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Iraq Salinity Assessment   Report 2: Potential Solutions

Managing Salinity in Iraq's Agriculture

Potential Solutions & Interventions

Approaches at farm, irrigation system and regional level

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Salinity in Iraq – Potential Solutions

An overview of the potential solutions and development of a national framework for the management of soil and water salinity in central and southern Iraq

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About this report

This report is the second in a series of three publications that comprises an overview of the Iraq Salinity Assessment. This report documents solutions and impacts identified in the first report in this series. The third report in the Assessment proposes investment options and methods to analyze the investment options to manage and remediate salinity in Iraq.

This report has been compiled from project contributions from a number of authors across all of its seven technical Components.

The Iraq Salinity Assessment synthesizes the results of the Iraq Salinity Project, a research partnership between five Iraqi ministries and national agencies and an international team of researchers, led by ICARDA, specialized in land and water management, crop improvement and plant breeding, and socio-economics.

This research builds on previous work and technical studies done in Iraq and on the expertise of Iraqi agencies working to promote agricultural development over the past decades. It provides solutions based on the analysis of historical data and new data compiled in the Iraq Salinity Project and provides methods of implementation to reduce salinity, or reduce the impact of salinity on agriculture and environment in Iraq.

The Assessment benefits from Australia's experience in dealing with similar salinity problems in its agricultural sector. The salinity situation and agro-hydrological problems faced by Iraq are similar to those faced in Australia's Murray-Darling river basin. Australia has tackled its salinity problem in a systematic way since the 1980's and today salinity is being controlled and reversed in many areas.

The solutions and implementations presented in this report are a synthesis of a body of research – field-level and technical studies in Southern and Central Iraq, a new body of data and information collected and compiled by the research team and a series of technical and background papers. All information related to this research can be consulted at Iraq.icarda.org.

Iraq salinity assessment – three reports

- Stage 1: Overview and scope of the problem.
- Stage 2: A detailed analysis of the problems and potential solutions and development of a framework for a national, integrated approach to salinity management in Iraq (this report).
- Stage 3: Investment options to support a long-term strategy of soil and water salinity management in Iraq.

Iraq salinity research – multi-disciplinary, multi-scale:

- A multi-scale focus, from the farm to irrigation project to the whole of the Mesopotamian plain
- A 'bright spots' approach, working with farmers to understand their practical approaches to fighting salinity at field level and studying ways to scale-up these innovations for use by many other farmers.
- Use of soil–water–plant modeling to determine optimal irrigation water allocations to control water tables and soil salinity.

- Assessment of optimal solutions for refurbishing irrigation and drainage infrastructure.
- Testing new crop varieties of salt-resistant crops to be used in Iraqi farming. This includes forage crops that can bring increased income to communities that are living in areas with degraded soils.
- Investigation of the socio-economic impacts of soil salinity on farmers and national agricultural production.
- Mapping of soil salinity and river salinity in the Tigris and Euphrates river basins.

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1 Key findings

1.1 Key findings of the second report

This is the second assessment report from the project. The first report gave an overview and described the scope of the salinity problems in Central and Southern Iraq. This report deals with the potential solutions as identified by researchers across all seven technical components of the project.

1. Salinity will need to be managed at different scales; most irrigation-based systems can be divided into field, irrigation command and regional levels. Different stakeholders are involved at each scale, while those that benefit most can overlap all scales.
2. A national irrigated land capability understanding should guide decisions on reclamation and rehabilitation to ensure efficient use of Iraq's soil and water resources.

   Therefore we suggest the following actions:

   - Develop land and crop suitability maps based on soil, water, land drainage, watertable depth and groundwater quality and other agro-hydrological conditions prevailing in different areas;
   - Develop suitable farming systems for different areas based on water availability and climate conditions. This can be done quickly using modern tools such as remote sensing and GIS; and
   - Ministry of Agriculture (MoA) should refine their extension services to educate farmers on the technical and management aspects of these farming systems.
3. Managing the salinity problem in Iraq requires an iterative process (plan–act–review–plan) at all levels. Actions must be driven by the need to achieve rapid improvements on the ground, but these should also be evaluated and reviewed frequently enough for improvements to be identified and implemented. Adoption of continuous improvement will require the development of objectives and goals at the national level that integrate the management of water and land across key institutions.
4. Matching water requirements to crop use and groundwater depth provides a win-win solution to increased productivity and water use efficiency. Better calculation of irrigation requirements, and the transfer of this information into management approaches, may therefore increase crop production and decrease environmental degradation.
5. A comprehensive on-farm water management program should be launched to educate farmers on the precise irrigation requirements of different crops under the conditions of the existing salinity and watertable depth.
6. The water allocation requirements for different crops should be revised so that water application by farmers is based on crop needs, not infrastructure capacity. This will require the generation of reliable information on the water requirements of different crops in areas with different agro-climatological conditions. These needs should be shared between MoA and MoWR for endorsement, and then extended through local water offices via simple guidelines for farmers.
7. No comprehensive study has been undertaken to assess the extent of irrigation-induced salinity. The monitoring network to record spatial and temporal changes and characterization of salt-affected soils in different parts of the country is almost non-existent. A clear understanding of the scale of the salinity problem and how it is changing is required as a performance measure of how it can be successfully managed.

