

BEYOND TREATMENT: DESIGNING TREATED WASTEWATER REUSE AS AN INTEGRATED SYSTEM OF TERRITORIAL SERVICES

AU-DELÀ DU TRAITEMENT: CONCEVOIR LA RÉUTILISATION DES EAUX USÉES TRAITÉES COMME UN SYSTÈME INTÉGRÉ DE SERVICES TERRITORIAUX

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ABSTRACT

The reuse of treated wastewater is frequently presented as a technical upgrade of wastewater treatment plants. This interpretation overlooks what actually determines success at scale. In the Mediterranean basin and the Middle East, which are exposed to climate change, climate projections point to intensified water stress, and many countries are already below the scarcity threshold of 1,000 m³/capita/year (1). In these contexts, the reuse of treated wastewater must function as a public service: reliable, financed, regulated and operated on a daily basis.

Projects stagnate when stakeholders do not share the same definition of the service, when responsibilities remain unclear and when the cost structure ignores the last kilometer of transport and distribution to users. Under these conditions, social acceptability becomes a major constraint, not because of a communication deficit, but because the system fails to demonstrate its safety and reliability in a verifiable manner. Based on a comparative literature review of Mediterranean and arid contexts (2), the article identifies three minimum conditions for viable and replicable reuse of treated wastewater at large scale: (i) use-specific quality objectives translated into enforceable authorizations; (ii) a whole-chain economic model explicitly financing transport, distribution and long-term maintenance; and (iii) evidence-based acceptability mechanisms backed by transparent monitoring. These conditions are articulated through three service models: peri-urban non-food reuse, agricultural reuse and industrial reuse, forming a 3×3 decision matrix (Table 1).

Applied to Morocco (219 wastewater treatment plants, a treatment rate of 58%, and a reused volume increasing from 23.5 million cubic meters in 2019 to 52.6 million cubic meters in 2024), the framework reveals a country whose investment trajectory is strong but whose service architecture remains incomplete. Completing the regulatory framework, structuring agricultural financing, designating an institutional coordinator, and adapting service models to project sponsors' capacities are the four conditions still to be met before strategic objectives can be achieved.

Keywords: Reuse of treated wastewater; territorial services; institutional design; Morocco; Mediterranean.

RÉSUMÉ

La réutilisation des eaux usées traitées est souvent présentée comme une amélioration technique des stations d'épuration. Cette interprétation néglige ce qui détermine réellement la réussite à grande échelle. Dans le bassin méditerranéen et au Moyen-Orient, régions exposées au changement climatique, les projections climatiques laissent entrevoir une aggravation du stress hydrique, et de nombreux pays se situent déjà en dessous du seuil de pénurie de 1 000 m³ par habitant et par an. Dans ces contextes, la réutilisation des eaux usées traitées doit fonctionner comme un service public : fiable, financé, réglementé et géré au quotidien.

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Les projets stagnent lorsque les parties prenantes ne partagent pas la même définition du service, lorsque les responsabilités restent floues et lorsque la structure des coûts ne tient pas compte du « dernier kilomètre » de transport et de distribution vers les usagers. Dans ces conditions, l'acceptabilité sociale devient une contrainte majeure, non pas en raison d'un déficit de communication, mais parce que le système ne parvient pas à démontrer sa sécurité et sa fiabilité de manière vérifiable.

Sur la base d'une revue comparative de la littérature portant sur les contextes méditerranéens et arides (2), cet article identifie trois conditions minimales pour une réutilisation viable et reproductible des eaux usées traitées à grande échelle : (i) des objectifs de qualité spécifiques à chaque usage, traduits en autorisations exécutoires ; (ii) un modèle économique couvrant l'ensemble de la chaîne, finançant explicitement le transport, la distribution et l'entretien à long terme ; et (iii) des mécanismes d'acceptabilité fondés sur des données probantes et étayés par un suivi transparent. Ces conditions s'articulent autour de trois modèles de services : la réutilisation périurbaine à des fins non alimentaires, la réutilisation agricole et la réutilisation industrielle, formant une matrice de décision 3×3 (Tableau 1).

Appliqué au Maroc (219 stations d'épuration, un taux de traitement de 58 % et un volume réutilisé passant de 23,5 millions de mètres cubes en 2019 à 52,6 millions de mètres cubes en 2024), ce cadre met en évidence un pays dont la trajectoire d'investissement est solide, mais dont l'architecture des services reste incomplète. Parachever le cadre réglementaire, structurer le financement agricole, désigner un coordinateur institutionnel et adapter les modèles de services aux capacités des porteurs de projets sont les quatre conditions qui restent à remplir avant que les objectifs stratégiques puissent être atteints.

