their official mandates. They also support participatory governance and equity, but their implementation capacity is effectively limited by overlapping responsibilities, lack of resources and political pressure. Nevertheless, in the context of 1MAO, they appear to be important allies of environmental and social objectives. Local authorities are in a delicate position: their official orientation pushes them towards participatory governance, equity and quality of life, but their responsibility to promote local economic development often forces them to partially support industrial and port expansion, which places them in the face of an internal contradiction. UTICA, representing industry, trade and crafts, is directly aligned with the industrial sector, clearly supporting the E3 approach while opposing restrictive environmental and governance objectives, thus strengthening the coalition for development. UTAP, representing agriculture and fisheries, presents a more nuanced picture: it supports artisanal fishing (E1) and shellfish farming (E2), in line with its members, but tends to resist strict regulation when it is perceived as a drag on productivity, thus creating a partial divergence with NGOs and environmental institutions. NGOs and associations, alongside universities and the international community, are positioning themselves within 1MAO as the most fervent defenders of environmental and social objectives: they systematically support water quality, biodiversity, participatory governance and regulation, while opposing industrial development that threatens ecological integrity; universities bring the dimension of scientific monitoring

and knowledge production, while international actors exert external normative pressure and finance sustainable practices, thus strengthening these objectives. Residents and local communities share the same concerns as fishermen and NGOs, emphasizing health, equity and access to resources, which are directly linked to their daily lives, even if their influence is more diffuse and less structured. Finally, the army occupies a unique position: not being primarily oriented towards environmental or social objectives, it is implicitly opposed to participatory governance and equal access because of its control over restricted areas of the lagoon. However, it also does not show strong support for industrial expansion, maintaining an isolated and control-oriented position. Overall, the 1MAO

We find that the economic objectives (E1-E3) generate the greatest number of disagreements (n=10), with industrial players (+3) and fishermen (-3) being in irreconcilable opposition about industrial development (E3). Conversely, social objectives (SE1-SE2) are the subject of a remarkable consensus (agreements: n=23), with all actors, except industrial (neutral) actors, supporting public health (SE2 ≥+1). Environmental objectives (V1-V2) present a moderate conflict (disagreements: n=5), mainly between development-oriented actors (industrialists, UTICA: ≤0) and conservation advocates (NGO, ME: ≥+2).

1MAO	FISH.S	S FARMING	IND.PORT	EQUITY	HEALTH. Q	WATER QUAL	BIODIVERSI	Gov. Part.	Gov.Reg	Absolute sum
Fishermen	1	-1	-1	1	1	1	1	1	1	9
Shellfish	0	1	-1	1	1	1	1	1	1	8
Industrial	0	-1	1	0	0	-1	-1	-1	-1	6
Farmers	0	0	-1	1	0	-1	-1	1	-1	6
ME	0	1	-1	1	1	1	1	1	1	8
MAWRF	1	1	-1	1	1	1	1	1	1	9
ONAS	0	0	0	0	1	1	0	0	1	3
CRDA.B	1	1	0	1	1	1	1	1	1	8
Local Auth	0	0	1	1	1	1	0	1	1	6
UTICA	0	-1	1	0	0	-1	0	-1	-1	5
UTAP	1	0	-1	1	1	1	0	1	1	7
Local Comm	1	0	0	1	1	1	1	1	1	7
NGO	1	0	-1	1	1	1	1	1	1	8
University	0	0	0	0	1	1	1	1	1	5
INTERN	1	1	1	0	1	1	1	1	1	8
Military	0	0	0	0	1	0	0	0	1	2
Number of agreements	7	5	4	10	13	12	9	12	13	
Number of disagreements	0	-3	-7	0	0	-3	-2	-2	-3	
Number of positions	7	8	11	10	13	15	11	14	16	

This configuration demonstrates that the conflicts in the Bizerte lagoon are not random, but structured along clear fault lines: economic expansion versus ecological preservation, centralized control versus participatory governance, and short-term gains versus long-term sustainability. The value of these results lies precisely in their ability to provide decision-makers and stakeholders with a clear and systematic picture of the fault lines that shape the governance of the lagoon. First, the 1MAO matrix identifies potential coalitions: for example, the strong alignment between fishermen, shellfish farmers, NGOs and local residents indicates a natural basis for a collective platform for ecological integrity and social justice, which could be mobilized through negotiations or participatory processes. Second, it highlights the structural antagonism between industry and the environmental and social coalition, making it clear that attempts to build consensus without addressing this fundamental opposition are unlikely to succeed; governance strategies must therefore recognize and manage this conflict. Thirdly, the results draw attention to key players, such as farmers, local authorities and some institutions, who do not easily fall into one camp and whose support could be decisive in tilting the balance towards more sustainable

results. Understanding their motivations and constraints is therefore crucial to designing effective policies. Fourth, the 1MAO matrix clarifies the role of institutions: while ministries and agencies formally support environmental objectives, their effectiveness depends on political will, resources and their ability to withstand industrial pressures; institutional capacity building therefore becomes an explicit priority. Finally, by highlighting divergent and converging interests, the matrix provides a basis for dialog, negotiation and conflict resolution: it transforms diffuse perceptions of conflict into structured knowledge that can be used to design governance mechanisms, participatory processes and even compensation schemes that recognize winners and losers. In other words, the value of the results of the 1MAO matrix is not only analytical, but also practical: they offer a strategic tool to understand, anticipate and manage conflicts of use in the Bizerte lagoon, bringing clarity where daily debates are often dominated by ambiguity, competing narratives and power imbalances.

The 2MAO

The comparative analysis of the 1MAO and 2MAO matrices reveals how the actors' influence networks are reshaping in depth the feasibility of the economic, socio-ecological and institutional objectives of the governance system of the Bizerte lagoon, highlighting systemic pathologies and highlighting a potential for transformation.