8. There is an urgent need to invest in rehabilitating and modernizing irrigation infrastructure. However, it is recognized that this is a hugely expensive undertaking. As such, carefully prepared business cases will be needed for each set of modernization investments.
9. Irrigation delivery and drainage infrastructure needs to be modernized at the irrigation command level and integrated into a broader regional framework. Clear, appropriately resourced roles and responsibilities between Government and farmers should be agreed. Furthermore, there is a need to increase the capacity and capability of the managers of irrigation commands.
10. Surface-water salinity must be controlled by tackling the major sources of saline water inflows to rivers within Iraq, including the increase in salinity due to reductions in flow. This will be best achieved by the development and implementation of a salinity management framework for the entire Tigris and Euphrates Rivers system. Options that can be adopted are varied and include major engineered structures and infrastructure such as water treatment. The objectives should be to maximize the volume of good quality water, and minimize the volume of saline water, separate good quality water from saline water and reduce evaporative losses in the system
11. The policy environment in Iraq is complex and the integration of actions may not be efficient. It would be valuable to investigate how agriculture, water and research policies in Iraq have affected land and water salinity and to recommend actions that resolve institutional problems.
12. Salinity in Iraq is a complicated and ongoing issue and short term projects for two to three years will not solve the problems in the long term. Authorities should explore an approach that establishes a National Program for Salinity Management in Iraq, similar to existing national agricultural programs. This would centralize the coordination of efforts and ensure high-level integration between the water, agricultural and environmental sectors of Government.
13. In order to improve management at different levels, it is important to increase the efficiency of extension systems, and increase farmer participation through robust extension delivery. The agricultural extension network has been ineffectual in encouraging farmers to adopt improved farming techniques including the adoption of saline agriculture. Participatory programs (demonstration, training, communication) are needed to empower and educate farmers and the broader community about better (sustainable and adoptable) agricultural options for saline landscapes.
14. In addition to specific sources of salinity-induced reductions to farm productivity, farmers face a range of constraints and limitations that increase the severity of the salinity problem that ultimately leads to a decrease in the productivity per unit of land. The complex mix of drivers needs to be understood to enable targeted management of the problem.
15. In areas where salt-affected soils exist and drainage waters are generated on a large scale, production systems based on salt-tolerant plant species are likely to be the key for future agricultural and economic growth. However, the use of saline water in Iraq, to a large extent, is still confined to the growth of salt resistant grasses for fodder, bushes and trees. Research to compare imported and local plant varieties for salt tolerance and adaptation needs to continue, with the best plants being demonstrated on-farm to growers.
16. One unpalatable truth is that not all land is capable of economic use. Land and water needs to be classified in terms of its capability. Most investment needs to be focused on land and water of high capability. Some land and water will have such low capability that no investment in these areas will be the optimal solution.
17. The growth of salt-tolerant forage species for ruminant production offers the only opportunity to use land and water resources that are too saline for conventional crops and forages.

1.2 Key findings from the first report

The first assessment report established the following key findings:

Irrigation and salinity in the Mesopotamian plain

1. Iraqi agriculture is dominated by irrigated agriculture in the Mesopotamian plain.
2. The Mesopotamian plain has poor drainage and large stores of salt; salinity has been a problem there since Babylonian times, nearly 4000 years ago. However soil salinity is now more widespread and possibly more severe than any of previous assessments indicated, with virtually all areas affected by soil salinity. Currently a large, but unquantified, amount of agricultural land is lost to salinity every year.
3. Water productivity in many areas is very low as a result of degradation of irrigation and drainage infrastructure. For example, overall irrigation efficiency in the Dujaila irrigation project is as low as 31–38%. This low efficiency is leading to soil salinization.
4. The water in the Tigris and Euphrates rivers in Iraq is becoming increasingly saline (e.g., up to 7 dS/m at Basra, too salty to support most crops) because of the salinity of the soil in the Mesopotamian plain; this is a relatively new phenomenon. This increase in river-water salinity has serious consequences for the water supplies of communities and agriculture.
5. Salinity and waterlogging is currently impacting upon agricultural production, society and the economy, culture, and the environment:
    a) Agricultural production: In salt-affected areas farmers are cropping only about 30% of their land and are achieving only about 50% of expected yields. With current salinity levels we estimate that about US$300 million per year is lost due to salinity effects. There is thus a great opportunity to increase production if water and salinity management can be improved.
    b) Socio-economic aspects: Many farmers make up a large majority of the poor in Iraq. In 2009, the country imported some US$2.1 billion-worth of crops that could be grown in Iraq, including US$342 million- worth of fruit and vegetables that could be grown under irrigation.
    c) Cultural issues: The ancient practice of date farming and the lives of marsh Arabs are severely affected.
    d) The environment: The land, marshes, rivers, and estuary ecosystems have been severely affected.

