TECHNICAL REPORT

Scaling Water and Soil Salinity Solutions in Egypt's Nile Delta

Governance, Knowledge, Markets, and Finance in Kafr El-Sheikh

Fayrouz Eldabbagh and Atef Nassar

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Front cover photo: Irrigation Canal in Qora Kharigin, West Nubariyah/Housh Eissa region at the Beheira Governorate, Egypt (*photo*: Mohamed Samy/Waft Agency)
Back cover photo: Surface salt accumulation and soil cracking in salinity-affected farmland, Ezbet Abou Eita, Kafr El Sheikh, Egypt. (*photo*: Ibrahim Gaafar).

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Acronyms and Abbreviations

Acronym	Full Name
ABE	Agricultural Bank of Egypt
AKIS	Agricultural Knowledge and Innovation System
AOAD	Arab Organization for Agricultural Development
ARC	Agricultural Research Center
CAPEX	Capital Expenditure
CAPMAS	Central Agency for Public Mobilization and Statistics
CBA	Cost–Benefit Analysis
CBE	Central Bank of Egypt
CGIAR	Consultative Group on International Agricultural Research
DRI	Drainage Research Institute
EC	Electrical Conductivity
ECES	Egyptian Center for Economic Studies
EEAA	Egyptian Environmental Affairs Agency
EPADP	Egyptian Public Authority for Drainage Projects
ESP	Exchangeable Sodium Percentage
FAO	Food and Agriculture Organization of the United Nations
IFAD	International Fund for Agricultural Development
IIIMP	Integrated Irrigation Improvement and Management Project
IPCC	Intergovernmental Panel on Climate Change
IWMI	International Water Management Institute
JICA	Japan International Cooperation Agency
KPI	Key Performance Indicator
LFRPDA	Lakes and Fish Resources Protection and Development Agency
MALR	Ministry of Agriculture and Land Reclamation
MHUUD	Ministry of Housing, Utilities and Urban Development
MSMEDA	Micro, Small and Medium Enterprises Development Agency
MWRI	Ministry of Water Resources and Irrigation
NBE	National Bank of Egypt
NWRC	National Water Research Center
NWRP	National Water Resources Plan
O&M	Operation and Maintenance
OPEX	Operating Expenditure
PV	Photovoltaic
SADS	Sustainable Agricultural Development Strategy
SAR	Sodium Adsorption Ratio
SLR	Sea Level Rise
SOP	Standard Operating Procedure
S4I	Scaling for Impact
SWERI	Soil, Water and Environment Research Institute
UNDP	United Nations Development Programme
WEF	Water–Energy–Food
WMRI	Water Management Research Institute
WUA	Water User Association

Executive Summary

Water and soil salinity pose biophysical and economic pressure on agricultural productivity in the Nile Delta region of Egypt, most visibly in downstream governorates such as Kafr El-Sheikh governorate. Although Egypt has developed strong technical innovations on soil and water salinity management at the level of national research institutes, decentralized adoption remains limited.

This research is part of the CGIAR Science Program on Scaling for Impact, particularly Area of Work 3, which marks a step change that shifts the focus from identifying additional technical solutions to assessing the enabling environment that determines the adoption and sustainability of these solutions on a wider scale.

Through this science program, the International Water Management Institute (IWMI) seeks to provide a system-level analysis to support evidence-based investment, coherent policy instruments and institutional arrangements that are behind the successful scaling of inclusive salinity management practices in water and agri-food systems.

Based on a literature review and policy dialogue held during the 8th edition of Cairo Water Week and a case study in Kafr El-Sheikh Governorate, the report examines bottlenecks and enablers associated with governance, policy coherence, financing, land tenure, knowledge systems, and social norms that shape the adoption and scale of salinity management solutions. It demonstrates how the effectiveness of salinity mitigation and adaptation is shaped by fragmented mandates, misaligned incentives, weak data-to-action pathways, and risk structures - on water quality, pricing, tenure insecurity, and delayed returns - that discourage long-term investment among farmers and local institutions.

Key findings

- Salinity governance is fragmented: irrigation, drainage, soil management, and cropping decisions are institutionally siloed and weakly coordinated.
- Current policy instruments prioritize water delivery and hardware investments, e.g., canal lining, while salinity, drainage performance, and soil health remain outside routine accountability frameworks. Monitoring data exists, but is rarely translated into operational rules for reuse, blending, and irrigation schedules.
- The costs of salinity are disproportionately borne by tail-end and downstream farmers in Kafr El-Sheikh, who depend most on drainage-water reuse and have the least access to monitoring, finance, and tenure security.
- Farmers under-invest in salinity management as an economically rational response to water quality risk, delayed returns, fragmented holdings, and informal tenure arrangements that prevent them from internalizing multi-year benefits.
- Value chains and financing in saline lands are in many areas structured around trader-led informal credit, agricultural input and market captivity, and an institutional inertia built around conventional cropping rather than salt-tolerant production systems.

In this regard, the analytical framework identifies two phases of policy action to address salinity bottlenecks and seize opportunities: immediate measures to operationalize existing capacity (1–3 years), and structural reforms to sustain and scale outcomes (beyond 3 years).

Priority actions (1-3 years)

- Establish joint protocols between the Ministry of Water Resources and Irrigation (MWRI) and the Ministry of Agriculture and Land Reclamation (MALR) at the governorate level to align irrigation, drainage, soil amendments, and crop guidance.
- Institutionalize a governorate-level ‘salinity-safe reuse’ Standard Operating Procedure (SOP), defining monitoring points, Electrical Conductivity (EC) thresholds, and response actions for reuse.
- Operationalize salinity monitoring by linking EC data to irrigation scheduling, blending rules, and extension advisories in hotspot zones.
- Introduce salinity-relevant performance indicators into seasonal reviews for irrigation, drainage and agricultural directorates.

Priority actions beyond 3 years

- Embed salinity management into national water and agricultural planning and reorient incentive and subsidy structures so that delivery agencies, cooperatives, and farmers are rewarded for salinity-relevant outcomes rather than service coverage alone.
- Scale blended finance and risk-sharing mechanisms for salinity management through cooperatives, service providers, and pioneered Water User Associations (WUAs) in salinity hotspots. This finance could be oriented to a coherent salinity solutions package that includes monitoring, amendments, leaching, and crop choice.
- Strengthen value chains and contract farming for salt-tolerant and salinity-smart crops in a way that strengthens coordination between farmers, processors, and lenders.
- Adapt credit, advisory, and input-support systems to reflect the different land tenure arrangements, including tenancy, family-based farming, and mixed operating arrangements in Kafr El-Sheikh, which influence who actually makes day-to-day decisions about salinity management.
- Institutionalize integrated data platforms linking water quality, soil salinity, crop productivity, input costs, profits, and salinity monitoring.

Introduction

Salinity in the Nile Delta: National Context

Water and soil salinity have become more visible across large parts of the Nile Delta in recent decades, which is influenced by the interplay across water access and use, agronomic practices, and climate-related pressures. In 2025, a study led by the International Water Management Institute (IWMI) and the Arab Organization for Agricultural Development (AOAD) produced updated water and soil salinity maps covering four governorates: Kafr El-Sheikh, Ismailia, Qalyoubia, and Fayoum (Lahham et al., 2025). These maps were developed using remote sensing techniques and validated through systematic ground-based sampling of soil and water.

The study documented the increasing challenge of managing rising water and soil salinity levels while maintaining high biophysical and economic water productivity. Surveyed farmers consistently identified challenges that are related to deteriorating soil quality, shallow groundwater tables, constraints in irrigation and drainage management, limited availability of freshwater for leaching, poor drainage water quality, low adoption of modern technologies, and weak access to water and soil lab testing services (Lahham et al., 2025). While these challenges are typically framed as technical or biophysical, their persistence at scale points out to enabling environment gaps that shape how existing technical solutions could be largely adopted and sustained.

This report is the second synthesis in a series aimed at developing a roadmap for salinity management, with this edition focusing on the enabling environment for scaling integrated water and soil salinity solutions. Building on the earlier technical studies, it draws on historical evidence and new data compiled in the 2025 Salinity Roadmap Report. To ground the national framework in local realities, the report focuses on a single governorate. Kafr El-Sheikh Governorate was selected because it consistently emerges as the most salinity-stressed among the four benchmark governorates in the 2025 study, where it combines acute biophysical exposure with dense agricultural production systems.