2MAO	FISH.S	S FARMING	IND.PORT	EQUITY	HEALTH. Q	WATER QUAL	BIODIVERSI	Gov. Part.	Gov.Reg	Absolute sum
Fishermen	4	-1	-1	3	3	4	2	2	3	23
Shellfish	0	4	-2	3	3	4	2	2	3	23
Industrial	0	-1	4	0	0	-1	-1	-1	-3	11
Farmers	0	0	-2	2	0	-1	-1	2	-1	9
ME	0	1	-1	2	2	3	3	2	3	17
MAWRF	4	4	-1	3	3	1	3	2	1	22
ONAS	0	0	0	0	2	4	0	0	3	9
CRDA.B	3	3	0	3	3	1	2	2	2	19
Local Auth	0	0	2	3	3	3	0	2	4	17
UTICA	0	-1	4	0	0	-1	0	-1	-3	10
UTAP	4	0	-1	3	3	1	0	3	2	17
Local Comm	2	0	0	3	4	3	1	3	3	19
NGO	1	0	-3	4	4	4	1	2	4	23
University	0	0	0	0	3	4	4	2	2	15
INTERN	2	2	1	0	2	4	3	3	1	18
Military	0	0	0	0	1	0	0	0	4	5
Number of agreements	20	14	11	29	36	36	21	27	35	
Number of disagreements	0	-3	-11	0	0	-3	-2	-2	-7	
Number of positions	20	17	22	29	36	39	23	29	42	

The impact of stakeholder influence networks on the achievement of objectives in the governance system of the Bizerte lagoon reveals profound transformations in the economic, social, ecological and institutional dimensions, as highlighted by the comparative analysis of the 1MAO and 2MAO matrices. The economic objectives – artisanal fishing (E1), shellfish farming (E2), and industrial port development (E3) – demonstrate how networks of influence amplify power asymmetries, transforming initial positions into entrenched conflicts or synergistic opportunities. Artisanal fishing (E1) illustrates a successful amplification thanks to community networks: the position of fishermen is strengthened from +1 to +4 in 2MAO thanks to their exceptional dependency score (Di = 155), reflecting their ability to mobilize historical legitimacy and local knowledge to exercise an institutional leverage effect. Shellfish farming (E2) follows a similar trajectory: shellfish farmers increase their support from +1 to +4 (Ii=91, Di=152), thanks to their expertise, while opposition from fishermen intensifies, from -1 to -3 (Ii=99, Di=155), thus revealing a dynamic of competition for resources. The development of industrial ports (E3), on the other hand, perfectly illustrates the « asymmetric polarization »:

industrial actors mobilize an exceptionally high capacity for influence (Ii=172), allowing them to exert asymmetric pressure on institutional players while remaining marginally dependent on them (MDII=9 of the MAWRF, i.e. 10.5% of Di=86). This asymmetry makes it possible to convert economic power into institutional leverage without virtually any vulnerability. As a result, their position on the development of industrial ports (E3) is considerably strengthened, going from +1 in the first month of the year to +4 in the second month of the year. This change creates an impasse in governance, accentuated by the reinforced opposition of NGOs (position changing from -1 to -3, Ii=63). However, this opposition remains structurally insufficient to challenge industrial dominance due to persistent disparities in the distribution of influence.

This impasse is consolidated by the support of local authorities, whose position goes from +1 to +2 (Ii=158, Di=188), and by the constant support of the international community (+1 in both matrices). Industrial actors maintain their influence despite the intensification of environmental conflicts through institutional capture mechanisms: they actively shape regulatory frameworks to their advantage while resisting environmental regulation (Gov.Reg going from -1 to -3). This dynamic generates pathological dependency loops, especially with local authorities (MDII=7), where ecological concerns are structurally subordinated to economic imperatives. Importantly, these dependencies are less rooted in direct financial dependence than in deep-rooted structural interdependencies within the governance system.

Ecological objectives – water quality (V1) and biodiversity conservation (V2) – reveal contrasting dynamics, shaped by networks of influence. Water quality (V1) illustrates a successful « synergistic amplification »: fishermen see their influence go from +1 to +3 (Di=155), ONAS from +1 to +4 (Ii=145), universities from +1 to +3 and the international community from +1 to +4, resulting in 36 agreements thanks to complementary expertise and community mobilization. This success is based on the creation of positive feedback loops by networks of influence: fishermen mobilize communities, ONAS offers evidence-based advocacy, universities provide scientific validation and international actors guarantee resources and legitimacy. Biodiversity (V2), on the other hand, highlights the limits of influence networks: ONAS maintains a score of +1 in both matrices, its technical influence (Ii=145) being neutralized by industrial opposition (Ii=172) without eroding, revealing how economic power can drive ecological objectives. Fishermen are increasing their support from +1 to +2, and the international community from +1 to +3, but this translates into a weaker consensus (21 agreements), illustrating how the veto right of industrialists (Ii=172) can even lead to an enhanced ecological advocacy.

Institutional goals – participatory governance (Gov.Part) and environmental regulation (Gov.Reg) – reveal the deepest political pathologies, where networks of influence perpetuate stagnant governance despite cosmetic support. Participatory governance (Gov.Part) perfectly illustrates the « participatory facade syndrome »: while 2MAO displays 27 agreements, industrial opposition persists at -1, and marginalized actors like UTAP show only a slight amplification (+1 to +3, Ii=45), revealing that inclusion is a mere performance rather than a real redistribution. Local authorities are stepping up their support from +1 to +3 (Di=188), taking advantage of their centrality to promote participation, but their dependence on industrial actors (MDII=7) limits their potential for transformation. Environmental regulation (Gov.Reg) reveals extreme polarization: local authorities are stepping up their support from +1 to +4 (Ii=158, Di=188), taking advantage of their local roots to advance regulatory frameworks, while industrial players are stepping up their opposition from -1 to -3 (Ii=172), and UTICA is getting tougher, from -1 to -3, creating a deadlock (11 agreements, 7 agreements). The role of the international community is limited here: it strengthens support for regulation (+1 to +3) but fails to counter the industry's veto power due to its low dependence (Di=51), which highlights its effectiveness in advocacy, but impotence in governance reform.