Mots-clés : Réutilisation des eaux usées traitées; Services territoriaux; Conception institutionnelle; Maroc ; Méditerranée.

1. INTRODUCTION

Global water demand has increased sixfold over the last century, at a rate twice as high as population growth (3). The Mediterranean basin and the Middle East are particularly exposed to climate change. Projections foresee rising temperatures, declining rainfall and intensifying droughts in regions where many countries are already below the water scarcity threshold of 1,000 cubic meters per capita per year (1). In this context, the reuse of treated wastewater is increasingly proposed as a strategic response to structural water deficits (2).

The deployment of treated wastewater reuse nevertheless remains highly uneven. Kuwait, for example, has a reuse rate of 55% and the United Arab Emirates 42%, both supported by policies that explicitly link the reuse of treated wastewater to national water security (2). This disparity between the level of water stress and the effective reuse rate is illustrated in Figure 1 for a set of countries with water stress above 100% (4).

Conversely, Morocco, whose water availability is around 650 cubic meters per capita per year, well below the scarcity threshold, reused 52.6 million cubic meters in 2024, corresponding to around 14% of the treated volume. The national infrastructure includes 219 wastewater treatment plants with a total capacity of 1.40 million cubic meters per day, of which 90 are equipped with tertiary treatment (5). The treatment infrastructure exists, but the service architecture³ remains to be completed.

The literature on the economics of infrastructure services (6) (7) has shown that the performance of a public service depends less on its technical characteristics than on the institutional architecture that governs it. This article asks the following question: what are the minimum institutional and economic conditions that allow a treated wastewater reuse project to function as a viable and replicable territorial service at large scale? To answer this question, it mobilizes an analytical framework structured around

³ By "service architecture" is meant the ensemble of institutional, regulatory, financial and operational arrangements that make it possible ensuring the production, transport, distribution, control and continuity of the treated wastewater reuse service.

three dimensions of infrastructure service governance: regulatory, financial and social. This framework is confronted with a comparative analysis of Mediterranean and arid contexts (2), with Morocco as the main illustrative case.

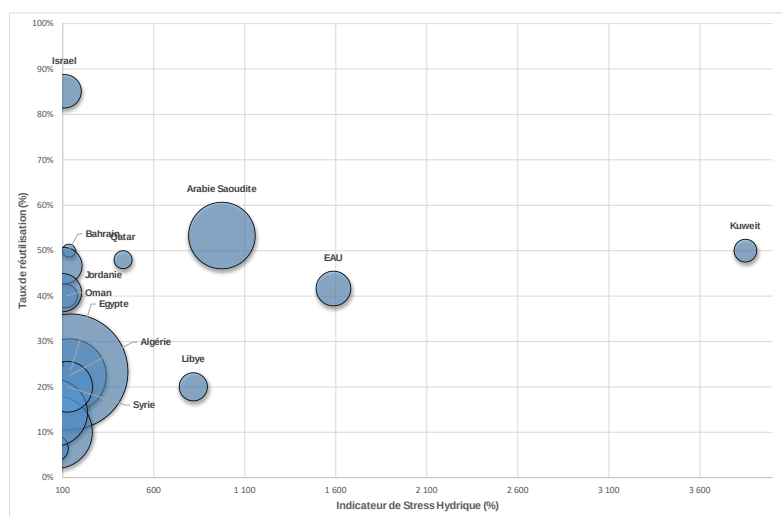


Figure 1 : Comparison between the reuse rate and the water stress indicator for countries with water stress above 100% ⁴ (2)

In regions subject to structural water stress, the reuse of treated wastewater can no longer be limited to treatment; it must be conceived as a reliable, financed, regulated and daily operated public service. The central argument of this article is that the obstacles to deploying treated wastewater reuse at large scale are structurally linked to the central problem of a service architecture with quality, cost allocation and responsibility obligations that are not sufficiently specified.

2. THREE SYSTEMIC FAILURE MODES

The comparative analysis of treated wastewater reuse projects across the Mediterranean basin and in comparable arid contexts reveals three recurring failure modes, observed both in Morocco and in neighbouring countries around the Mediterranean (2).