Current approaches to managing salinity

1. There is no strategic framework for efforts to manage and adapt to salinity in the Mesopotamian plain.
2. Current efforts aimed at managing land salinity are piecemeal and not based on targeted interventions.
3. Currently there is little emphasis on controlling salinity in the surface waters within Iraq.
4. There has been a lack of coordination between ministries in tackling agricultural, water resource management, and salinisation problems.
5. The Iraqi Government has rarely evaluated its policies related to agriculture and water management.
6. Although science in Iraq takes a multidisciplinary approach, implementation of solutions does not occur consistently.

Future requirements to manage salinity

1. There needs to be a strategic approach to the rehabilitation and reclamation of saline irrigated areas, based on the recognition that some areas will strongly benefit from investment, benefits will be limited in some areas, and it may not be possible to restore irrigated agriculture in some areas. Farming systems may have to change according to land capability. This approach will help direct funding and human resources to the places where they will deliver the greatest impact.
2. There needs to be an integrated approach to resolving the salinity problems. This should start with the development of a salinity management framework for the surface waters of the Mesopotamian plain.
3. Surface-water salinity must be controlled by tackling the major sources of surface-water salinization within Iraq.
4. Irrigation and drainage systems should be rehabilitated concurrently. The work should be conducted within the salinity management framework, and based on analyses of upstream/downstream impacts, costs and benefits. Funding should be targeted to maximize the return on investment and speed of return on investment.
5. There is a clear need for increased testing of salt-tolerant crops (for mildly to moderately saline areas) and forages (for moderately to highly saline areas) because of the limited trials to date. The nutritive value of forages and their fit within existing, new, and evolving feeding systems should be considered when introducing new species. Data over a longer period (at least 3 years) needs to be collected at different sites to make the screening and evaluation of genotypes successful.
6. An integrated and multidisciplinary approach to the salinity problem is required. Tackling the problem from one approach, one scale, or one area alone will not result in a sustainable solution.
7. There needs to be strong co-ordination between the Ministry of Water Resources, the Ministry of Agriculture, and other ministries to tackle the salinity problems within an integrated catchment approach. A multidisciplinary approach is essential.
8. Managing the salinity problem in Iraq requires a cyclical process ((plan–act–review–plan) at all levels. Actions must be strongly driven by the need to achieve rapid improvements on the ground and should be evaluated continuously for improvements.
9. Participation by Iraqi farmers in tackling the salinity problems should be considered in any integrated and multidisciplinary approach aimed at solving these problems.

2 Introduction

The second synthesis report of the Iraq Salinity Assessment provides proposed options and strategies for the long-term management and reduction of salinity in Iraqi irrigated agriculture. The options are grouped under two simple themes that outline the most beneficial approaches: managing or adapting to salinity.

Salinity is used here to denote two fundamental processes, the increase in salinity levels in the soil due to irrigation practices (and high watertables) and the increase in salinity of the applied water; these processes are linked but are driven by different factors. Its correct terminology is secondary salinisation due to irrigation. The options for managing the two types of salinity increase are different and those differences are important to recognize.

Salinity management in agriculture has the objective to reduce and manage the impact of high salt concentrations in the soil solution on crop production. In effect, salinity management's role is to increase production within the available soil and water constraints.

Salinity will need to be managed at different scales; most irrigation-based systems divide these into field, irrigation district and watershed scales. Each of these has different stakeholders, while the beneficiary groups can vary or overlap.

The main objective for salinity management at the field level is to maintain or increase agricultural production and income for the farmer (producer).

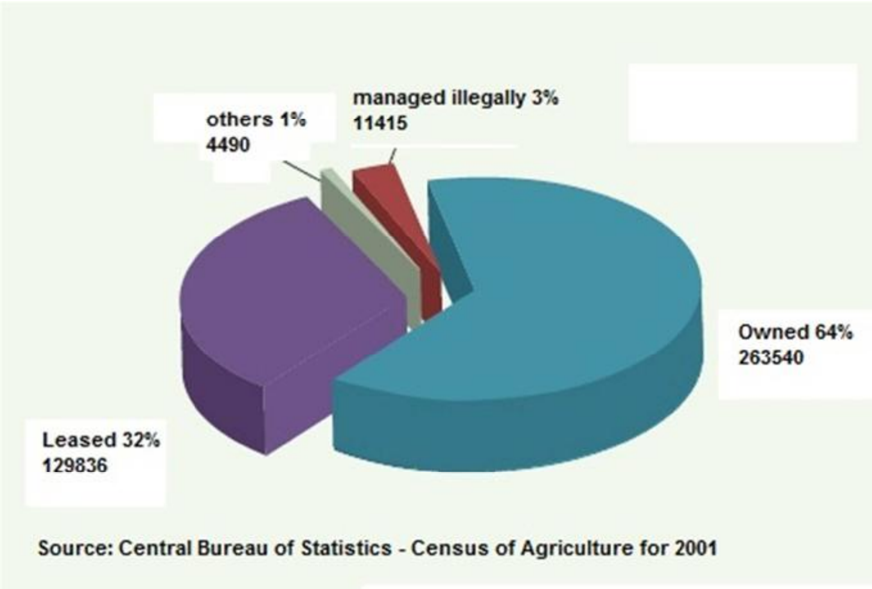
The main objective for salinity management at irrigation command level is to provide acceptable quality, quantity and regularity of water supply to the farm gate to manage and reduce the impact of salinity on the farm. At the same time, the irrigation command is tasked with managing saline drainage water at the tail end of the farm, thereby removing salt mass from the area, reducing the accumulation of salts in the soils of the command area.