Three systemic pathologies emerge from the set of objectives. First, a « paralysis through centralized influence » affects state agencies like ME (Ii=215/Di=162) and MAWRF (Ii=183/Di=162), which monopolize formal power but suffer from crippling dependencies, preventing them from advancing even sustained goals like biodiversity (V2). Second, « participatory stagnation » characterizes Gov.Part, where majority support masks the exclusion of marginalized voices due to the veto power of industrial actors. Third, a « decoupling of objectives » is manifested by the divergence between the technical consensus (water quality V1: 36 agreements) and the governance conflict (Gov.Part: 27 agreements, 2 disagreements), revealing the disconnection between ecological solutions and institutional reform. The influence of the international community – powerful to amplify socio-ecological objectives (SE2: +4,

V1: +4) but limited in the economic (E3: +1) and institutional (Gov.Reg: +3) fields – accentuates these dysfunctions, as its technical and financial resources cannot compensate for local power imbalances.

The 2MAO matrix demonstrates that the feasibility of objectives depends not on static positions of actors, but on dynamic ecosystems of influence: economic objectives become battlefields of asymmetrical powers (E3 impasse), socio-ecological objectives succeed thanks to synergistic amplification (SE2, V1 consensus), and institutional objectives stagnate due to deep-rooted dysfunctions (Gov.Part stagnation, Gov.Reg polarization). To achieve sustainable governance, it is necessary to restructure these networks in order to strengthen the role of community actors (local authorities: Di=188, fishermen: Di=155) and technical agencies (ONAS: Ii=145), while mitigating the industry's veto power (Ii=172), and to transform symbolic participation into operational co-governance through a rebalanced influence dynamic. Without addressing these dysfunctions, the lagoon's governance remains locked in a cycle in which consensus on technical goals coexists with paralysis of institutional reforms, perpetuating an unresolved conflict.

2MAO also allowed us to measure the degree of involvement of each stakeholder in all objectives by summing the absolute values along the lines (Yeo and Benchekara, 2015). Therefore, the actors most involved are NGOs (23), fishermen (23) and shellfish farmers (23). These actors pursue many objectives, reflecting their existential dependence on the ecological integrity of the lagoon and their direct interest in holistic governance encompassing economic sustainability (E1, E2), environmental protection (V1, V2), social equity (SE1, SE2) and participatory frameworks (Gov.Part, Gov.Reg), which reinforces their missions within the lagoon governance system. This trio of local actors functions as the de facto guardians of the commons, but their maximum mobilization contrasts sharply with their limited formal authority, revealing a critical inversion between power and mobilization. Local communities (19) — representing local populations and residents — demonstrate an equally high systemic commitment, mobilizing around public health (SE2), equitable access to resources (SE1) and environmental objectives (V1, V2), motivated by their direct vulnerability to pollution and spatial exclusion. Their score of 19 positions them as essential liaison actors. Between users of hypermobilized resources (fishermen, shellfish farmers) and state institutions, local demands for participatory governance (Gov.Part) are growing, while actors bear a disproportionate burden of industrial degradation. State agencies have a high but fragmented mobilization: MAWRF (22) focuses on fisheries and water resources, but has little involvement in industrial regulation; CRDA (19) and formal local authorities (19) focus on spatial planning and public health, but lack enforcement; while the Ministry of Environment (ME, 17) is at the forefront of environmental objectives, but neglects participatory governance. International organizations (18) are strongly mobilized around the global sustainable development goals, but disconnect from local economic realities, creating gaps in implementation. Universities (15) play a central role as knowledge intermediaries, engaging in research-oriented objectives (V1, V2, SE2) but remaining detached from operational governance and economic sectors, limiting their potential for conflict mediation. Conversely, the weakly mobilized actors – industrialists (11), farmers (9) and ONAS – are far from being fully involved. (9) – present a local commitment that perfectly illustrates the behavior of stowaways: industrialists exclusively pursue industrial development (E3) while resisting environmental regulations (V1, V2, Gov.Reg); farmers are marginally interested in water quality (V1) but ignore governance in the broad sense; and ONAS, paradoxically as a national sanitation agency, focuses on water treatment while disengaging from public health (SE2), regulatory enforcement (Gov.Reg) and inter-agency coordination. The army (<9) operates entirely outside the governance framework, creating security blind spots in coastal management. This mobilization landscape reveals three systemic pathologies: firstly, a reversal of the power of mobilization where highly engaged actors (fishermen, NGOs, local communities) have no decision-making power while less engaged actors (industry, military) dominate the allocation of resources; secondly, selective free-riding behavior on the part of economic actors who profit from the lagoon without assuming the sustainability costs; thirdly, institutional fragmentation where state agencies (MAWRF, ME, CRDA, ONAS) operate in silos, compromising the integrated application of the regulations. The resulting governance Fragility is manifested by persistent conflicts between industrial expansion (E3) and environmental preservation (V1, V2), with marginalized communities (fishermen, shellfish farmers, local residents) bearing a disproportionate burden despite their maximum mobilization. Transformative interventions must therefore strengthen the power of hypermobilized local actors – including local communities (19) – by formalizing co-management roles, impose a broader engagement of the industrial

and military sectors through binding sustainability agreements, restructure fragmented state institutions under a unified lagoon authority, and and to strengthen the role of universities as transdisciplinary knowledge integrators. Ultimately, the 2MAO matrix demonstrates that sustainable governance in the Bizerte lagoon is structurally inaccessible without resolving this decoupling between mobilization and authority – where the systemic engagement of civil society (23, 19) remains disconnected from the decision-making power held by disengaged elites (11, <9), thus perpetuating a cycle of environmental degradation and social inequalities that the MACTOR methodology uniquely highlights through its quantitative actor-objective diagnostics.

2MAO has both a diagnostic and normative dimension, identifying potential alliances to rebalance governance and institutional reforms needed to convert social consensus into political power. It fundamentally distinguishes between numerical consensus and strategic feasibility: equitable access to lagoon resources, although socially legitimate, is opposed by dominant actors and therefore depends on institutional redefinition; conversely, industrial development, strategically achievable with the support of powerful actors, lacks social legitimacy and generates instability. This duality between competitiveness and legitimacy is central: sustainable governance requires aligning these two dimensions.