2.1 The absence of a common service reference framework

The stakeholders involved in the treated wastewater reuse value chain, namely wastewater treatment plant operators, river basin agencies, health authorities, ministries in charge of water, agriculture and the interior, local authorities and final users, operate with divergent conceptions of the service. Operators focus on water quality at the outlet of the wastewater treatment plant. Farmers define the service by water availability at farm level. Health authorities focus on pathogen thresholds and contamination risks. River basin agencies focus on authorization, control and monitoring conditions for resource quality. Regions and municipalities focus on the territorial deployment of access to treated water and the mobilization of financing.

In Morocco, Law 36-15 on water, articles 5 and 64 to 71, requires that any reuse be authorized by the river basin agency, which is also responsible for control. Decree No. 2-97-875 of 4 February 1998 relating to the use of wastewater and Order No. 1276-01 of 17 October 2002 setting the quality standards for water intended for irrigation constitute the existing regulatory framework and are currently under revision (5). These texts are more than twenty years old and need to be updated to respond to the current challenges of treated wastewater reuse. However, the implementing decrees specifying the

⁴ The size of the bubbles represents the population of the country

quality requirements by category of use and the sanctions have not yet been published. Without these texts, which represent the enforceable common reference framework, the definition of service quality varies from one treated wastewater reuse agreement to another (8).

2.2 Structural underfinancing of distribution, the last kilometer

Treated wastewater reuse investment programmes concentrate expenditure on treatment infrastructure, the component that naturally concentrates the attention of donors, to the detriment of transport, distribution to the final user and long-term maintenance (9; 10).

In the agricultural sector, the tariff level charged for treated water generally do not cover the capital costs of treatment and distribution facilities, even though such infrastructure is expected to be profitable in the long term. In Morocco, investment programmes have historically prioritized treatment infrastructure over distribution networks, leaving the last-kilometer segment structurally underfinanced regardless of the cost-sharing arrangement applied (5).

2.3 Social acceptability: the wrong culprit

The negative perception of treated wastewater reuse, based on representations of health risk and purity, is widely documented in the Mediterranean context (2). This resistance is nevertheless misdiagnosed when it is treated as an autonomous cause to be resolved through communication: it is endogenous to service failures, not exogenous to them (11).

In Morocco, the experience of the water operator's network in the Rabat-Salé-Témara agglomeration, with smart hydrants, real-time display of quality and 900 hectares of green spaces served (ONEE, 2024), illustrates that a transparent and verifiable service architecture produces acceptability that no communication campaign can generate alone. Acceptability is a downstream result, not a prerequisite (12).

3. DESIGNING THE REUSE OF TREATED WASTEWATER AS A TERRITORIAL SERVICE: THREE REQUIREMENTS

Three essential conditions must be met simultaneously for treated wastewater reuse to function as a viable service: use-specific enforceable reference frameworks and authorizations, sustainable financing of the whole value chain, and evidence-based acceptability mechanisms.

3.1. Use-specific quality objectives with enforceable authorizations

The 1998 decree⁵ and the 2002 order⁶ constitute the regulatory basis of treated wastewater reuse in Morocco (5). They set the fundamental principles requiring prior authorization by the river basin agency, define the conditions for granting State financial support, and establish quality standards for water intended for irrigation.

The first condition consists in extending this basis by translating these standards into enforceable authorizations specific to each category of use, specifying monitoring obligations, incident management protocols and a graduated sanctions regime. This is the step that transforms a quality standard into a service contract. It links obligations to identifiable actors, verifiable deadlines and defined consequences in the event of non-compliance. Furthermore, implementing texts should not be limited to normative aspects and authorization procedures, but should also include dimensions relating to epidemiological

⁵ Decree No. 2-97-875 of 6 Chaoual 1418 (4 February 1998) relating to the use of wastewater. Official Bulletin of the Kingdom of Morocco, No. 4581, 5 February 1998.

⁶ Joint Order of the Minister of Equipment and the Minister in charge of Spatial Planning, Environment, Urban Planning and Housing No. 1276-01 of 10 Chaabane 1423 (17 October 2002) setting quality standards for water intended for irrigation. Official Bulletin of the Kingdom of Morocco, No. 5062, 5 December 2002.

and public health monitoring, health and environmental risk assessment, and post-evaluation of projects. This would make it possible to assess the effective achievement of the objectives assigned in terms of resource recovery, savings in conventional water and sustainability of uses (5). Without these elements, the standard exists but does not produce the service.