The main objective for salinity management at watershed/river catchment scale is to provide the water command areas with the highest quality (and quantity) of water. At the same time, the watershed/river catchment managing agency is a recipient of saline drainage water and manages this to minimize impact on downstream users (agricultural, urban and environmental).

All investment in Iraq's irrigated lands across all three scales must be done within a robust investment framework where the benefits can be assessed relative to the costs. Another way of considering the issue in a non-economic sense is to develop a framework within which the degree of improvement to the national good can be objectively analysed against the costs involved. What is the return to the nation and can a greater return be gained elsewhere for the same input? This is a difficult question and is not easily answered. However, it is a necessary question in the case of Iraq where the task is large and the current funds are limited.

A major obstacle for increasing agricultural production in Iraq is the process of land fragmentation due to land tenure change according to cultural rules, where holdings have become very small and un-economical. The agricultural sector has two main farm types, namely private owned (64%), and leased (32%), while other forms do not exceed 4% (Figure 1).

Figure 1: Number of agricultural holdings and percentages of ownership by type



3 Managing salinity

Salinity management can be achieved by a number of different approaches, with the only certainty being that a combination of approaches is required; no single approach is capable of achieving the optimal salinity management outcome. These combinations of approaches are required at a variety of scales and involve a range of key stakeholders. The sections below outline these approaches and are grouped into three scales: field or farm level, irrigation district or command level and regional level. It is overly simplistic to consider these scales as being mutually exclusive; rather they represent levels of activities that correspond with current thinking. By their nature, many approaches will cross these scales and successful management will require integration of effort at all levels.

Some of these approaches can be likened to direct action activities where specific actions occur on the ground and can be seen as tangible outputs of a process, whilst others can be seen as enabling activities (or indirect action) where actions are required to assist or guide implementation of on-ground activities. Neither type of activity should be seen as preferred over the other as all are required to achieve sustainable irrigated agriculture in Iraq.

The approach across scales and with direct and enabling actions is one of an holistic nature where all actions and approaches are undertaken in a coordinated and integrated fashion.

3.1 Focus most on land with highest capability, less on land with lower capability (regional level)

During the course of project work, it became evident that selection of crops in Iraq is not made on the basis of prevailing soil, water, drainage and salinity conditions. Crops are mainly selected based on farmers’ experience, and the availability of labor and other needed inputs. Considering the poor drainage conditions of most of the soils, it is of extreme importance that cropping choices are based on land capability.

The emphasis should be on developing a region-wide decision support tool that enables choices to be made between supporting farming systems that utilize differing water salinities.

Iraq needs to take a strategic approach to the rehabilitation and reclamation of saline irrigated areas, based on the recognition that funds for investment are not abundant, and the available funds need to be spent in a way that maximizes the benefit per unit cost invested. The benefit may be measured differently than for a market economy, but nevertheless, national wellbeing in terms of food production, poverty alleviation, environmental sustainability and national wealth are all pertinent goals to achieve.

Land suitable for irrigation will vary in its capability based on: (a) soil characteristics (salinity, texture, drainability, etc.), (b) groundwater characteristics (depth, groundwater salinity, chemical composition, etc.) and (c) irrigation water characteristics (amount, salinity, frequency of availability). Land should be categorized based on these criteria. Where funds for investment are limited, they should be employed first and mostly to preserve and rehabilitate the land of highest capability. Some areas will benefit strongly from investment, benefits will be more limited in some areas, and in other areas it may not be possible to restore irrigated agriculture. Depending on the availability of investment funds, some farms will continue to grow traditional crops, although there may still be benefits from the growth of more salt tolerant genotypes. However, in more severely salinity affected areas, with lower capability, farming systems may have to change, relying less on traditional crops and more on salt tolerant forages and trees. Taking this approach will help direct funding and human resources to the places where they will deliver the greatest impact in terms of both the efficient use of Iraq's soil and water resources, and in terms of improving the standard of living of its people.

Work is required to be undertaken that will develop a framework within which rehabilitation and reclamation of saline irrigated areas can be identified on the basis of the highest return on investment to Iraq in terms of benefits to the national good.