For the Bizerte lagoon, 2MAO reveals that governance failure results less from low capacity than from structural asymmetries where powerful actors impose conflicting objectives while consensus objectives remain underfunded. This impasse deepens ecological and social vulnerabilities despite apparent consensus. The solution involves strengthening the institutional weight of consensus objectives (public health, water quality, biodiversity) within binding frameworks, while limiting divisible objectives (industrial development) through impact assessments and negotiations.

2MAO thus demonstrates that only participatory, transparent and adaptive governance can transform fragile consensus into resilient strategies and structural divergences into negotiated compromises, without which the system remains trapped in a cycle where power asymmetries systematically undermine consensual objectives and reproduce conflicts.

3MAO

The comparative analysis of 3MAO (weighted by the competitiveness index of the Ri actors) compared to 2MAO (gross positions) reveals profound readjustments in the relations between actors and objectives. The Ri vector, which synthesizes direct and indirect influences, dependencies and feedback loops, uncovers occult power dynamics that profoundly reshape strategic priorities and conflict contexts.

The economic objectives are undergoing the most radical transformation: E3 (Industrial and port development) is the most mobilized economic objective of the system (23.6 to 3MAO), thanks to the massive support of industrialists (+7.5). This strategic reversal, which marks a break with neutrality (0 to 2MAO), is made possible by their high Ri index (1.89). It reflects a calculated prioritization of port expansion, perceived as a high value-added and low regulatory risk opportunity, taking advantage of their control over logistics infrastructure and alignment with local authorities (+3.4) and UTICA (+0). Conversely, the E2 objective (Shellfish farming) suffers from systemic marginalization (mobilization: 17.7) due to the increased opposition of the industrialists (-1.9), which transforms their initial disapproval (-1) into a right of veto through the weighting Ri. This opposition stems from space competition (aquaculture versus port areas), pollution risks and lack of control over the value chain, aggravated by resistance from farmers (-1.4) and hostility from UTICA (-1.2), making EM's nominal support (+2.5) and shellfish farmers' neutrality ineffective (0). The social objectives reveal a double dynamic: the SE1 objective (Equitable Access) achieves a moderate mobilization (23.6) but is recovered by institutional actors (ME: +5.1, local authorities: +3.4), which reduces it to a tool of legitimacy while marginalizing riparian communities (local communities: +1.4) and NGOs (+0.4). The SE2 program (Public Health/Quality of Life) enjoys a positive consensus (mobilization: 28.9) thanks to a large institutional support (ME: +5.1; ONAS: +2.5; local authorities: +3.4), even if its universality masks the exclusion of citizens' voices. The environmental objectives are dominated by the hegemony of the State: the V1 program (Water Quality) registers a strong mobilization (32.4) but is monopolized by the EM (+7.6), which uses its influence (2.53) to stifle NGOs (+1.5) and universities (+0.9), thus illustrating an « environmental authoritarianism ». The V2 program (Biodiversity) follows a similar pattern (mobilization: 21.6), with the EM (+7.6) largely dominating the environmental actors, which highlights the vulnerability of ecological objectives to instrumentalization. Institutional objectives crystallize

systemic tensions: Gov.Reg (Regulation) becomes the most confrontational objective (mobilization 45.2) due to a high Ri impasse between the military (+8.6) advocating law enforcement and industrialists (-5.7) resistant to constraints, while Gov.Part. (Participatory governance) achieved moderate mobilization (23.2) but lack of transformative power, relying on medium-income actors (CRDA.B: +1.6, Local Authority: +1.6) and excluding fishermen (+1.2) or NGOs (+0.8).
ME (Ri 2.53) is the most powerful player in the system (mobilization 43), using its Ri to dominate environmental (V1: +7.6, V2: +7.6) and social (SE1: +5.1) objectives while selectively supporting the economic objectives that correspond to its agenda. Industrialists (Ri 1.89) act as stewards of the economy, repressing E2 (-1.9) and stimulating E3 (+7.5) thanks to an influence amplified by the Ri, embodying regulatory capture where they shape policies to maximize port profits while blocking competing aquaculture. The army (Ri 2,14) leverages its competitiveness to enforce regulations (Gov.Reg: +8,6), revealing an unexpected role in environmental governance as a state oversight body. The low Ri (Ri) index actors – fishermen (Ri 0.61), NGOs (Ri 0.38) and universities (Ri 0.23) – are systematically marginalized: the commitment of fishermen (absolute sum: 23) drops to 14.1 in 2 months (3 months), that of NGOs drops from 23 to 8.6 and that of universities plummets from 15 to 3.5, illustrating how the Ri neutralizes expertise and advocacy. Intermediate-level actors, such as local authorities (Ri 1,12; mobilization: 19), ONAS (Ri 1,25; 11,3) and MAWRF (Ri 1,5; 33), play a coalition-building role, but lack autonomy to challenge the dominance of high-Ri actors. The international community (INTERN; Ri 0.44) remains peripheral, with scattered positions (FISH.S: +0.9, BIODIVERSI: +1.3) failing to elevate a goal to priority, reflecting its limited influence in entrenched local conflicts.