At European level, Regulation (European Union) 2020/741 on minimum requirements for water reuse, establishing quality classes by use, risk management plans and interinstitutional coordination obligations, provides a reference model (13). The future Directive (European Union) 2024/3019, replacing Directive 91/271/EEC from 2027 onwards, further strengthens this integrated approach (14). Although designed in a different institutional context and in a framework where implementation of treated wastewater reuse remains variable and still limited in several European countries, these frameworks constitute a relevant reference for Morocco's next regulatory step, particularly the publication of the implementing decrees of Law 36-15, currently being finalized (5).

3.2 An economic model that does not stop at the wastewater treatment plant

The second condition requires explicit financing of the entire service chain: collection, treatment, transport, distribution and long-term maintenance at the point of use. This requirement is based on a structural observation: treated wastewater reuse financing models tend to concentrate public resources on treatment, the most capital-intensive component and the easiest to justify to donors, to the detriment of downstream segments that nevertheless condition the operational viability of the service.

Several instruments make it possible to structure the financing of the whole chain: differentiated tariffs by use and volume, public subsidies targeted at non-profitable segments, blended financing combining public and private resources, and take-or-pay contracts guaranteeing a minimum revenue to the operator. These instruments are not mutually exclusive and their optimal combination depends on the institutional context, the profile of final users and the cost structure specific to each sectoral service model. The prerequisite is to treat the last-kilometer deficit as a financing item in its own right, and not as a residual detail whose coverage will be adjusted during the operation phase (10).

The Israeli model, with differentiated tariffs, subsidies to farmer users and long-term purchase agreements creating a financially viable wholesale market for recycled water, demonstrates the viability of such an architecture for intensive agricultural reuse of treated wastewater (15). In Morocco, the Rabat-Salé-Témara system, with a transfer network of 190 km (projected 310 km) and a total investment of around EUR 60 million (12), illustrates the scale of infrastructure required to deliver peri-urban reuse of treated wastewater as a service.

For agricultural reuse of treated wastewater, however, no whole-chain financing model is in place. Even where investment is fully publicly financed, project viability remains weakened by operating costs and by the limited price differential between treated water and conventional water (11).

3.3 Evidence-based acceptability mechanisms

The third condition reframes social acceptability as the result of a monitoring and transparency system that functions. Minimum requirements include transparent monitoring results publicly accessible at the point of use, and not only at the outlet of the wastewater treatment plant, user-oriented reports in accessible formats, structured complaint and response channels, and participatory engagement with final user communities. The Rabat experience, with smart hydrants providing real-time information on water quality at reuse points and connected to the monitoring system of the National Office for Electricity and Drinking Water (12) is an operational illustration at urban scale: where the service becomes visible and verifiable, trust is built without resorting to communication campaigns.

Furthermore, indirect reuse, including aquifer recharge with treated wastewater and planned discharges into water bodies from which later abstraction is carried out, must be formally recognized and governed by requirements adapted to risk levels, intended uses and technical and economic constraints, distinct from those applicable to direct reuse. In Morocco, the informal use of partially treated effluents in peri-

urban areas of Meknès, Settat and other cities is documented (16), representing de facto indirect reuse outside any monitoring framework.

The ongoing revision of general discharge limit values, as well as specific limit values applicable to domestic discharges into watercourses, could open the way to more flexible indirect reuse, better adapted to local realities, by differentiating requirements according to risk levels and intended uses. The systematic application of the same standards as for direct reuse may generate treatment, monitoring and control costs that are disproportionate to the expected benefits, particularly for low-risk uses.

4. THREE SECTORAL CONFIGURATIONS, THREE SERVICE LOGICS

Three replicable service models emerge from the comparative analysis of Mediterranean and arid contexts (2) : peri-urban non-food reuse, for green spaces, golf courses and urban services, agricultural reuse; and industrial reuse. Each mobilizes a specific risk profile, governance intensity and financing logic, whose articulation forms the 3×3 decision matrix presented in Table 1.