This will require, as input to the framework, consideration of national objectives concerning the place of irrigated agriculture in a modern Iraq and what the use of the land and water is required to achieve. It will also require consideration and agreement on what a modernized irrigation sector in the Iraqi economy will look like as a set of objectives to guide rehabilitation efforts. It will be counter-productive to rehabilitate irrigation command areas back to their original design, which may be outdated and ill-suited to current farming activities. Rehabilitation and reclamation will also need to be undertaken within the context of a fully functioning drainage strategy that links farm scale water re-use and efficiency measures with national management objectives for the operation of the Main Drain. One of Iraq's greatest assets is the Main Drain and it will be pivotal in managing saline irrigation disposal water.

A national irrigated land capability understanding should guide decisions on reclamation and rehabilitation to ensure efficient use of Iraq's soil and water resources

Therefore we suggest the following actions:

- Develop land and crop suitability maps based on soil, water, land drainage, watertable depth and groundwater quality and other agro-hydrological conditions prevailing in different areas;
- Develop suitable farming systems for different areas based on water availability and climate conditions. This can be done quickly using modern tools such as remote sensing and GIS; and
- Ministry of Agriculture (MoA) should refine their extension services to educate farmers on the technical and management aspects of these farming systems.

3.2 Adopt a continuous improvement (adaptive management) approach (regional level)

Managing the salinity problem in Iraq requires an iterative process (plan–act–review–plan) at all levels. Operating in this manner requires combining a sense of urgency with an ability to reflect on progress. Actions must be driven by the need to achieve rapid improvements on the ground, but these should also be evaluated and reviewed frequently enough for improvements to be identified and implemented. Amongst other actions this will require the implementation of a national program for salinity management, with specified review processes and checkpoints. It also requires the establishment of a culture throughout all institutions that values and rewards innovation and efficiency in the national interest, rather than just the interests of local communities.

Specific actions include institutional strengthening to promote a culture of review and change.

Adoption of continuous improvement will require the development of objectives and goals at the national level that integrate the management of water and land across key institutions, including at the national and governorate level, action plans for the implementation of national goals and the implementation of policies to facilitate the desired outcomes.

3.3 Managing salinity through irrigation water application (field level)

It was shown in this study, that irrigation methods at two case study sites resulted in over-watering and in turn, a rising watertable. This led to high watertables that increased soil salinity in the growing zone and caused reduction in crop yield.

Excessive irrigation not only reduces the availability of water for other crops on the farm or other farms, but also increases the drainage requirements, which can be an economic burden for the larger area and an environmental problem for the disposal of effluent. Better calculation of irrigation requirements, and the transfer of this information into management approaches, may therefore increase crop production and decrease environmental degradation.

Our simulations of irrigation practice suggested that even in the absence of effective drainage systems, controlling irrigation applications could be a beneficial strategy to control the high watertables and consequent soil salinity. For the prevailing groundwater and salinity conditions at both case study sites, optimum irrigation watering amounts were about 500 mm for wheat and about 600 mm for maize. These irrigation amounts will produce optimal crop yields while keeping the watertable depth and soil salinity within acceptable limits. These irrigation rates are substantially lower than those currently applied.

For the existing soil and water conditions in both study areas, a watertable depth of about 200 cm was sufficient to attain near maximum crop yields. In the Al-Mussaib project area, the modeled crop yields that could be attained were 3.85 t/ha for wheat and 2.16 t/ha for maize (maize is more sensitive to salinity than wheat). With these practices, the salinity of soil solution at field capacity would be about 9 dS/m. In the Al-Dujaila area where the soil and groundwater salinities are higher, the attainable modeled crop yields under existing conditions would be lower – 2.52 t/ha for wheat and 1.80 t/ha for maize.

The reduction in applied water under these scenarios would provide water savings that could be used elsewhere to assist in managing Iraq's water availability concerns.

Matching water requirements to crop use and groundwater depth provides a win-win solution to increased productivity and water use efficiency

The results of our work did not factor in the benefits of water savings from integrated drainage and its impacts on reducing groundwater levels. Further benefits can be expected once drainage is managed to an acceptable level.

It is important to recognize that this win-win approach will need to be implemented at the irrigation command scale before large benefits in terms of water efficiency are obtained. However, farm level production benefits should be realizable almost immediately upon implementation.

A comprehensive on-farm water management program should be launched to educate farmers on the precise irrigation requirements of different crops under the conditions of the existing salinity and watertable depth.

3.4 Managing salinity through irrigation water application (irrigation command level)

At present, the allocation of irrigation water to farmers is not based on crop water requirements, and this usually results in the over-irrigation of some crops and the under-irrigation of others. In both cases, crop yields suffer negatively. Therefore we suggest that water allocations for different crops should be revised. For this purpose, the following steps should be implemented.