Convergence and Divergence between Actors

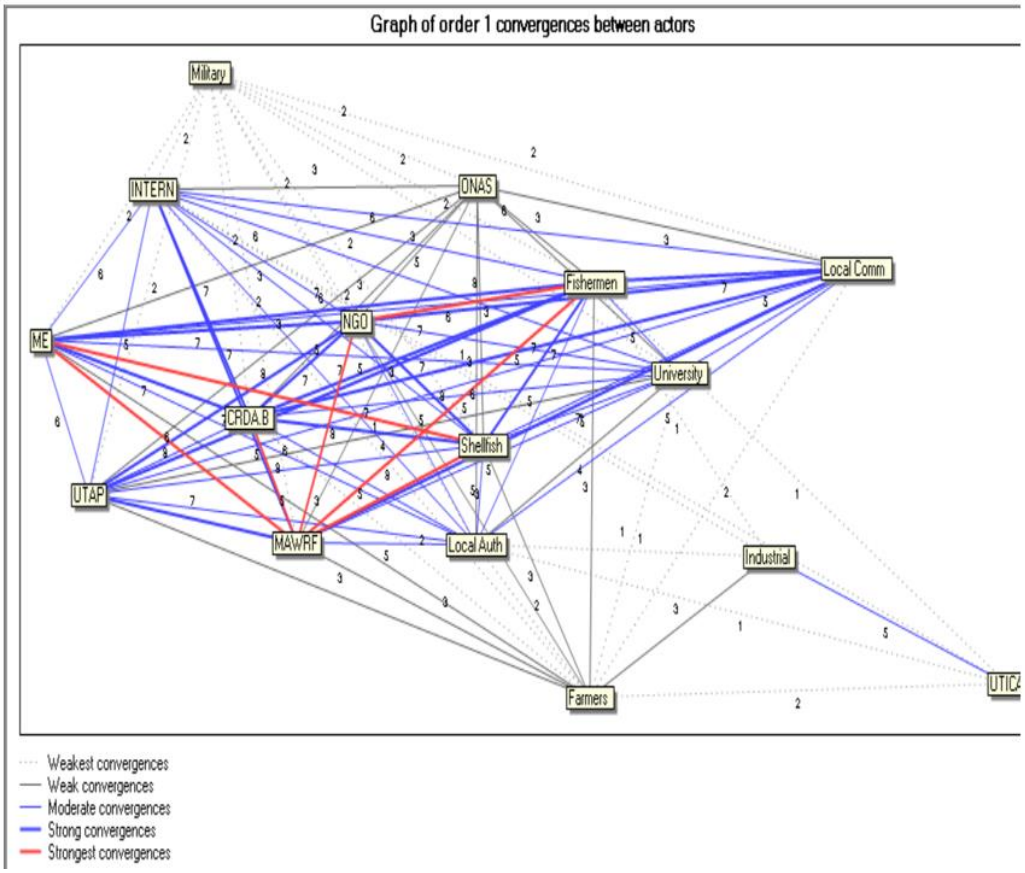
The Convergence Actor-Actor (CAA) matrix and FIGURE 1 visualization expose a **critical governance paradox** in the Bizerte Lagoon

Table 6. CAA Matrix: level of convergence between actors in the management of lagoon ecosystem areas in Bizerte, Tunisia

1CAA	Fishermen	Shellfish	Industrial	Farmers	ME	MAWRF	ONAS	CRDA.B	Local Auth	UTICA	UTAP	Local Comm	NGO	University	INTERN	Military
Fishermen	0	7	1	3	7	8	3	7	5	1	7	7	8	5	6	2
Shellfish	7	0	0	3	8	8	3	7	5	0	6	6	7	5	6	2
Industrial	1	0	0	3	0	0	0	0	1	5	0	0	0	0	1	0
Farmers	3	3	3	0	3	3	0	2	2	2	3	2	3	1	1	0
ME	7	8	0	3	0	8	3	7	5	0	6	6	7	5	6	2
MAWRF	8	8	0	3	8	0	3	8	5	0	7	7	8	5	7	2
ONAS	3	3	0	0	3	3	0	3	3	0	3	3	3	3	3	2
CRDA.B	7	7	0	2	7	8	3	0	5	0	6	7	7	5	7	2
Local Auth	5	5	1	2	5	5	3	5	0	1	5	5	5	4	5	2
UTICA	1	0	5	2	0	0	0	0	1	0	0	0	0	0	1	0
UTAP	7	6	0	3	6	7	3	6	5	0	0	6	7	4	5	2
Local Comm	7	6	0	2	6	7	3	7	5	0	6	0	7	5	6	2
NGO	8	7	0	3	7	8	3	7	5	0	7	7	0	5	6	2
University	5	5	0	1	5	5	3	5	4	0	4	5	5	0	5	2
INTERN	6	6	1	1	6	7	3	7	5	1	5	6	6	5	0	2
Military	2	2	0	0	2	2	2	2	2	0	2	2	2	2	2	0
Number of convergences	77	73	11	31	73	79	35	73	58	10	67	69	75	54	67	24

The values represent the degree of convergence: the higher the intesity, the more actors have common interests

Figure 1. The level of convergence between actors in the management of lagoon ecosystem areas in Bizerte, Tunisia



The actor-actor convergence matrix (CAA), as defined by Godet (1982, 1991, 2006), quantifies the probability of forming alliances between actors with a view to common objectives. The higher the convergence value, the greater the potential for cooperation. The analysis of the 1CAA matrix identifies four distinct groups of actors: Group 1 (ME-73, MAWRF-79, NGO-75, CRDA-73, Pêcheurs-77, Coquillages-73) has the highest convergence potential (mean: 75), reflecting a strong convergence of conservation objectives and a high probability of strategic alliances, as visually confirmed by the dense network of thick red and blue lines in Figure 1 (e.g. ME-MAWRF = 35, ME-NGO = 24.4). However, this formal cohesion masks important limits: the almost total isolation of Group 1 from the productive sectors (ME-Industrial = 0; Farmers-ME = 3) makes it structurally powerless in the face of industrial pollution or agricultural runoff, the main conflicts of use of the lagoon. Group 2 (UTAP-67, Local Community-69, Intern-67, Local Community-58, University-54) shows moderate convergence (mean: 63), indicating partial objective compatibility and mediation potential. However, Figure 1 reveals its effectiveness limited by tenuous links marginally linking it to Groups 1 (Local Authority-ME = 23.6) and 3-4 (Local Authority-Industrial = 1). Group 3 (farmers: 31, ONAS: 35, military: 24) shows low convergence (average: 30), revealing fragmented interests and unresolved land-sea conflicts (e.g. farmers-fishermen: 3.9). Group 4 (industrial: 11, UTICA: 10) shows very low convergence (average: 10.5) with environmental players. Paradoxically, the study identifies Group 4 as the de facto dominant player, thanks to its economic influence and its grip on regulation – as illustrated by the isolated red line in Figure 1 (Industrialists-UTICA: 15.6), representing a defensive alliance giving industrialists a veto over environmental regulation. This creates a governance impasse: the strong convergence of Group 1 does not translate into concrete ecological results, while the weak convergence of Group 4 masks its functional dominance. This underlines the crucial role of Group 2 actors as mediators in resolving conflicts of use. However, their effectiveness is based on three conditions: (1) empowerment by delegation of power and resources in order to overcome their moderate convergence and bridge the gap between the environmental coalition of Group 1 and the marginalized productive sectors (Groups 3 and