Kafr El-Sheikh Context

Kafr El-Sheikh Governorate is one of Egypt's most important agricultural regions, with over 745 thousand feddans (*312 thousand hectares*) of arable land, making it among the largest cultivated governorates in the Nile Delta (CAPMAS, 2024). The 2025 study report indicates that water and soil exhibit varying degrees of salinity in different parts of the governorate; salinity is increasingly salient in northern, coastal, and agricultural drainage-dependent zones, where shallow groundwater tables, drainage congestion, and sea intrusion are pronounced (Lahham et al., 2025).

Hydrological Setting

Kafr El-Sheikh is characterized by a dense irrigation and drainage network, where it lies at the downstream end of the Nile irrigation system. Competition for freshwater and distributional constraints in tail-end locations have increased reliance on agricultural drainage water reuse, which typically contains elevated concentrations of dissolved salts, agrochemical residues, and organic loads that exceed recommended salinity thresholds (Abdel-Azim & Allam, 2005; El-Agha et al., 2020). Unmanaged reuse accelerates salinity build-up, especially when blending ratios are constrained by lack of available freshwater (El-Agha et al., 2020; Molle et al., 2018).

Districts such as Sidi Salem and Village 71 rely on a mix of freshwater and drainage water, while Al-Hamul, Biala, Demro, and El-Zawia depend almost entirely on reused drainage flows (Lahham et al., 2025). Some of these districts are highly or moderately vulnerable to inundation under sea-level rise scenarios, such as Sidi Salem (Hassaan, 2013). In fact, the social and environmental costs of water scarcity are felt most acutely by downstream communities, which highlights the spatial disparities in agricultural risk and productivity.

In salinity-prone tail-end areas, higher 'efficiency' does not automatically mean lower salinity risk because when irrigation efficiency improves, it reduces return flows to the drainage system, which increases its salt concentration and reduces flow to drainage-dependent agriculture and aquaculture farms (Molle et al., 2018). Another trade-off is shown when drainage operation and maintenance are poor, rice cultivation and leaching become ineffective, and salts gradually reaccumulate within the soil profile, undermining crop productivity over time (Eid et al., 2011; Omar et al., 2021).

Agronomic Practices and Cropping Patterns

Large areas, particularly in Zawia, Sidi Salem, and parts of Al-Hamul and Biala districts, are characterized by saline soils, which signals long-term exposure to marginal irrigation water (Lahham et al., 2025). The cultivation of water-intensive crops, most notably rice, has played a role in controlling salinity by flushing salt from the soil profile and limiting seawater intrusion in low-lying areas. However, under scarcity scenarios and rice-area restrictions, the loss of salinity-flushing function increases salt accumulation (Lasheen, 2022; Wally & Akingbe, 2021).

The literature thus describes salinity in Kafr El-Sheikh as emerging through interacting processes: the use of saline or marginal-quality irrigation water and the accumulation of salts driven by irrigation practices. While closely linked, these processes originate from different hydrological and agronomic pathways and vary spatially across the governorate.

Economic Pressures and Livelihood Context

A 2012 study estimated losses from sea-level rise at approximately USD 164-328 million by 2030 and USD 328 million – 2 billion by 2060, equivalent to EGP 1–2 billion and EGP 2–16 billion, respectively, at the 2012 exchange rate (Smith et al., 2012). Because the Egyptian pound has depreciated substantially against the US dollar since 2012 to date, these projections are expected to be accompanied by a higher burden on farmers and public budgets.

Water and soil salinity have tangible economic implications for farmers in Kafr El-Sheikh. Managing saline soils often entails higher variable input costs, including additional energy for water pumping, soil amendments such as gypsum, and more frequent land preparation (Lahham et al., 2025). These costs reduce net returns and can increase indebtedness, particularly for smallholders and tenants (Elsafty et al., 2025). Nevertheless, the continued profitability of certain crops in saline areas, such as rice and clover, helps explain farmers' willingness to absorb higher salinity management costs where market prices remain attractive (Lahham et al., 2025).

Kafr El-Sheikh has a predominantly rural population, with approximately 76% of residents living in rural areas, and agriculture remains a central source of income (CAPMAS, 2017). Alongside agriculture, aquaculture has become a defining feature of its local economy, where it produces approximately 46% of Egypt's national aquaculture output (Soliman & Yacout, 2016). Much of this production relies on agricultural drainage water and brackish water, linking aquaculture in Kafr El-Sheikh directly to salinity adaptation and to reuse within the Nile Delta landscape (Rossignoli et al., 2023). Nevertheless, aquaculture is roughly five times less profitable per unit of input cost than agriculture (1.29 compared to 6.7) because it involves higher input costs, notably feed (see Table 1) (CAPMAS, 2025). In addition, surveyed evidence from Kafr El-Sheikh shows that 86.7 per cent of aquaculture actors rely on self-finance, with only 3.3 per cent accessing formal bank credit (El-Sayed et al., 2015; Elsorougy & Abd EL-Rahim, 2025).

Table 1. Unit in USD billion[1] in 2023/2024 (Source: (CAPMAS, 2025)

Sector	Product Value (USD Billion)	Input Cost (USD Billion)	Net Income (USD Billion)	Net Ratio (net income / input cost)
Agriculture	2.18	0.28	1.9	6.7
Aquaculture	1.87	0.81	1.06	1.29

Land Tenure Insecurity and Fragmentation

The hydrological, agronomic, and economic dynamics, outlined above, operate within a tenure structure that is fragmented in scale and tenure insecure. According to land tax records, more than 277,000 registered agricultural holdings in Egypt are smaller than one *feddan*, collectively accounting for approximately 96,000 *feddans* nationwide (CAPMAS, 2024b). This fragmentation was the result of the 1952 agrarian reforms, which redistributed land to smallholders, and the partial reversal of those reforms under Law 96/1992, which reset tenancy on market terms and reorganized rural property relations in favour of registered owners (Abdel Razek & Shawkat, 2025; Bush, 2007). In addition, inheritance practices have compounded subdivision over successive generations (Bush, 2007).

[1] Values converted from EGP to USD at approximately EGP 36.5 per USD (the 2023/2024 exchange rate). Original agriculture values: EGP 79,610 million product value, EGP 10,299 million input costs, EGP 69,311 million net income. Aquaculture values converted using the same rate; original EGP figures available from CAPMAS (2025). Original aquaculture values: EGP 68,264 million for product value, EGP 29,741 million for input costs, and EGP EGP 38,523 million for net income.

Alongside fragmentation, tenure in Kafr El-Sheikh is characterized by informal and normative ('urfi) arrangements. In the aquaculture sector, much of the land used for aquaculture has historically been leased or temporarily allocated (Elsorougy & Abd EL-Rahim, 2025; Rothuis et al., 2013).

Research Gap: From Technical Solutions to Implementation at Scale

Many biophysical and technical salinity solutions are documented extensively or applied on a pilot scale. However, a gap remains in understanding the drivers of their sustainable adoption and scaling by users, particularly in high-risk areas in Kafr El-Sheikh. This report addresses this gap by shifting the analytical focus from additional technical solutions to the enabling environment that shapes their adoption and scaling.

Enabling Environment Framework for Salinity Management

Purpose and scope

Under the CGIAR science program on Scaling for Impact, and within the area of work on enabling environment, this technical report analyzes the bottlenecks and the enabling factors that allow the adoption and scaling of some locally tested salinity management responses. It is based on a synthesis of literature identified in technical studies compiled under the 2025 Salinity Roadmap Report, complemented by literature and field-based evidence from Kafr El-Sheikh Governorate. Moreover, it combines insights from a policy dialogue with national and regional stakeholders from the Ministry of Water Resources and Irrigation, Drainage Research Institute (DRI), Soil, Water, Environment Research Institute (SWERI), as well as the International Center for Agricultural Research in the Dry Areas, Worldfish, and the Embassy of the Netherlands during the 8th edition of Cairo Water Week in 2025.

Three dimensions of solutions/innovations for salinity management:

1. **Governance Scale**: these solutions are managed at different governance scales, ranging from field-level/tertiary canals practices to branch canals and drainage command systems, and national measures. Different stakeholders are involved at each scale, including farmers/WUAs, directorates, and central planning.