- Generate reliable information on the irrigation requirements for different crops in areas with different agro-climatological conditions. This research should focus on the water required for crop growth and the management of the salinity of the soil solution, and can be carried out by a range of institutions within the Government of Iraq. This will provide a basis for the water allocation needs of farmers in different areas.
- Water allocation needs should be shared and discussed with the Ministries of Water Resources and Agriculture for their endorsement. After finalization, this information should be translated into simple guidelines, which can be distributed to local water managers and to farmers as guidelines and information packages.
- With the cooperation of the Ministry of Water Resources, local water authority offices should implement the changes in typical water application rates according to estimated available consumptive use for different crops as a governing step in allocating water to different commands. Further work is also required to facilitate more responsive water delivery schedules and rules.

- MoWR should revise its water allocation and supply schedules to meet these water requirements. In areas where existing farming patterns do not match with the availability of water, adjustments in patterns should be made in consultation with the farmers to keep their profit margins at the same level.
- Despite the shortage of water, there is a general tendency for over-irrigation by Iraqi farmers. As a result, irrigation efficiencies are very low (Al-Zubaidi, 1992). The uneven distribution of water due to poor land leveling produces patches of low and high infiltration rates, which in turn produces patches of low and high salinity within the same field. Improved cultural practices such as precision land-leveling, zero tillage and bed and furrow-bed methods of planting can save up to 40% of the water applied without compromising crop yields. Steps should therefore be taken to introduce farmers to these techniques, possibly through State sponsored improvement programs.

3.5 Assessing the extent of irrigation-induced salinity (regional level)

Despite widespread salinization of land and water resources in Iraq, no comprehensive study has been undertaken to assess the extent of irrigation-induced salinity. The monitoring network to record spatial and temporal changes and characterization of salt-affected soils in different parts of the country is almost non-existent. In the absence of scientific evidence, local knowledge is used to substantiate salinity problems; indicators used by the farming community include: patchy stands of crops, retarded crop growth, leaf burn and changes in soil color. In addition, monitoring is inadequate in assessing changes in water quality both in rivers and drainage systems.

In view of the complexity and scale of the problem, modern approaches to salinity monitoring such as collecting and analyzing remotely sensed data in Geographic Information Systems (GIS) would be advantageous, enabling spatial and temporal changes in soil salinity to be more clearly seen. These approaches have proved highly useful in land evaluation in countries such as Australia, China, USA and India. Integration of remotely sensed data in GIS platforms and their analysis using spatial statistics can assist in modeling large scale variability to predict the presence and distribution pattern of particular agricultural systems or different plant species, as well as soil characteristics. Scattered efforts are being made by different institutions in Iraq to deal with the problem of mapping land salinisation on a national scale. However, more integrated efforts are needed to focus research on salinity assessment. This would be possible by preparing a national approach to the characterization of salt affected lands in Iraq, and the preparation of maps showing the extent of salinisation. These will need to be done on a regular basis, perhaps once every three years.

A clear understanding of the scale of the problem and how it is changing is required as a performance measure of how it can be successfully managed

3.6 Modernize irrigation infrastructure (irrigation command level)

There is an urgent need to invest in rehabilitating and modernizing irrigation infrastructure. However, it is recognized that this is a hugely expensive undertaking. As such, carefully prepared business cases will be needed for each set of modernization investments.

Currently, the management, operation and maintenance responsibilities of irrigation and drainage projects are shared within a partnership between the Ministry of Water Resources (MoWR) and farmers. Current systems are in need of repair and technology is unable to be deployed due to problems of maintenance and security. Under the current operational environment the efficiency of infrastructure operation is low. For example, the efficiency of regulatory structures at Dujaila is only 54-60%.

Investment is required to rehabilitate the water delivery systems including canals/channels, pump lifts, farm intakes and weirs, and regulator structures. However, such rehabilitation should be undertaken to new modernized design specifications that reflect how the irrigation system should be operated in the future, and the current availability of water. Investment is required to maintain the delivery systems and clear roles and responsibilities need to be agreed.

The implementation of an integrated drainage system is a clear enabling technology that can profoundly affect the productive capacity of land. However, it is an expensive and time consuming activity. The drainage network is in urgent need of rehabilitation in most irrigated areas of southern and central Iraq. For example, the drainage network at both case study sites for this project, operates through pumps with efficiencies of between 70 and 80% at Mussaib and 50 and 60% at Dujaila.

Roles and responsibilities for the drainage network are complex and farmers especially cannot maintain their side of the drainage agreements. Consequently drains have low efficiency which in turn causes watertable rise, contributing to waterlogging and salinity problems. There also appears to be little coordination between the irrigation command level drainage operation and the management of the Main Drain.

To achieve maximum yields, an effective drainage system would be essential to remove excessive salts from the root zone. However, there are limits to how deep such drains should be installed. At deeper watertable levels, although average root zone salinity will be further decreased, the resultant yield increases will be marginal. Therefore drains deeper than 200 cm may not be economically viable for these areas as construction costs will increase and crop responses will be marginal.