4); (2) strategic positioning as neutral mediators to take advantage of their partial links (e.g. Local authorities – Industrial sector = 1) and transform the antagonisms linked to low convergence into compromise frameworks for industrial pollution and agricultural runoff; and (3) institutional autonomy to resist the control of dominant actors, thus allowing inter-group alliances (e.g. knowledge transfer between universities and NGOs, co-management between local communities and fishermen). The 1CAA matrix fundamentally advances governance analysis by quantifying alliance probabilities (Godet, 2006), revealing hidden power dynamics – such as the paradoxical dominance of low-convergence industrial actors – and identifying structural levers. By mapping convergence values, it reveals how formal alignments mask functional impotence while providing empirical evidence to activate Group 2 as strategic mediators. This allows targeted interventions to reconfigure asymmetric power relations, transforming the lagoon governance from a dysfunctional equilibrium into an adaptive co-management system capable of resolving persistent conflicts of use. Without this reconfiguration, the Bizerte lagoon remains trapped in a cycle where strong environmental convergence coexists with industrial dominance, perpetuating ecological degradation and socio-ecological inequalities.

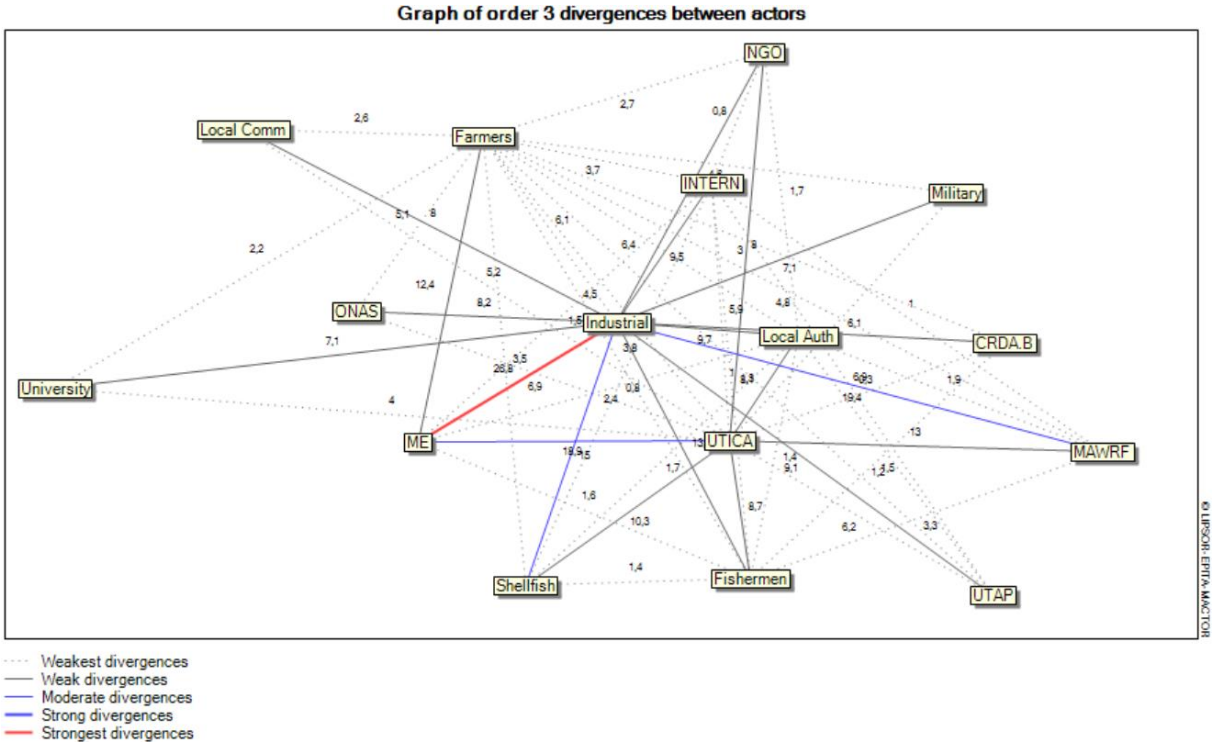
The comparative analysis of 1CAA and 3CAA matrices reveals a systemic reconfiguration crucial for the ecological transition. The quantitative weighting of the 3CAA matrix highlights governance dynamics invisible in the 1CAA matrix, transforming the perception of relationships between actors into operational levers and structural obstacles. The Ministry of the Environment (ME) appears as a central pivot (278.6, +281.6% compared to the 1CAA matrix), surpassing the MAWRF (212.8) thanks to high-impact strategic alliances (ME↔MAWRF: 35, weighting 4.375). Local authorities (Local authorities: 162.3, +179.8%) are becoming essential operational mediators, capable of integrating industrial interests (Local authorities↔Industry: 4.9, weighting 4.9), despite their persistent marginalization. This reconfiguration highlights three major governance problems that undermine the ecological transition: (1) decision-making fragmentation where the dominant environmental block (ME, MAWRF, NGOs) excludes economic interests (Industry: 31.5; UTICA: 26.1), creating a paralyzing duality illustrated by a persistent antagonism between Industry and Fishermen (1.3; weighting: 1.3); (2) under-exploited synergies with relationships with high unexploited potential such as ME and Farmers (8.4; weighting: 2.8) and University and MAWRF (9.2; weighting: 1.84), revealing a waste of resources and a lack of coordination between scientific expertise and public action; (3) a lack of inclusive mechanisms where potential mediators (NGOs: 127.6; INTERN: 118.6) lack institutional tools to transform) convergences in concrete actions, while peripheral actors (Farmers: 50.8; Military: 90.8) remain structurally fragile. The conditions for an effective ecological transition therefore require: strategic optimization of key relationships through integrated projects (e.g. sustainable agriculture and wetland protection led by ME↔MAWRF), the creation of sectoral compromise chambers to arbitrate land use conflicts (e.g. pollution thresholds negotiated between industrialists and fishermen), and a hybridization of roles (NGOs as operators of international projects, universities as independent evaluators). Without this reorientation, the system will remain trapped in a logic of confrontation where ecological and economic interests are mutually exclusive, demonstrating that the resolution of governance problems depends less on the creation of new convergences than on the targeted optimization of existing high-impact operational relationships.