4.1 Peri-urban non-food reuse

In peri-urban areas, the reuse of treated wastewater for watering green spaces, golf courses, street cleaning and urban services is today the most rapidly deployable service model. Buyers are stable institutional clients, local authorities and operators of sports facilities, with contractual capacity, predictable demand and strong public visibility. The project portfolio of the National Office for Electricity and Drinking Water illustrates the achievable scale: 30 golf courses consuming 20.5 million cubic metres per year and 16 green space sites using 11.5 million cubic metres per year, supplied through agreements setting quality requirements, responsibilities and billing arrangements (12). Twenty-two additional golf courses are planned or under construction, representing an additional estimated potential of 13 million cubic metres per year. Major urban programmes confirm the model: the Marrakech wastewater treatment plant, with a capacity of 33 million cubic metres per year, currently supplies 14 golf courses and the palm grove, covering 810 hectares, with 10.4 million cubic metres per year reused (8), the M'Zar wastewater treatment plant in Greater Agadir supplies 4 golf courses, covering 600 hectares, with 3.2 million cubic metres per year.

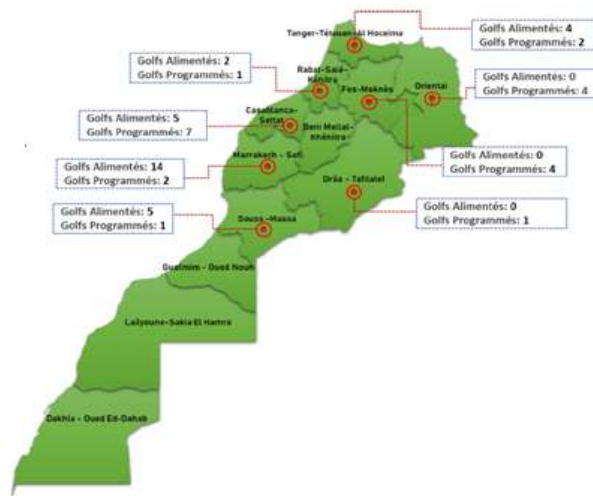


Figure 2 : Reuse for golf course irrigation in Morocco

Morocco's current reuse profile, 52.6 million cubic metres in 2024: 20.5 million cubic metres for golf courses, 11.5 million cubic metres for green spaces and 20.6 million cubic metres for industry (12) corresponds almost exclusively to this service model, confirming its value as an entry point but signalling the under-use of agricultural pathways.

4.2 Agricultural reuse

Agricultural reuse of treated wastewater presents the highest governance intensity of the three service models. The multiplicity of final users generates high transaction costs for monitoring and compliance. The risk of rebound effect, where increased water availability induces an expansion of irrigated areas that increases rather than substitutes conventional water withdrawals, requires explicit anticipatory rules, particularly in contexts of groundwater overexploitation (2; 4). Minimum conditions include clear authorization of crop categories with monitoring protocols, collective organization, such as Agricultural Water Users Associations or equivalent bodies, to reduce transaction costs, enforceable anti-rebound rules, and a differentiated tariff structure making substitution financially attractive. The comparative analysis of six countries (16) identifies two structural challenges for agricultural reuse of treated wastewater in Morocco: in irrigated perimeters where conventional water is priced, the treated wastewater reuse tariff is not sufficiently differentiated to induce substitution. In non-irrigated peri-urban areas, farmers' interest is higher because treated wastewater represents a net new resource. Three large-scale agricultural reuse projects, in Tiznit, Settat and Oujda, were under preparation at the time of this analysis (16) and constitute priority pilot sites, subject to collective organization frameworks and enforceable authorizations, themselves conditional on the publication of the implementing decrees of Law 36-15 on water.

4.3 Industrial reuse

Industrial reuse offers the highest volumetric returns per unit of governance investment when source control is in place. The OCP Group operates three dedicated treatment plants (Khouribga, Benguerir, Youssoufia) with a combined capacity of 32,200 cubic metres per day, treating municipal effluents for phosphate washing (12) This demonstrates the viability of the model for high-volume industrial use. Between 2019 and 2024, the OCP Group invested around 2.1 billion Moroccan dirhams in treated wastewater reuse infrastructure, making it the largest private investment in the Moroccan treated wastewater reuse sector. Port and agro-industrial zones, where several users share geographical proximity, offer opportunities for scaling up through shared distribution infrastructure and grouped service contracts. The prerequisite remains identical to that of other service models: quality obligations, shared costs and responsibilities in the event of non-compliance must be explicitly defined before deployment, and not negotiated during operation.