2. **Intent**: these solutions are distinguished according to whether they aim to either mitigate salinity, by reducing salt accumulation and limiting the processes that drive salinization, or adapt to salinity, by enabling agricultural production and livelihoods to persist under existing or unavoidable saline drivers

3. **Domain of action**: these solutions are defined based on the type of resource intervention, either managing soil salinity, defined as soil amendments, crop choice, and others, or managing water salinity, defined as drainage management, reuse practices, and others. Most importantly, this report seeks to identify coherent and integrated solutions between water and soil salinity management, which are particularly relevant in low-lying and drainage-dependent areas of Kafr El-Sheikh.

Rationale for combined and context-specific approaches

Evidence from Kafr El-Sheikh and comparable delta environments demonstrates that no single intervention or actor is sufficient to manage salinity effectively. Instead, salinity management requires combinations of practices, implemented in a coordinated manner between relevant stakeholders and adapted to local environmental and socio-economic conditions (Evans et al., 2013; Olabanji & Chitakira, 2025).

For example, on-farm practices such as periodic leaching, gypsum application, or deep tillage can improve soil conditions, but their effectiveness depends on adequate availability of freshwater, proper timing and application, and functional drainage systems capable of removing mobilized salts (Molle et al., 2018). Similarly, drainage water reuse can help address short-term water shortages, but when undertaken without adequate blending, monitoring, or drainage maintenance, it may exacerbate soil and water salinity in the long term (Abdel-Azim & Allam, 2005; El-Agha et al., 2020; Molle et al., 2018). Salinity management is therefore inherently systemic, which links farm-level decisions with canal operations and drainage infrastructure.

Dimensions of the enabling environment

This research maps five interrelated pillars of the enabling environment that shape whether salinity-management solutions can be adopted, sustained, and scaled at the governorate level:

1. **Institutional arrangements and power dynamics**: roles, mandates, and coordination among water, agriculture, and drainage authorities, and the relationships between these authorities and farmer organizations.
2. **Policy frameworks and coherence:** the design, alignment, and trade-offs across water-allocation, crop-choice, and salinity-management instruments, including gaps in operational and monitoring rules.
3. **Financing, cost-sharing mechanisms, and value-chain integration**: the financial and market structures that determine farmers' capacity to invest in salinity management and absorb associated risks.
4. **Land tenure arrangements:** the ownership, tenancy, and informal operating arrangements that shape access to resources, bankability, and the distribution of salinity-management risk.
5. **Social norms and behaviors**: the everyday behaviours, peer networks, and gender dynamics that influence how farmers perceive salinity risks and respond to proposed solutions.

The five dimensions provide a diagnostic lens for identifying where the enabling environment supports or constrains adoption. Figure 1 complements this lens with a Theory of Change that traces how coordinated action across these dimensions is expected to translate into scaled adoption of bundled salinity-management solutions. It shows the causal pathway from identifying the different technical solutions to interventions across the five enabling-environment dimensions to the expected biophysical and socio-economic outcomes.

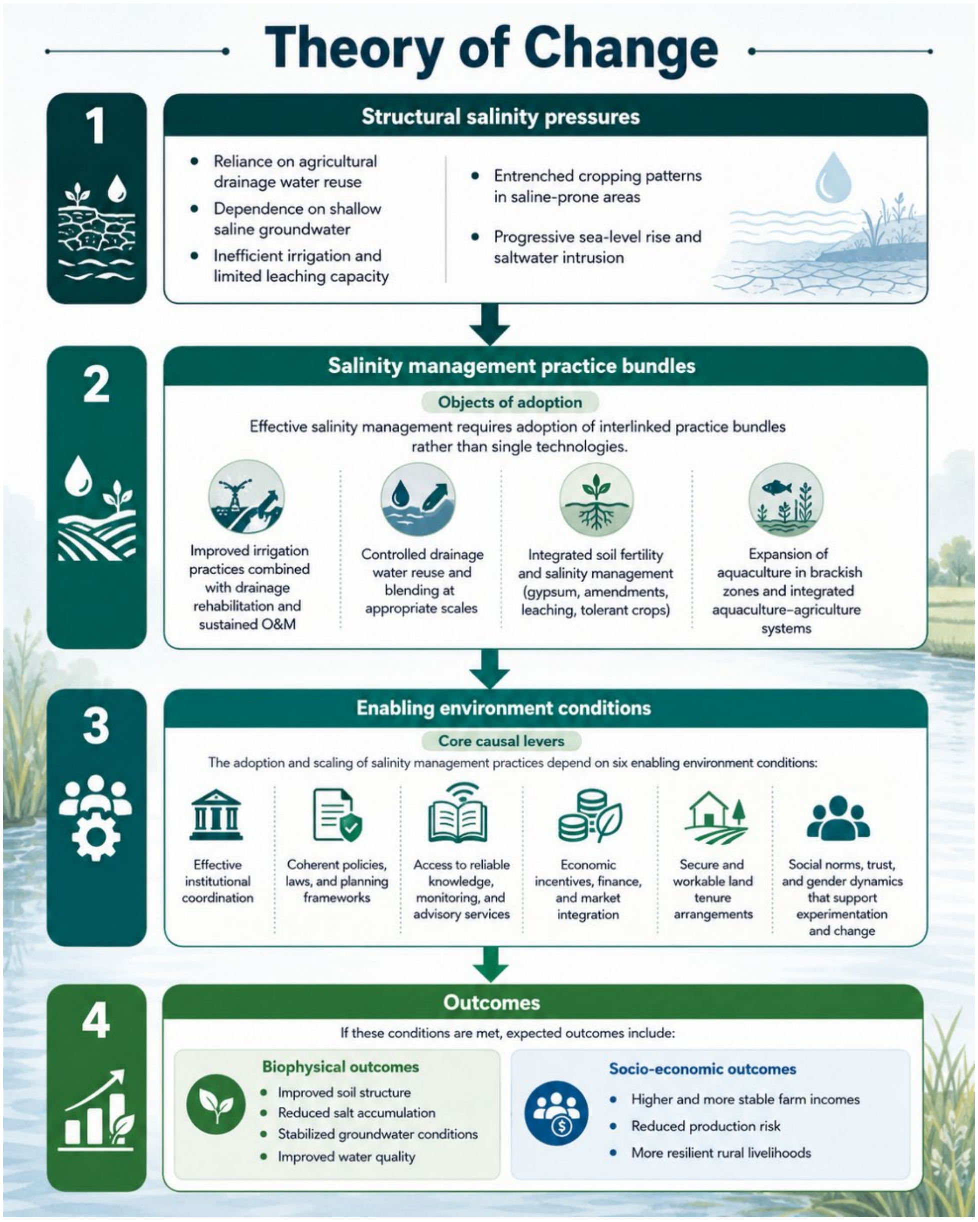

Figure 1. Theory of Change for scaling bundled salinity-management solutions

Enabling Environment Conditions

1. Governance, Institutional Alignment and Coordination

1.1 Description: Institutional landscape and governance dynamics

Water and soil salinity management in Kafr El-Sheikh is governed through a multi-layered institutional structure that links cross-sectoral ministries and research institutes horizontally, and governorate directorates and farmer-level organizations vertically. Formal mandates are relatively well defined, but institutional power and effectiveness vary substantially, shaping how (and whether) salinity control translates into practice (Eldabbagh et al., 2024).

The Ministry of Water Resources and Irrigation (MWRI) is one of the dominant actors in the salinity governance chain because it controls basin-level flows, canal and drainage operations, reuse regulation, licensing, and water quality monitoring system (Ministry of Water Resources and Irrigation, 2017; *Water Resources Law*, 2021). Day-to-day implementation runs through MWRI's governorate irrigation engineers. In Kafr El-Sheikh, irrigation engineers manage canal rotations, discharge rates, and mesqa improvements.

The Egyptian Public Authority for Drainage Projects (EPADP) oversees subsurface drainage infrastructure, rehabilitation, and related operations and maintenance. Drainage performance is a salinity-control function because water table depth and salt leaching depend on functioning subsurface collectors and maintained drains.

MWRI's research and technical support functions sit within the **National Water Research Center (NWRC)**. Within NWRC, the **Water Management Research Institute (WMRI)** supports irrigation scheduling and allocation guidance, while the **Drainage Research Institute (DRI)** focuses on drainage water quality and reuse planning. These entities generate technical guidance and monitoring data, but their influence on operational decisions remains indirect and depends on whether recommendations are translated into binding procedures at the directorate level (Salman et al., 2007).