3CAA	Fishermen	Shellfish	Industrial	Farmers	ME	MAWRF	ONAS	CRDA.B	Local Auth	UTICA	UTAP	Local Comm	NGO	University	INTERN	Military
Fishermen	0,0	10,7	1,3	3,9	25,8	20,3	8,7	12,8	13,0	0,9	7,7	10,8	11,1	6,0	8,8	7,2
Shellfish	10,7	0,0	0,0	4,0	27,7	19,8	8,4	12,0	12,5	0,0	5,8	8,5	9,3	5,5	8,2	7,0
Industrial	1,3	0,0	0,0	5,8	0,0	0,0	0,0	0,0	4,9	15,6	0,0	0,0	0,0	0,0	4,0	0,0
Farmers	3,9	4,0	5,8	0,0	8,4	6,6	0,0	3,4	4,2	3,2	2,7	2,8	3,8	0,9	1,3	0,0
ME	25,8	27,7	0,0	8,4	0,0	35,0	15,8	26,6	23,6	0,0	17,6	22,9	24,4	18,2	21,0	11,7
MAWRF	20,3	19,8	0,0	6,6	35,0	0,0	9,4	23,3	15,9	0,0	12,8	17,1	17,8	9,2	17,3	8,4
ONAS	8,7	8,4	0,0	0,0	15,8	9,4	0,0	8,0	11,2	0,0	6,2	7,9	7,9	6,7	7,2	8,5
CRDA.B	12,8	12,0	0,0	3,4	26,6	23,3	8,0	0,0	12,7	0,0	7,0	10,7	10,1	5,7	10,1	7,3
Local Auth	13,0	12,5	4,9	4,2	23,6	15,9	11,2	12,7	0,0	3,6	9,5	12,1	11,8	8,0	10,2	9,3
UTICA	0,9	0,0	15,6	3,2	0,0	0,0	0,0	0,0	3,6	0,0	0,0	0,0	0,0	0,0	2,7	0,0
UTAP	7,7	5,8	0,0	2,7	17,6	12,8	6,2	7,0	9,5	0,0	0,0	5,6	5,7	2,1	3,8	5,8
Local Comm	10,8	8,5	0,0	2,8	22,9	17,1	7,9	10,7	12,1	0,0	5,6	0,0	8,1	5,0	7,0	7,0
NGO	11,1	9,3	0,0	3,8	24,4	17,8	7,9	10,1	11,8	0,0	5,7	8,1	0,0	4,6	6,3	6,9
University	6,0	5,5	0,0	0,9	18,2	9,2	6,7	5,7	8,0	0,0	2,1	5,0	4,6	0,0	4,6	5,9
INTERN	8,8	8,2	4,0	1,3	21,0	17,3	7,2	10,1	10,2	2,7	3,8	7,0	6,3	4,6	0,0	6,0
Military	7,2	7,0	0,0	0,0	11,7	8,4	8,5	7,3	9,3	0,0	5,8	7,0	6,9	5,9	6,0	0,0
Number of convergences	148,8	139,3	31,5	50,8	278,6	212,8	105,8	149,6	162,3	26,1	92,5	125,4	127,6	82,4	118,6	90,8
Degree of convergence (%)	0,0															

Values represent the degree of convergence: the higher the intensity, the more common interests the actors share.

The matrix and the graph of the third order divergences between the actors of the environmental governance of the Bizerte lagoon reveal a complex conflictual landscape, centered on the priorities of use and management of resources. The quantitative matrix shows that industrial actors have the highest total divergence (161.7), indicating deep conflicts with multiple stakeholders, including ME (26.8 – the highest individual divergence) and shellfish farmers (15.0). Similarly, UTICA (professional association) shows a significant aggregate divergence (112.7), notably with ME (18.9) and MAWRF (13.0), underlining the tensions between economic interests and regulatory/environmental bodies. Conversely, fishermen and shellfish farmers have moderate differences with industrial actors, but minimal conflicts with local authorities (e.g. 0 with ONAS/CRDA.B), suggesting local alignment on some issues. The graph visually reinforces these trends through its line thickness coding: thick/continuous red lines connect high conflict pairs (e.g. Industrie-ME, UTICA-MAWRF), while fine/dotted lines represent lower tensions (e.g. Fishermen-Local Authority at 1.4). In particular, the Local Commission and the University appear as nodes with low divergence (15.8 and 13.3 in total), potentially indicating neutral or mediation roles. The lack of connections between several actors (e.g. Fishermen-NGOs at 0) on the graph further clarifies areas of consensus or disengagement.
This dual representation highlights governance challenges where industrial expansion and commercial interests (UTICA/Industry) are strongly opposed to environmental and halieutic resources institutions (ME/MAWRF) and resource users (Fishermen/Shellfish), while local administrative bodies (locale/CRDA.B Authority) occupy intermediate conflict positions. This visualization makes it possible to effectively prioritize intervention targets by focusing on the most polarized relationships, which is essential to resolve conflicts of use in the Bizerte lagoon ecosystem.