Table 1 : Decision matrix: Sectoral service models × minimum conditions

	Peri-urban (non-food)	Agricultural	Industrial-port
Regulatory	Authorization by use category	Authorization by crop (positive list)	Source control and industrial pre-treatment
	Monitoring at delivery point	Collective monitoring (AUEA)	Contractual quality specifications
	Public disclosure of results	Enforceable anti-rebound rule (reuse replaces, does not add to, conventional water)	Shared compliance obligations and penalties
	Incident reporting protocol	Implementing orders under Law 36-15	Incident communication plan
Financial	Cost recovery via service tariff	Whole-chain financing (treatment and last kilometre)	Take-or-pay contracts with industrial buyer
	State: 100% of tertiary treatment	Subsidy for smallholders, State: 100% of tertiary treatment	Shared infrastructure costs (port zones)
	40% State / 60% beneficiaries for distribution	Tariff signal favoring substitution, State 60%, private sponsors 40%	Sectoral financial incentives
	Maintenance provision in concession contract	Cost recovery above the floor of €0.02/m ³	Full-cost accounting including pre-treatment
Social	Smart kiosks with real-time quality display	Collective organization (WUA or equivalent)	Contractual liability clauses
	Complaint and response channel	Participatory allocation governance	Industrial user engagement protocol
	Visible signage at reuse points	Transparent evidence of cost-benefit for users	Independent audit and public reporting

5. MOROCCO: FROM A PROMISING TECHNICAL TRAJECTORY TO AN INTEGRATED SERVICE

5.1 Technical trajectory and investment momentum

Morocco's trajectory in treated wastewater reuse is clearly positive. The national infrastructure included 219 wastewater treatment plants with a total capacity of 1.40 million cubic meters per day at end-2024, with a treatment rate reaching 58%, compared with 7% in 2006. The infrastructure of the National Office for Electricity and Drinking Water alone includes 144 plants treating around 195 million cubic meters per year, including an estimated potential of 107 million cubic meters per year technically suitable for reuse thanks to tertiary treatment, and 40 million cubic meters per year already allocated to reuse applications (12). The reused volume reached 52.6 million cubic meters in 2024, compared with 37 million cubic meters in 2023 and 23.5 million cubic meters in 2019, representing a 124% increase in five years. Total investment between 2019 and 2024 reached around 3 billion Moroccan dirhams through State and National Shared Sanitation Programme funding, plus 2.1 billion Moroccan dirhams from the OCP Group and 256 million Moroccan dirhams from the Regions. The long-term objectives of the National Shared Sanitation Programme envisage a reusable potential of 531 million cubic meters per year.

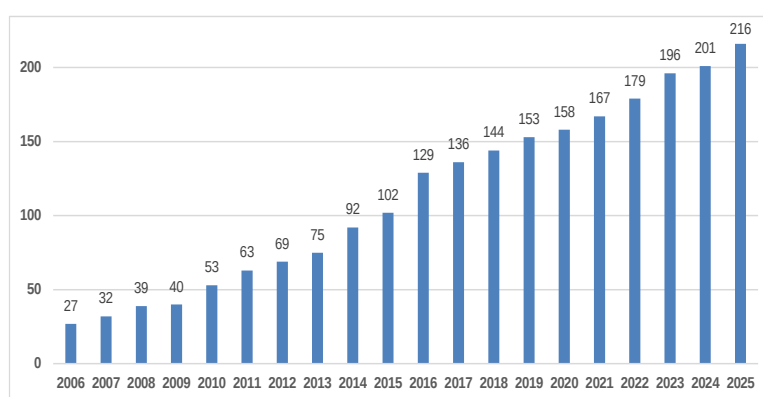


Figure 3 : Evolution of the number of wastewater treatment plants in Morocco

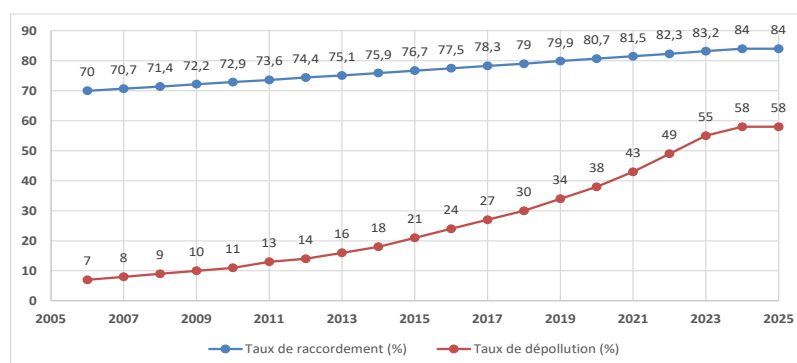


Figure 4 : Evolution of connection and treatment rates in Morocco

5.2 Four conditions to be consolidated for scale-up

For this investment dynamic to translate into scaling up towards a strategic objective for Morocco, four conditions remain to be consolidated.