On the agricultural side, the **Ministry of Agriculture and Land Reclamation (MALR)** influences salinity outcomes through extension services and recommendations on crops, soil amendments, and agronomic practices. The **Agricultural Research Center (ARC)**, including SWERI and the Sakha station in Kafr El-Sheikh, provides the technical foundation for soil salinity assessment, gypsum and organic amendment guidance, and water–soil–crop suitability recommendations. In practice, salinity governance is inherently cross-sector where MALR and ARC shape "what farmers should do," while MWRI shapes "when and how much quantity and quality water arrives".

The **Ministry of Environment**, through the **Egyptian Environmental Affairs Agency (EEAA)**, plays a monitoring and coordination role on waste discharge and compliance under environmental requirements, including Law 48/1982. However, licensing authority and binding enforcement instruments for water abstraction, effluent discharge, and reuse practices are exercised primarily by MWRI (Mumssen & Triche, 2017).

The Lakes and Fish Resources Protection and Development Agency (LFRPDA) oversees fish farming licenses, controls access to land and water, and provides technical advice (Goulding & Kamel, 2013; Soliman & Yacout, 2016).

At the user level, the legal framework increasingly recognizes collective water management, through **Water User Associations (WUAs)**, under Law 147/2021. In Kafr El-Sheikh, the mesqa is the level at which collective action is most feasible, as it aligns with day-to-day irrigation scheduling and local pumping practices.

1.2 Bottlenecks: Institutional fragmentation and weak integration of irrigation, drainage, and soil management

Bottleneck 1: Horizontal fragmentation across the water–soil–crop system at the national level

Salinity governance is shared across multiple institutions. Water delivery is managed by the irrigation department, drainage operation, and drainage-water reuse are overseen by EPADP; mixing and reuse regulations are created by NWRC institutes (DRI, WMRI) and must be followed by irrigation directorates; soil health and crop response to salinity are handled by MALR and ARC/SWERI. Yet coordination across irrigation, drainage, and on-farm practices remains constrained by fragmented administrative structures and limited information sharing (Molle, 2018). The result is recurrent gaps, especially around decision-making on linking water delivery and reuse decisions with soil salinity risk.

Bottleneck 2: Vertical fragmentation between research guidance and operational practice at the governorate level

Evidence on Egypt's agricultural knowledge and innovation systems points to weak connections among national research institutes, local agencies, and extension services, which limit the translation of technical guidance into routinized agricultural practice (Zahran et al., 2020). WMRI and DRI generate extensive monitoring data, modelling tools, and technical guidance to inform water planning and management. However, the literature suggests that institutional fragmentation, weak information sharing, and limited coordination across water-sector agencies can constrain the systematic incorporation of these technical outputs into operational decision-making (Metawie, 2002; Molle, 2018). This disconnect occurs under staffing and resource constraints in governorate offices, particularly extension, which limits regular sampling and tailored technical advice (Kassem et al., 2021).

Bottleneck 3: Data-to-action gaps in salinity monitoring and irrigation scheduling

DRI operates extensive drainage-water monitoring networks and maintains databases, modelling tools, and analytical systems to assess water quality and salinity conditions across the Nile Delta. Monitoring results reveal considerable spatial and temporal variability in drainage-water quality (Metawie, 2002; Mostafa et al., 2005). However, the literature primarily documents the use of these data for assessment, national planning, and scenario evaluation, providing limited evidence on how monitoring information is systematically integrated into day-to-day operational decisions regarding water reuse and irrigation scheduling (Metawie, 2002; Mostafa et al., 2005).

Bottleneck 4: Misaligned incentives where delivery performance is prioritized over salinity outcomes

At the directorate level, performance of irrigation directorates is judged primarily on maintaining irrigation service delivery (adequacy/reliability and conflict avoidance), while soil health and water quality are not routinely embedded in operational performance metrics. While maintaining sustainable water access is important, it could mask long-term salinity risks from local maladaptation or climate-related events (Bos et al., 2005).

Bottleneck 5: Limited effectiveness and data gaps on WUAs in Kafr El-Sheikh

Empirical studies indicate that many WUAs remain underdeveloped or partially operational, with informal scheduling based on social relations continuing to dominate. In several locations, farmers have reverted to individual pumping arrangements, while recently installed collective pumping and maintenance systems do not function as intended (Elhadad et al., 2020). Similarly, aquaculture cooperatives in Egypt remain weakly developed. As of 2020, the number of registered fish farming cooperatives was very limited, around 13 nationally, reflecting both institutional fragility and low incentives for collective organization in the sector (CAPMAS, 2022). Most fish farmers operate individually, which reduces their bargaining power in accessing quality inputs, finance, and markets, and increases their dependence on intermediaries.

1.3 Enablers: Align MWRI–MALR mandates around joint irrigation-drainage-soil-crop packages

Enabler 1: Establishing an Interministerial Committee on Water and Soil Salinity Control

In light of the Prime Minister's Decision No 3742 of 2025 on an interministerial water council at the national and governorate scales, the creation of a sub-committee on water and soil salinity control could enable a coherent policy between irrigation scheduling and allocation (MWRI), drainage rehabilitation and O&M (MWRI/EPADP), reuse rules and mixing operations (MWRI/NWRC), soil amendments and crop response packages (MALR/ARC/SWERI). This mechanism enables higher transparency and accountability across mandates and decision-making streams when salinity risks increase.

Enabler 2: Formalize Binding Protocols at the Directorate Level

National protocols would focus on joint standards, mandates, and data flows, while governorate protocols would focus on who does what, when, and with which thresholds. Cross-sectoral protocols and SOPs at the directorate level are significant where decisions about daily reuse and salinity control are made and where farmers receive inconsistent advice (Zahran et al., 2020). A priority in Kafr El-Sheikh is governorate-level protocols that define:

- Trigger Thresholds: which EC thresholds trigger operational review. Crop-specific "alert" and "action" EC thresholds (e.g., for rice, wheat, and berseem) agreed jointly by WMRI, DRI, and ARC, based on existing salinity guidelines. When mixed water exceeds the "alert" level, reuse rates are reviewed; at the "action" level, reuse is temporarily reduced, or additional leaching quotas are scheduled.
- Operational response: which operational responses are required (adjustment of mixing ratios, irrigation schedules, advisory messages). DRI/WMRI issues short advisory notes, and MALR extension immediately updates farmers' messages on leaching, gypsum, and cropping options in the relevant command area.
- Communication roles: joint MWRI–MALR field committees and WUAs communicate on-farm responses, which serve as feedback mechanisms, which feed back to the directorate and national levels.

Enabler 3: Align incentives and accountability with salinity outcomes

Scaling salinity management requires shifting incentives to enhance salinity-relevant outcomes. A realistic approach is to introduce a set of joint salinity indicators (e.g., frequency of EC exceedance at mixing points; soil salinity trends in hotspot zones; yield stability in saline blocks) and incorporate them into seasonal review meetings and reporting (see Annex for a proposed set of joint salinity indicators).

Enabler 4: Strengthen WUAs as grassroots collective management

Rather than assuming WUAs will function uniformly, a feasible approach is to prioritize strengthening mesqa-level associations in salinity hotspots, focusing on water distribution and scheduling consistency, collective pump management, small-scale maintenance coordination, and systematic connections to MWRI engineers and MALR extension staff.

WUAs are most useful in participatory governance when they become credible intermediaries for communication and dispute resolution in situations of scarcity and mixed water quality. More research is needed to assess the willingness and readiness of Water User Associations (WUAs) in Kafr el-Sheikh to lead joint investments in infrastructure, pumps, filters, or EC meters, and their perceived benefits (quality, equity) and concerns (free-riding, maintenance, governance). Similarly, strengthening aquaculture cooperatives would require simplifying regulatory frameworks, improving access to finance, and integrating cooperatives into extension, water accounting, and market certification systems.

2. Policies, Regulations, and Incentives

2.1 Policy and regulatory framework

Fields in the downstream Nile Delta increasingly rely on reused drainage water. Evidence from Kafr El-Sheikh and other Delta governorates indicates that drainage channels receive agricultural, municipal, and industrial discharges, and that key water-quality parameters, including salinity (EC), frequently exceed recommended thresholds for direct irrigation reuse. Unless it is blended or treated, the current drainage water in Kafr El-Sheikh and the nearby governorates frequently does not fulfil standards for direct reuse (Abd El-Aziz et al., 2025; Ashour et al., 2021).