Detailed drainage design is required to meet the needs of the current and forecast farming systems, and the range of watertable depths

The rehabilitation of existing drainage systems will remain a challenge in many areas of Iraq for some time to come, primarily due to the large investments required. Managing irrigation applications to control rising watertable and consequent soil salinity problems will provide a short term benefit in the near future while broader decisions are made concerning rehabilitation and reclamation investment.

Irrigation command management suffers from a shortage of equipment, financial allocations and technical staff to carry out maintenance and rehabilitation work at irrigation canal regulators and gates. There is a lack of awareness among the farmers regarding the importance of the efficient use of irrigation water, which results in large scale waterlogging and salinity problems. Moreover, farmers lack technical and financial abilities to undertake their share of maintenance works. There is an absence of water user's associations, which can be bodies that support the responsibilities of operation and maintenance within specific levels.

Irrigation delivery and drainage infrastructure needs to be modernized at the irrigation command level and integrated into a broader regional framework. Clear, appropriately resourced roles and responsibilities between Government and farmers should be agreed. Furthermore, there is a need to increase the capacity and capability of the managers of irrigation commands.

3.7 Manage surface water salinity (regional level)

Surface-water salinity must be controlled by tackling the major sources of saline water inflows to rivers within Iraq, including the increase in salinity due to reductions in flow. This will be best achieved by the development and implementation of a salinity management framework for the entire Tigris and Euphrates Rivers system. Options that can be adopted are varied and include major engineered structures and infrastructure such as water treatment.

The project has identified a number of areas where salinity processes are contributing to the salinization of water resources of the Tigris Euphrates River systems. These areas can be addressed by the following actions.

3.7.1 Improving infrastructure and operational efficiency

Improving water resource infrastructure efficiency and infrastructure operating guidelines for simultaneous water and salt load management (at multiple scales throughout the Mesopotamian plain) is an intervention focusing on the water supply side. Since the objective of this intervention is to maximize the volume of good quality water, and minimize the volume of saline water, the primary goal is to separate good quality water from saline water, and to reduce evaporative losses in the fresh water system (evaporation control). Evaporative losses are a loss of available water and result in an increase of salinity in the water.

The objectives should be to maximize the volume of good quality water, and minimize the volume of saline water, separate good quality water from saline water and reduce evaporative losses in the system

For example, one area where it may be possible to improve water management for better salinity control is the use of Lake Tharthar for water storage. The purpose of Lake Tharthar is to eliminate flooding risks from the Tigris River by diverting excess water flows to the reservoir, and to store excess water and re-release it to the Tigris and Euphrates rivers for irrigation purposes (WCC, 2006). Currently, low salinity flood-water mixes with saline water in Lake Tharthar, and covers a large surface area. This results in an increase of salinity of the flood-water due to mixing and evapo-concentration. One possible intervention could be to partition Lake Tharthar so that smaller sections are used to store low salinity flood-water for release to irrigation. These interventions should focus both on the physical layout, as well as the operational efficiency in the region.

3.7.2 Direct salt reduction interventions

Direct salt reduction interventions focus on the removal of salt influxes into the water supply system. This could be achieved by developing "terminal" salt storages, such as evaporation basins, utilizing the Main Drain in a more efficient manner, or by installing a groundwater-pumping network to intercept return saline flow to the Tigris and Euphrates.

In the Mesopotamian plain, the lower reaches of the Tigris and Euphrates appear suitable for salt interception pumping systems. However, the investment and benefits of these interventions must be carefully evaluated. The benefits of salt interception schemes are highly dependent on the land use planning described in later sections. If no irrigation or other beneficial water use occurs down stream of the location of the salt interception scheme, the benefits of the scheme will be less than when a large part of the population (or environmental systems) depends on the river water.

3.8 Policy and legislative environment (regional level)

The policy environment in Iraq is complex and the integration of actions may not be efficient. It would be valuable to investigate how agriculture, water and research policies in Iraq have affected land and water salinity. Questions that need to be addressed are outlined below:

How have past policies in Iraq contributed to the widespread land and water salinity we currently find in Iraq? This needs to consider several areas:

a) How do agricultural policies affect the viability of farming in Iraq and do they provide an incentive for farmers to invest?
b) How much has the government invested in irrigation and drainage infrastructure and has there been any private sector investment in irrigation or drainage?
c) What is known about water availability, distribution, and costs of use for irrigation? Who is responsible, who pays, and what are the objectives – equity or productivity?
d) What types of land tenure are in effect and how do they affect government and individual investment in land?
e) Who takes responsibility for land salinity, who is accountable? Is it the government, farmers' associations, or farmers themselves?
f) Who takes responsibility for managing river salinity and how? What are the objectives?
g) Who conducts agricultural research in Iraq, who pays for it, and how is it strategically planned to meet national objectives?
h) Are policies to educate farmers and extension policies effective?

What are the current policies? How have they changed from the past?

Will current policies promote good management of land and water salinity?

How could policies to manage land and water salinity be improved?

Much of the above will come down to four key issues:

Who actually has responsibility for land and water salinity, i.e., which ministers and other bureaucrats are responsible for this issue? Are farmers also responsible? How does this responsibility cut across jurisdictions, e.g., federal and governorate?