- **Completing the regulatory framework.** Law 36-15, articles 5 and 64 to 71, provides the legislative basis, and the existing implementing texts, Decree No. 2-97-875 of 4 February 1998 relating to the

use of wastewater and Order No. 1276-01 of 17 October 2002 setting quality standards for water intended for irrigation, constitute a reference framework (5). The next step consists in completing it through implementing decrees specifying quality requirements by category of use, authorization procedures, monitoring obligations and the sanctions regime under Law 36-15 on water. This step would allow each project to rely on a common enforceable standard rather than on an ad hoc agreement, thus supporting the logic of replication needed to reach national scale.

- **Structuring agricultural financing.** The National Shared Sanitation Programme assigns tertiary treatment costs to the State through the dedicated financing mechanism and distributes distribution costs between 40% State and 60% beneficiaries (5). This model has demonstrated its effectiveness for the peri-urban non-food service model. Its extension to agricultural reuse of treated wastewater calls for adaptation: even if treated wastewater reuse projects led by Agricultural Water Users Associations are financed 100% by the State at investment stage, including distribution costs, solutions remain to be provided for operating and management costs. The tariff applied does not cover operating and maintenance costs (16), and whole-chain financing for agricultural distribution, including a subsidy mechanism for small farmers and a sufficient tariff signal to promote substitution for conventional water, remains to be structured.
- **Designation of an institutional coordinator.** Coordination between wastewater treatment plant operators, distribution managers, agricultural regulators and health authorities is a condition for the coherence of the system (5). Comparative experience in North Africa shows that intersectoral coordination bodies gain in effectiveness when they have a mandated secretariat, a driving authority and dedicated resources (16). The formal designation of a national coordinator for treated wastewater reuse in Morocco would constitute a structuring lever for the next phase of the programme.
- **Adaptation of service models to the capacities of agricultural project sponsors.** The choice between direct and indirect reuse in the agricultural sector depends strongly on the profile of the project sponsor and the associated economic and territorial objectives. Projects led by large private operators or farms with an industrial purpose generally have the financial and technical capacities needed to ensure treatment, transport, monitoring and operation investments, and favour direct reuse models with quality requirements adapted to high-value crops or industrial-purpose crops. Conversely, the integration of small farmers remains more complex because of the economic, technical and organizational constraints they face: more flexible approaches, particularly through indirect reuse of treated wastewater or shared systems, may constitute solutions better adapted to their capacities. The choice of projects must therefore take into account not only health and environmental requirements, but also the capacities of beneficiaries, the economic viability of the proposed systems and equity issues in access to non-conventional water resources (11).

6. CONCLUSION

The comparative analysis conducted in this article provides a structured answer to the question raised in the introduction: the minimum conditions that allow the reuse of treated wastewater to function as a viable and replicable territorial service are not independent. Whether regulatory, financial or social, they all reflect the same gap, namely a service whose rules, costs and responsibilities have not yet been fully defined.

The proposed 3×3 decision matrix constitutes the central analytical contribution of the article. It makes it possible to characterize each service model, peri-urban non-food, agricultural and industrial, by the minimum conditions required for its viability, and to identify the interdependencies between these conditions: the regulatory condition without the financial condition produces standards without service. The financial condition without the social condition produces a service without users. The social condition without the first two produces communication without foundation. Applied to Morocco, the matrix reveals a characteristic asymmetry: a strong investment trajectory (124% growth in reused volume between 2019 and 2024) (12), yet requiring four institutional conditions before scale-up can be

achieved: completing the regulatory framework, structuring agricultural financing, designating an institutional coordinator, and adapting service models to the capacities of agricultural project sponsors.

Two limitations deserve to be noted. The matrix is typological and not predictive: it identifies necessary conditions but does not model the dynamic interactions between them or the transition pathways from one configuration to another. Furthermore, the data mobilized on the Moroccan case mainly come from institutional sources, which calls for triangulation through field surveys among final users, particularly agricultural users.

These limitations point to two research directions: first, modelling the interactions between viability conditions in contexts of strong budgetary constraint. Second, longitudinal analysis of rebound effects in agricultural treated wastewater reuse perimeters, which remains to date poorly documented empirically (2).

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