Egypt's broader planning framework, particularly the National Water Resources Plan (NWRP) and National Vision for Wastewater reuse in Egypt, explicitly recognizes the growing role of wastewater and drainage-water reuse under scarcity pressures, including the use of controlled mixing with freshwater. Environmental and water-quality regulation (including Law 48/1982 and the environmental framework Law 4/1994) provides general standards and restrictions for pollution and discharges into water bodies. According to MWRI, complementary MALR policies under the ARC promote crop diversity and salinity-tolerant cultivars through joint extension on pressurised systems and blending (Ministry of Agriculture and Land Reclamation, 2020).

The legal and policy architecture acknowledges: (i) the need for irrigation and drainage management, (ii) the reality of reuse under scarcity, and (iii) the importance of protecting water quality. This framework is applicable nationwide, including in downstream Delta governorates such as Kafr El-Sheikh, where water reuse and shallow groundwater salinity are persistent features of the landscape.

2.2 Bottlenecks: enforcement gaps and policy incoherence

Bottleneck 1: Reuse is legally enabled, but regular monitoring is uneven

In tail-end and reuse-dependent zones, farmers and pump operators often treat drain pumping as a risk-management necessity to protect standing crops when canal supplies are uncertain (JICA, 2016). When water delivery is uncertain, and the consequences of crop failure are predictable, actors will prioritize access to water over standards unless the standards are paired with workable operating rules and credible support (JICA, 2016).

Monitoring is the policy instrument that converts legal permission into enforceable operational control. Without reliable and operationalized salinity monitoring:

- Drainage water reuse becomes informal and weakly regulated, allowing high-salinity water to circulate through the irrigation systems (Abdel-Azim & Allam, 2005; Tawfik et al., 2021)
- Freshwater allocations and rotation schedules in the Nile Delta remain driven by fixed, quantity-based rules and supply predictability rather than by real-time water quality or salinity indicators. While salinity and

drainage water use strongly affect farm-level outcomes, they are not incorporated as operational signals to irrigation scheduling (Molle et al., 2019).

- Farmers cannot confidently apply blending, leaching, or soil-amelioration packages because they lack affordable tools (EC meters, soil tests) and timely interpretation.

Bottleneck 2: Drainage system is not backed by systematic and enforceable O&M service standards

Salinity control depends on drainage performance and maintenance, which face recurring funding O&M constraints that weaken the effectiveness of both leaching and on-farm soil improvements (Abbott & El Quosy, 1996; El-Ghannam et al., 2021). This produces a persistent policy gap related to minimum service standards for drainage O&M in salinity hotspots; accountability for meeting those standards; and rules linking poor drainage performance to operational adjustments (e.g., reuse limits, leaching windows, or targeted crop advice).

Bottleneck 3: Crop and water policy signals are not consistently salinity-sensitive in North Delta hotspots

National water-saving objectives and cropping regulations may conflict with local needs for controlling salinity. In Kafr El-Sheikh, salinity dynamics interact with cropping systems (notably rice for leaching in some zones) in ways that require spatial differentiation. Some cropping practices function as short-term salinity buffers while also posing water-demand concerns. When policy signals emphasize water saving without explicitly defining spatial differentiation (coastal/tail-end/reuse-intensive zones) and salinity-sensitive exceptions or rules, farmers receive mixed signals and tend to prioritize short-term risk management and profitability.

Bottleneck 4: Incentive instruments are not designed to reward salinity-safe behaviour

Current policies have rarely translated into predictable and targeted incentives for local directorates, farmers, or collective organizations (WUAs/cooperatives) to adopt and sustain salinity mitigation and adaptation practices. Key instrument gaps could include spatial targeting logic in instrument design where rules and advisories often remain general rather than hotspot-specific.

Bottleneck 5: Incoherence between water quality regulatory framework and aquaculture practices

The rapid expansion of aquaculture in the Nile Delta has generated significant production and livelihood gains, particularly in Kafr El-Sheikh; however, it has also exposed a structural policy mismatch between aquaculture promotion and water-quality regulation. The policy and legal framework in Egypt has historically treated aquaculture, water reuse, and salinity control as separate agendas (Eldabbagh et al., 2024). Water and environmental laws governing drainage reuse impose quality standards primarily designed for irrigation efficiency and public health protection rather than for fish farming. This mismatch is evident in the application of Law 48/1982 on the Protection of the Nile River and Waterways, which requires reused water to meet specific quality thresholds and generally prohibits the use of polluted drains unless suitability is demonstrated. In practice, however, a large share of fish farms in Kafr El-Sheikh pump water directly from agricultural drains characterized by variable nutrient loads, organic pollution, and trace metals (Shaaban et al., 2022).

2.3 Enablers: operational governance and targeted support for salinity management

Enabler 1: Institutionalize a "salinity-safe reuse" SOP for hotspot zones.

Adopt a governorate-level Standard Operating Procedure (SOP) that defines monitoring points, threshold categories, response actions, and communication roles for reuse areas. An SOP creates legibility (the state can see risk), predictability (farmers know what to expect), and accountability (someone is responsible when damage happens). A governorate-level SOP can convert monitoring into routine management by defining (i) hotspot zones where reuse risks are chronic; (ii) a minimal set of sentinel monitoring points at mixing and tail-end locations; (iii) simple threshold categories (normal/alert/action) linked to seasonal crop sensitivity; (iv) pre-agreed response actions for MWRI operators and MALR extension; and (v) a single communication protocol so farmers receive consistent signals.

The JICA-supported Drainage Water Quality Control Project identifies drainage water quality monitoring as a core technical activity and explicitly calls for strengthening the effective use of monitoring systems to support reuse planning and pollution control. Monitoring data are intended to inform decisions on drainage water reuse, with shared responsibilities across MWRI and its authorities (including EPADP), NWRC institutes such as DRI, and environmental and sanitation agencies (EEAA, MHUUD). Current reporting pathways flow from DRI's 28 stations to the NWRC database to quarterly MWRI bulletins, while decentralized pilot projects work better when data and decisions originate in the field. Thus, it is recommended to apply a citizen science approach through routinized EC monitoring at key points (mesqa tails, drain intakes, representative fields) that would transform DRI data into localized actionable services: bi-weekly sampling during irrigation season (May–Oct) using portable EC meters (cost EGP 15,000–25,000/unit, calibrated annually), simple colour-coded dashboards (green <3 dS/m, yellow 3–5 dS/m, red >5 dS/m) delivered via SMS to WUAs and MALR extension within 24 hours, triggering blending rules (1:3 for yellow, leaching fraction 0.2 for red).

Enabler 2: Reorient input support toward salinity-smart packages

Egypt retains functioning subsidy distribution channels (e.g., cooperatives and digitized registries such as the new "AgriNet" system). AgriNet is an e-finance digital network that links agricultural holders to 5700 digitized agricultural cooperatives to receive subsidized fertilizers and other inputs using a Meeza bank card (eFinance, n.d.). These channels can be incrementally adapted to support a limited set of salinity-relevant inputs and services in high-risk areas, without dismantling the entire subsidy system.

Evidence Box 1:
Evidence from the Northern Nile Delta (Kafr El-Sheikh/Sakha) shows that combined salinity-management measures, especially gypsum application, paired with better irrigation timing and, where feasible, organic amendments, can maintain or raise rice yields, improve water-use efficiency, and reduce soil salinity/sodicity. Kafr El-Sheikh Sakha Local Research Station found that gypsum with shorter irrigation intervals (about 4–6 days) improved soil conditions (lower salinity/sodicity indicators) and increased rice yields compared with less favorable practices (Hafez et al., 2015) Another study shows that gypsum, especially when combined with an organic amendment (compost tea)—improves salt and sodium leaching efficiency and lowers soil salinity/sodicity measures, even when irrigation water is moderately saline (up to ~3 dS m^{-1}) (Khalifa et al., 2024).