3DAA	Fishermen	Shellfish	Industrial	Farmers	ME	MAWRF	ONAS	CRDA.B	Local Auth	UTICA	UTAP	Local Comm	NGO	University	INTERN	Military
Fishermen	0,0	1,4	13,1	3,8	1,6	3,3	0,0	1,5	1,4	8,7	0,0	0,0	0,0	0,0	1,3	0,0
Shellfish	1,4	0,0	15,0	3,5	0,0	0,0	0,0	0,0	1,7	10,3	0,0	0,0	0,0	0,0	0,8	0,0
Industrial	13,1	15,0	0,0	6,1	26,8	19,4	8,2	10,6	9,7	0,0	9,1	8,0	12,1	7,1	9,5	7,1
Farmers	3,8	3,5	6,1	0,0	12,4	4,8	5,1	3,0	6,4	4,5	1,0	2,6	2,7	2,2	3,7	4,6
ME	1,6	0,0	26,8	12,4	0,0	0,0	0,0	0,0	2,4	18,9	0,0	0,0	0,0	0,0	1,5	0,0
MAWRF	3,3	0,0	19,4	4,8	0,0	0,0	0,0	0,0	1,9	13,0	0,0	0,0	0,0	0,0	1,0	0,0
ONAS	0,0	0,0	8,2	5,1	0,0	0,0	0,0	0,0	0,0	6,9	0,0	0,0	0,0	0,0	0,0	0,0
CRDA.B	1,5	0,0	10,6	3,0	0,0	0,0	0,0	0,0	0,0	6,9	0,0	0,0	0,0	0,0	0,0	0,0
Local Auth	1,4	1,7	9,7	6,4	2,4	1,9	0,0	0,0	0,0	8,1	1,2	0,0	1,7	0,0	0,0	0,0
UTICA	8,7	10,3	0,0	4,5	18,9	13,0	6,9	6,9	8,1	0,0	6,2	5,2	8,0	4,0	5,9	6,1
UTAP	0,0	0,0	9,1	1,0	0,0	0,0	0,0	0,0	1,2	6,2	0,0	0,0	0,0	0,0	0,3	0,0
Local Comm	0,0	0,0	8,0	2,6	0,0	0,0	0,0	0,0	0,0	5,2	0,0	0,0	0,0	0,0	0,0	0,0
NGO	0,0	0,0	12,1	2,7	0,0	0,0	0,0	0,0	1,7	8,0	0,0	0,0	0,0	0,0	0,8	0,0
University	0,0	0,0	7,1	2,2	0,0	0,0	0,0	0,0	0,0	4,0	0,0	0,0	0,0	0,0	0,0	0,0
INTERN	1,3	0,8	9,5	3,7	1,5	1,0	0,0	0,0	0,0	5,9	0,3	0,0	0,8	0,0	0,0	0,0
Military	0,0	0,0	7,1	4,6	0,0	0,0	0,0	0,0	0,0	6,1	0,0	0,0	0,0	0,0	0,0	0,0
Number of divergences	36,0	32,6	161,7	66,4	63,5	43,3	20,1	21,9	34,5	112,7	17,9	15,8	25,3	13,3	24,7	17,9
Degree of divergence (%)	0,0															



4.5. Conclusion and Policy Recommendations

The strategic analysis of conflicts and environmental governance in the Bizerte Lagoon, conducted through the MACTOR method, reveals a systemic crisis rooted in entrenched power asymmetries, institutional fragmentation, and accelerating ecological degradation, where conflicts are not merely resource-driven but manifestations of governance failures that prioritize industrial and state interests over local communities and ecological integrity. The study identifies 17 key actors, including marginalized local users (fishers, shellfish farmers, residents) and dominant entities (industrial operators, central ministries, military), with influence-dependence matrices exposing a stratified governance structure: dominant actors (e.g., Ministry of Environment, industrial sector) exert high influence with low dependence, while local communities suffer high dependence with minimal influence, perpetuating exclusion and environmental injustice. Institutional fragmentation across several agencies (e.g., ANPE, APAL, ONAS, MAWRF….) creates jurisdictional silos, enabling regulatory capture by industrial actors and undermining coordinated action, as evidenced by weak enforcement of pollution controls and spatial conflicts where traditional fishing grounds are encroached upon by industrial, military, and aquaculture concessions. Ecologically, the lagoon faces critical thresholds of pollution (heavy metals, eutrophication) and habitat loss, driven by unregulated industrial discharge, agricultural runoff, and urbanization, which degrade water quality, trigger periodic bans on shellfish harvesting, and threaten biodiversity and livelihoods. Participatory mechanisms are tokenistic, lacking decision-making power and failing to incorporate local ecological knowledge, resulting in a legitimacy deficit and recurrent social conflicts, such as the 2019 vandalism of shellfish farms by displaced fishers. To address these challenges, the study proposes a transformative governance framework centered on four pillars: (1) Institutional reform through the establishment of a single Lagoon Authority (ALB) with unified regulatory, budgetary, and enforcement powers, replacing fragmented agencies and mandating cross-sectoral coordination protocols to align with integrated coastal zone management principles and international commitments (e.g., Ramsar Convention, SDG 14); (2) Inclusion and power redistribution via legally mandated co-management, with elected Lagoon Councils holding veto power over development projects, ensuring Free, Prior, and Informed Consent (FPIC) for affected communities, and capacity-building programs to empower local actors in negotiation and ecological monitoring, thereby redressing historical marginalization; (3) Spatial and ecological regulation through participatory zoning designating conservation areas (20%), sustainable use zones (60%), and controlled development zones

(20%), complemented by tradable permit systems for fisheries and aquaculture to cap exploitation and pollution, alongside large-scale restoration of seagrass beds and nutrient reduction funded by payments for ecosystem services (PES) and polluter-pays mechanisms; and (4) Robust financing, monitoring, and compliance through a Sustainable Lagoon Fund capitalized by industrial taxes, tourism revenues, and international climate finance (e.g., Green Climate Fund), a citizen observatory combining IoT sensors and community-based reporting for real-time transparency, and progressive sanctions with incentives for green technologies. This framework aligns with global environmental governance trends, such as the Escazú Agreement's emphasis on participatory rights and the UNEP's call for ecosystem-based management, but its success hinges on high-level political will in Tunisia to dismantle power imbalances, foster partnerships with international bodies (e.g., UNEP, EU) for technical and financial support, and innovate socially by integrating traditional knowledge with adaptive management. Ultimately, transforming the Bizerte Lagoon's governance from a conflict-ridden, degraded system into a model of resilience requires redefining power relations to center equity, transparency, and shared responsibility, turning conflicts into catalysts for sustainability and ensuring the lagoon's ecological and socio-economic viability for future generations.

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