The key is to treat salinity support as a targeted package (subsidized gypsum, organic matter, soil conditioners or amendments, salinity-tolerant crops, diversified rotations), rather than a universal input subsidy. Moreover, a reorientation of a subsidy package should also consider integrated aquaculture-agriculture systems, e.g., pond–crop rotations, use of pond effluent on salt-tolerant crops, investment in lined ponds, aeration and water-quality monitoring for farms using saline/drainage water. This needs to be carefully designed because it might encourage over-expansion of ponds, leading to environmental stress or conflict with land use policies.

Enabler 3: Spatial targeting in Kafr El-Sheikh based on measurable salinity and reuse indicators.

To avoid inefficient subsidy leakage, eligibility should be geographically targeted to salinity hotspots and reuse-dependent zones using measurable criteria such as irrigation-water EC at canals/mixing points, soil salinity/sodicity indicators from agricultural directorates, and reported pumping/reuse dependence. This is especially critical in Kafr El-Sheikh where water quality varies sharply between each area.

3. Finance and Economic Viability

Farmers often bear the upfront costs of salinity management, such as price risk, crop and water quality risk, while most benefits (soil protection, yield stability) accrue over multiple seasons. The core market problem is thus the bankability of salinity management: lenders and farmers need predictable cash flows to justify financing packages from financial actors, while value chains can shift salinity management from a cost into a revenue- and risk-management strategy when it reduces transaction costs.

3.1 Financial and market barriers to salinity-resilient agriculture

Bottleneck 1: Financing targets hardware, not salinity-management packages

In 2021, the Central Bank of Egypt (CBE) launched an irrigation finance facility with EGP 55.5 billion, providing agricultural cooperatives with zero-interest loans to upgrade up to 4 million feddans with pressurized irrigation or mesqa improvements. The current CBE loans are offered in 10-year installments beginning after one year through the National Bank of Egypt (NBE) and Agricultural Bank of Egypt (ABE) (Mounir, 2021). To support CBE's role in agricultural development, NBE actively promotes these loans through its branches in Kafr El-Sheikh or through cooperatives. This is based on past experiences where Rice farmers in Kafr El-Sheikh achieved 4.25 tonnes/feddan post-irrigation upgrades under related IIIMP projects (World Bank, 2022). Similar finance is also integrated into IFAD initiatives in Kafr El-Sheikh, where smallholders in priority areas receive 50% of loans for on-farm modernization through cooperatives or through the Micro, Small, and Medium Enterprises Development Agency (MSMEDA) (IFAD, 2009).

However, important limitations persist today. Smallholders outside cooperatives often lack access to credit. Loans are generally structured for hardware, such as pumps, drip or sprinkler systems, filtration units, and mesqa upgrades (Mounir, 2021). There is little evidence that credit lines are used for salinity-specific inputs such as gypsum, EC meters, or blending infrastructure. Creditworthiness and repayment capacity are undermined by water availability and water-quality volatility, which increases production risk and farmers' indebtedness (Saleh et al., 2013). As a result, access to finance remains partial and uneven.

Bottleneck 2: Land fragmentation undermines creditworthiness and investment scale

A structural constraint in Kafr El-Sheikh is high land fragmentation, with many farmers cultivating plots smaller than one or two feddans, either owned or leased. Fragmentation directly undermines economic viability by limiting collateral and formal creditworthiness, raising transaction costs for banks and cooperatives, and making small land tenants' and smallholders' investments in monitoring, filtration, or drainage economically inefficient (ECES, 2020; Mustafa et al., 2011). Fragmentation also weakens repayment capacity when yield fluctuates due to salinity or water-quality shocks. As a result, small land tenants and smallholders often access finance only through informal channels (S. Mansour et al., 2024).

Bottleneck 3: Limited and uneven access to capital for Aquaculture Farmers

Feed represents 70–95% (approx. 85% on average) of operating costs for Egyptian fish farms (El-Sayed et al., 2015). Small-scale farmers lack access to formal credit; many buy feed on short-term credit from mills or traders, paying 3–6% higher prices and sometimes receiving lower-quality feed (El-Sayed et al., 2015). In Kafr el-Sheikh, specifically, about 86.7% of surveyed actors rely on self-finance, only 3.3% have bank loans, and around 10% borrow informally from neighbors (Elsorougy & Abd EL-Rahim, 2025). Input suppliers (especially feed traders) already act as de facto financiers, supplying feed on credit with a markup.

Bottleneck 4: Risk allocation discourages long-term salinity investment

Salinity management requires upfront investments and carries higher risk, especially when its benefits are long-term, bear a high cost- and labour-intensive, while traditional management offer immediate low-cost benefits. Many farmers, especially tenants and smallholders, operate under financial pressure and uncertainty, where they bear most downside risk from salinity spikes, water-quality volatility, and rising pumping costs. Under this risk structure, farmers rationally favor low-cost short-term choices and underinvest in practices with delayed payoffs, even when they are technically sound.

Bottleneck 5: Market/Value chain cross-sector alignment

ARC and MALR sit at the core of varietal development programs, like salt-tolerant cereals and alternative crops using blended irrigation, including salt-tolerant barley (Giza 2000), quinoa, and pearl millet. However, adoption in Kafr El-Sheikh is shaped by constraints related to the availability, certification, and timely access to the seed system, in addition to the high upfront and recurrent costs for complementary practices required for salt-tolerant varieties to perform reliably, such as land preparation and appropriate blended-water management. In practice, farmers often favor crops that come with credible offtake arrangements, access to input credit, predictable prices, low-risk profitability, even when extension recommends more salinity-resilient alternatives (UNDP, 2025). In the absence of binding contracts or price premiums for salinity-resilient production, landowner and trader influence can outweigh extension advice.

3.2 Financing and market enablers for scaling salinity-management solutions

Enabler 1: Finance integrated salinity-management solutions

The lever is to link concessional loans and grants to the adoption of integrated salinity-management solutions. Instead of subsidizing or financing hardware only, support should also cover complementary inputs and services. Inputs include gypsum, soil amendments, EC monitoring services, and salinity-tolerant seeds, while services include policy instruments that address routine monitoring through testing and calibration, blending protocols, and sustained O&M.

Enabler 2: Institutionalize blended finance and risk-sharing mechanisms for salinity management packages

Blended finance models could combine concessional funds (donors, climate finance) with local bank credit and WUAs cost-sharing contributions. Similar instruments could be adapted for drainage-based aquaculture. These schemes are most effective when spatially targeted to salinity hotspots and linked to conditionality, including participation in monitoring, adherence to reuse schedules, or collective maintenance arrangements.

Enabler 3: Use scenario-based CBA to identify viable salinity-management packages under different scenarios
A cost–benefit analysis for Kafr El-Sheikh should compare alternative salinity-management packages—not individual technologies in isolation—under different water-quality, crop, soil and energy-cost scenarios. Packages could combine improved surface irrigation or gated pipes with water blending, EC monitoring, leaching and, where appropriate, gypsum or other soil amendments. Where brackish groundwater or highly saline drainage water is the primary available source, the analysis could also assess small-scale desalination including units powered by solar energy.

The key political-economy insight is that farmers adopt what protects short-term income and reduces downside risk; long-run soil benefits matter, but rarely drive decisions unless risks are shared. In Kafr El-Sheikh, where farmers usually depend on drainage water, CBA should treat on-farm filtration/EC monitoring and blending protocols as "first-line" options, then include options such as solar-powered pumping and, in specific locations, small-scale desalination. Evidence from irrigation valuation studies in the Nile Delta suggests positive willingness to pay for improved irrigation services but is limited where it must show visible near-term gains (yield stability, fuel/labour savings, reduced crop loss) (Abu Hatab et al., 2025). Therefore, the CBA section should explicitly distinguish "short-term benefits" (1–3 seasons): yield changes, fuel and labour savings, reduced input wastes from "long-term benefits" (4–10+ years): slower salinity build-up, soil-quality maintenance, reduced risk of yield collapse.

Enabler 4: Contract farming for salinity-resilient crops
Structured off-take agreements between farmers, processors, aggregators, and large buyers can reduce farmers' price and marketing uncertainty and can also facilitate access to credit by linking repayment to sales proceeds on salinity-resilient crops (Hamza, 2015). Egypt already has an institutional entry point through the Contract Farming Center (created by presidential decree) intended to support contract registration, market information, and dispute settlement. These mechanisms can help address a key adoption barrier when farmers are unlikely to shift toward alternative crops or salinity-resilient varieties unless they have confidence in market access and payment. However, contracts will only build trust if they include clear payment terms, transparent grading standards, and credible, accessible dispute-resolution mechanisms.

Enabler 5: Verification indicators for saline products
A "salinity-smart" practice is more likely to be adopted if market requirements are translated into a small number of clear, verifiable indicators that farmers, buyers, and lenders can use. These could include compliance with agreed water-quality or blending protocols, alongside crop-specific quality grades at delivery (World Bank, 2021). When linked to contracts, pricing, or access to finance, such indicators can turn monitoring from a compliance requirement into a tool for reducing uncertainty and improving the predictability of farm returns.

Enabler 6: Collective financing and service delivery
Because holdings are small and fragmented, individual lending and compliance arrangements are costly to administer and sustain. Aggregation can reduce transaction costs for banks and buyers, enable bulk purchasing of recurring inputs and services such as gypsum, testing, and filter maintenance, and allow finance to be channelled through a single accountable entity, such as a cooperative, WUA, or accredited service provider (World Bank, 2021).

4. Knowledge Management

4.1 Bottlenecks: why salinity knowledge does not translate into action

Bottleneck 1: Knowledge is available but not decision-ready.
Many farmers recognize salinity through visible crop symptoms and soil feel, yet uncertainty remains around what to do when water quality changes (e.g., crop-specific EC implications, blending choices, timing of leaching and amendments (Ragab, 2007; Tanji & Kielen, 2002).

Bottleneck 2: Extension advice is generalized rather than site-specific
Field measurements and spatial interpolation show wide ranges in EC, SAR, and groundwater salinity across canal tail-ends and coastal zones, indicating that reuse risks are highly site-specific rather than uniform. In such contexts, generalized advisories that do not account for local EC/SAR levels, soil permeability, and groundwater depth risk being poorly aligned with on-farm conditions (Hagage et al., 2024).

Bottleneck 3: Monitoring exists but is not accessible at the farm level
National research centers provide high-level technical guidance on salinity management. Despite this strong body of knowledge, farmers' access to timely guidance is hampered by limited extension coverage, declining numbers of extension workers, insufficient operational resources, and large supervision areas that reduce the frequency of

farmer outreach (Abdel-Ghany & Diab, 2013; T. Mansour et al., 2022). Without frequent local feedback, salinity management knowledge is often experiential and informal rather than systematic or documented.

4.2 Enablers: turning salinity knowledge into trusted and systematic practice

Enabler 1: Field-embedded learning that farmers can verify.

Effective knowledge management in Kafr El-Sheikh requires shifting from one-off training to continuous, field-embedded learning systems that reduce uncertainty and build trust over time. Knowledge is more likely to be adopted when it is demonstrated in local fields, repeated across seasons, and visibly linked to yield and soil outcomes. Demonstration plots in salinity hotspots are more credible than abstract guidance (ICARDA, 2024).

Enabler 2: Simplified rules-of-thumb linked to local data.

Monitoring salinity through EC measurements and other diagnostic tools can support irrigation scheduling, leaching decisions, and broader salinity-management strategies (Mahmoud et al., 2025). To make these results actionable, EC values and salinity diagnostics should be translated into practical, crop-specific decision rules that guide farmers and extension agents on when to adjust water reuse or increase leaching. Breeding and screening programs (ARC/Sakha and local universities) matter most when they remain connected to farmer conditions such as mixed water, shallow groundwater, and variable EC. Participatory trials and periodic recalibration of recommendations strengthen credibility and targeting.

Enabler 3: Digital tools as amplifiers, not substitutes.

Digital platforms (e.g. WhatsApp groups, short instructional videos, advisory apps) can amplify peer learning and extension reach, but only when anchored in local demonstration programs and supported by trusted institutions and made possible by businesses like Dr Mai Nosseir's initiative, which uses WhatsApp videos to give soil analysis and bio-based agricultural inputs to reduce reliance on chemical fertilizers (UNDP, 2025).

Enabler 4: Role of WUAs: Knowledge brokers and trust platforms

Instead of just being taught once as a technical lesson, information needs to be shared in a way that is relevant to the people who need it, repeated, and used in everyday life. Within this knowledge ecosystem, Water User Associations (WUAs) can play a facilitating role as knowledge and trust intermediaries. At the mesqa level, WUAs can support shared access to EC meters and basic testing, collective interpretation of salinity information, and coordination of demonstration activities and peer learning.

5. Land Tenure Arrangement

5.1 Bottlenecks blocking adoption: short-term and informal land tenure contracts eliminate incentives for long-term salinity management

Bottleneck 1: Land tenancy and customary agreements increase vulnerability

Law 96 of 1992 drastically reorganized agricultural tenancy in Egypt, which pushed toward market-based rental arrangements and greater landlord control over the renewal of tenancy contracts (Abdel Razek & Shawkat, 2025; Bush, 2007). Moreover, many tenancies often extend over medium- to longer-term periods, yet agreements are frequently customary "ʿurfi", which are weakly documente. In the aquaculture sector, a study showed that around 35% of aquaculture farmers rented land, and more than 50% don't own lands (Elsorougy & Abd EL-Rahim, 2025). Earlier assessments also note that many fish farms in the Nile Delta informally converted agricultural land, which could be under legal scrutiny (Rothuis et al., 2013).

Many support and input-delivery channels are organized around the registered landholding (ḥiyāza) rather than the actual farm operator, which affects tenant farmers' access to secured lending and are pushed to bear recurrent salinity-management costs (El-Gafy & El-Said, 2020; World Bank, 2022). In addition, salinity mitigation (drainage maintenance, soil amendment programs, leaching routines, filtration units, blending practices) pays back over multiple seasons. Therefore, when tenants cannot be confident that they will retain access to the land long enough to capture these benefits, their incentives to undertake such investments are weakened (Qadir et al., 2007).

5.2 Enablers: tenure-linked incentive mechanisms for salinity management

Without targeted governance mechanisms for tenancy arrangements, investment in salinity mitigation may remain financially unattractive or excessively risky for tenants and other operators who cannot reliably capture the long-term returns. Aligning tenure arrangements and investment horizons with salinity-management needs is therefore an important enabling condition.

Enabler 1: Seasonal salinity service bundles

Provide seasonal, pay-as-you-go salinity services rather than relying only on capital loans. These could include soil and water testing, gypsum or organic amendment application, leaching advice, and basic filtration maintenance. Services could be delivered through cooperatives, extension services, or private providers under public oversight.

Enabler 2: Integrate salinity risk into digital land records

By linking land records with soil and water salinity data, authorities can align financial and advisory support with both biophysical risk and tenure status. Crucially, digital records should be used for program targeting and monitoring.

Enabler 3: Tenure Security in New Lands

In reclaimed and newly developed areas, clearer and more predictable tenure arrangements can encourage investment in longer-term salinity management. Longer or more secure leases, transparent renewal conditions, and clearer land-allocation procedures would give farmers greater confidence to invest in drainage, soil rehabilitation, and other capital-intensive measures.

6. Social Norms and Behavior

6.1 Description: The Role of Women in Adoption and Water Management Decisions

Salinity management in Kafr El-Sheikh depends on daily behaviors, such as irrigation timing, reuse decisions, system maintenance, soil amendments, and monitoring. Empirical studies in Egypt show that women participate directly in irrigation and water-related farm operations in a large share of households, estimated at around 78% of surveyed farms (Abdel-Ghany & Diab, 2013; Najjar et al., 2019). Moreover, farmers favour experiential and peer-validated practices over formal advisories, with many farmers relying on peer networks, neighborhood pump operators and input suppliers for irrigation decisions while formal irrigation advisory/extension support often plays a more limited facilitating role (Molle, 2018).

6.2 Social and institutional bottlenecks to inclusive salinity management

Bottleneck 1: Structural barriers limit women's direct involvement and decision-making

Women's participation rarely converts into decision authority because formal irrigation institutions (e.g., WUAs/mesqa committees) are commonly structured around registered landholders and shaped by mobility and social norms (Najjar et al., 2019). Training and extension delivery also remains male-oriented in timing, location, and facilitation style, while care responsibilities constrain attendance. These constraints matter for salinity because many recommended practices require consistent, repeated actions (maintenance, monitoring, and timely amendments), not just technical awareness.

Bottleneck 2: Trust in formal information and advisory systems

Most farmers recognize that poor-quality drainage water and inconsistent supply contribute to soil salinity, lower yields, and reduced profits, built from observing crop stress and hardpan in mixed-water areas (Abdullah, 2019). In Kafr El-Sheikh, farmers' decisions about irrigation modernization and salinity management are shaped less by awareness and more by trust and day-to-day risk, where a minority of farmers trust official data sources while a much larger share relies on peer networks and informal contacts for arranging water allocation and advice (Elshrabassee & Bakr, 2022).

Bottleneck 3: Irrigation modernization creates labour displacement and skills-transition risks

Irrigation modernization changes the kind of labour farms and communities need. Traditional surface irrigation relies heavily on repeated manual tasks (water movement, bunding, night irrigation, informal guarding of turns). Modernized systems shift part of that effort into technical operation and maintenance: pump and filtration upkeep, emitter cleaning, leak detection, calibration, scheduling adjustments, and where reuse is common, basic monitoring and recordkeeping. Modernization may therefore reduce some forms of manual irrigation labour while generating demand for technicians, maintenance services, and repair businesses. However, these employment gains are not automatic: without local skills development, affordable service provision, and pathways for affected workers to transition into new roles, modernization may create short-term livelihood losses, particularly for landless and seasonal workers.

6.3 Enablers: enablers for inclusive and locally grounded salinity anagement

Enabler 1: Gender-responsive extension

Effective salinity management requires effective delivery of salinity guidance at the household/farm level, focusing on routine actions such as maintenance checks, irrigation timing, and simple reuse rules-of-thumb. Expanding the role of trained female staff/lead farmers can improve trust and communication with women farmers. Communities would also benefit from short, practical modules tied to seasonal calendars (before reuse peaks; before amendment timing), delivered through village visits, cooperatives, and service points.

Enabler 2: Peer learning and local demonstrations

Farmers tend to adopt new practices only after observing reliable results over several growing seasons. Because neighbors face similar risks and conditions, demonstration plots within the community and farmer-to-farmer training generate much higher participation than advice delivered through formal extension services.

Enabler 3: Local skills on modernization

Irrigation modernization in Kafr El-Sheikh is more durable when it is connected to local skills development. Programs can shift the skills from manual irrigation to more technical skills through locally delivered training on basic operation and maintenance (pumps, filtration, leak repair, scheduling), support for village-level service providers and spare-parts availability, and financing arrangements that cover O&M/service contracts alongside equipment.

Conclusion

This report set out to shift the analytical lens on salinity in Kafr El-Sheikh from the supply of technical solutions to the enabling environment that determines whether those solutions are adopted, sustained, and scaled. Salinity management is not biophysical or agronomic; it is a systemic challenge that is connected to different aspects of natural resources management – by farmers and decision-makers – associated with coherent policy instruments, knowledge sharing, market incentives, land tenure arrangements, and women and youth inclusion. Many practices on integrated water and soil salinity management in Kafr El-Sheikh, such as leaching, gypsum, water reuse, drainage maintenance, and salinity-tolerant varieties, are documented and locally tested. Their limited uptake at scale, therefore, signals a weak enabling environment rather than an absence of technical knowledge.

The enabling environment was assessed through six dimensions, which include institutional coordination, coherent policies, laws, and planning, access to reliable knowledge, economic incentives, finance, and market integration, secured land tenure, and social norms and trust. In institutional coordination, responsibility appears to be fragmented horizontally across several water and agricultural agencies – irrigation, drainage, soil and crop, and vertically between national and local research institutes to users in the field, compounded by the weak functioning of WUAs and aquaculture cooperatives. Institutionalizing joint decision-making through an interministerial salinity sub-committee that agrees on directorate-level integrated salinity management protocols with agreed EC thresholds and response actions, salinity-relevant accountability indicators, and strengthening users' associations.

National policies and laws reinforce the need for drainage water reuse, the need for water-quality protection, and the value of salinity-tolerant crops. Nevertheless, reuse is unevenly monitored, drainage O&M is hampered, and incentive instruments do not support integrated salinity management practices. Findings suggested converting general standards into hotspot-specific monitoring-operating rules within a governorate salinity-safe reuse, a reorientation of existing subsidy channels towards salinity-smart packages, and spatially targeted based on measurable EC, reuse indicators, and sea-level intrusion.

Bankability is another gap at the heart of salinity management. Salinity management benefits accrue over multiple seasons, which pushes tenants and smallholders toward low-cost, short-horizon choices. Existing credit lines are structured for hardware rather than salinity-specific inputs and services; land fragmentation undermines collateral and creditworthiness; and aquaculture farmers depend overwhelmingly on self- and informal finance. The enabling environment rests in financing integrated packages – services and inputs – rather than equipment alone, institutionalizing blended finance and risk sharing, using scenario-based cost-benefit analysis to identify efficient and effective salinity bundles, and increasing the use of contract farming, tapping into verifiable salinity smart indicators for agricultural products.

Farmers detect salinity through visible symptoms but remain uncertain about their decisions when water quality or soil characteristics shift. At the same time, extension advice is general and intermittent rather than site-specific. Knowledge is adopted and sustained when it is demonstrated locally, repeated across seasons, and visibly linked to yield gains. This could be achieved through demonstration plots in hotspots, simple rules of thumb tied to EC data, digital tools that amplify rather than replace extension, and the ability of WUAs to act as knowledge brokers across their peers.

Land tenure sits beneath the other dimensions as a decisive constraint. Fragmented holdings, market-based tenancy, and weakly documented customary arrangements affect land and water investments. Seasonal, pay-as-you-go salinity service bundles, the integration of salinity risk into digital land records for targeting and monitoring, and clearer, more secure tenure in reclaimed and new lands would strengthen the incentive structure.

Ultimately, salinity management is enacted through daily behavior – irrigation schedule, reuse decisions, maintenance, monitoring. Women participate extensively in these water- and soil-related operations yet rarely hold decision authority; farmers trust peer networks and informal intermediaries; and irrigation modernization risks displacing manual labor and daily wagers. Therefore, technical awareness is not sufficient without trust, locally replicable over seasons, and socially fit. Gender-responsive extension delivered through trusted local channels, peer learning anchored in community demonstration plots, and local skills development that helps workers transition into operation-and-maintenance roles strengthen the social dimensions of salinity practices.

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Annex. Performance Indicators for Joint Salinity Outcomes

Egypt has already piloted salinity-related performance assessment (e.g., drainage performance and complaint-based assessment). Building on this assessment and other literature, this report suggests the creation of performance indicators that reward joint salinity outcomes (Bos et al., 2005; CSIRO, 2007).

- **Biophysical salinity outcome indicators** (joint MWRI–MALR responsibility)
  - Share of irrigated area with soil ECe below crop-specific thresholds at the end of the season (e.g., % of wheat area with ECe < 4 dS/m).
  - Trends in groundwater EC in shallow wells within reuse zones.
  - The frequency of EC exceedance events at key mixing points refers to the number of days per season when mixed canal–drainage water exceeds agreed thresholds.
- **Productivity under Salinity Indicators**
  - Crop yield (or gross margin) per unit of “salt load” applied, not just per unit of water.
  - Yield stability in salinity hotspots (variance in yields over 3–5 years in tail-end or saline blocks).
  - The farm-level WEF (Water–Energy–Food) Nexus Index was adapted to include a salinity dimension, building on ICARDA’s existing index (ICARDA, 2022).
- **Procedural Governance Indicators**
  - Number of joint MWRI–MALR planning meetings held and recorded at the governorate level each season.
  - The percentage of WUAs/marwas that receive integrated water-soil-crop advisory packages each season
  - Extension events where both irrigation and agriculture services co-deliver messages.
  - The use of a joint digital platform (e.g., the Innovation Management Platform proposed in the Adaptation Fund/FAO project) to store and visualise salinity and performance data (Adaptation Fund Board, 2022).

The performance assessment would ensure:

- MWRI/DRI/WMRI are responsible for reporting water-quality and water-level data from canals, drains, and reuse stations; electrical conductivity (EC) of mixed water; and groundwater EC measurements at monitoring wells
- The MALR/ARC/extension directorates are responsible for monitoring soil ECe at sample farms, assessing crop yields and management practices, and promoting the adoption of gypsum and leaching packages.
- Joint research units, such as the ICARDA–IWMI–ARC pilots, are responsible for designing composite indicators and supporting analysis, benchmarking, and capacity building (ICARDA, 2022).

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