What land tenure do farmers have and how does it affect their incentives for private investment?

Does the total of agriculture, water and land policies provide incentive for farmers to invest in their lands to increase production?

Is government investment in irrigation and drainage infrastructure sustainable? What are the ownership, management, and maintenance issues?

Iraq has had a broad range of policies for agriculture and water management with varying objectives. It is now time to investigate whether these can help resolve the current salinity problems.

Salinity in Iraq is a complicated and ongoing issue and short term projects for two to three years will not solve the problems in the long term. Authorities should explore an approach that establishes a National Program for Salinity Management in Iraq, similar to existing national agricultural programs. This would centralize the coordination of efforts and ensure high-level integration between the water, agricultural and environmental sectors of Government. This new program could be partly based on the findings, experiences and information from both the Australian and Italian projects.

Irrigation and Drainage Infrastructure Rehabilitation Plan

In order to develop rehabilitation plans for the irrigation and drainage infrastructure for both project areas, a comprehensive process of consultation was launched. During the process, interviews were conducted with the officials from Ministries of Water Resources and Agriculture. Consultations were carried out with the staff of both projects and the farmers of the project areas. In addition, opinions of other stakeholders such as water experts, progressive farmers and officials of local governments were are also recorded.

Based on their suggestions, rehabilitation needs were divided into three phases of implementation i.e. short-term (2-3 years), medium-term (3-5 years) and long-term (5-10 years). The short-term needs are those which do not require significant financial resources, and where most of the work can be completed through the local project funds and with the involvement of the local farming community. In this instance, it will be very important to get quick relief from the choking of drains and to manage irrigation to lower watertables, control soil salinity and enhance crop productivity.

The medium-term plan would require commitment from the Central government both in terms of financial and technical support. The medium-term plan can also be implemented by mobilizing local funds and resources. Implementation of this plan would solve more than 80% of the problems of both project areas. The long-term plans are mainly to solve the regional irrigation and drainage problems, which go beyond the project areas. These plans need to be implemented to ensure long-term sustainability of irrigated agriculture in Mesopotamian plain. The suggestions for all three phases are given below:

Short-term needs

- Clean all branch canals (public benefit) from plants and sedimentation.
- Improve and rehabilitate weirs and roads on drains.
- Clean private benefit drains (collector and field drains).
- Rehabilitate structures on the branch canals and drainage canals (Head regulators, cross regulators, bridges, culverts and pedestrian bridges).
- Organize farmers into Water Users Associations (WUAs) to ensure maintenance work and equitable water distribution among all farmers.

Medium-term needs

- Line with concrete all public benefit canals including all structures on them (head, cross regulators and bridges for vehicles and pedestrians.
- Clean and rehabilitate main drains (north and south main drains) to ensure standard cross sections and all the structures on them.
- Rehabilitate collector drains to make the standard design cross sections and repair all outlets and structures.
- Rehabilitate the open field drains with all of its outlets.

- Develop plans (including incentives for farmers) to introduce modern irrigation techniques such drip/sprinkler in these areas to improve water use efficiency.

Long-term needs

- Complete concrete lining of private benefit canals with all structures.
- Concrete line the 5 km long Mussaib main canal.
- Land level 400000 donums (100,000 ha) of the project area.
- Replace of open field drains system by sub-surface pipe drain system.

In addition to this rehabilitation work, government should also take certain administrative and management steps to improve governance and educate farmers about their responsibilities regarding water use and operation and maintenance of irrigation and drainage systems. These may include:

- Organize farmer meetings with the Directorate of Water Resources to educate them about water allocation laws and their due share of water.
- Work with farmers to remove all unauthorized pumps and pipes especially for fish ponds
- Develop a mechanism of water pricing to control unauthorized water extraction.

Develop water-pricing mechanism on volume basis instead of area basis. It is learned that such mechanism is present however its implementation is delayed due to different reasons. MoWR should take steps in order to implement this pricing mechanism.

3.9 Key deficiencies in the system (irrigation command level)

In order to improve management at different levels, it is important to increase the efficiency of extension systems, and increase farmer participation through robust extension delivery. The agricultural extension network has been ineffectual in encouraging farmers to adopt improved farming techniques including the adoption of saline agriculture. Participatory programs (demonstration, training, communication) are needed to empower and educate farmers and the broader community about better (sustainable and adoptable) agricultural options for saline landscapes. Visible success on the ground will mobilize further broad-based community support.

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Agricultural extension in Iraq links the research and education resources and activities of government agencies with colleges and universities. These institutions reach out to interested individuals in rural, urban, or suburban communities with information about better agricultural practices, technologies, and current research in an effort to address problems and increase production. For decades the research-extension-farmer linkage was based on a rather simple model (with some exceptions). In order to achieve development, "modern" research results, new options and best practices had to be transferred to the "traditional" farmer, and extension seemed to be the appropriate means to do so. The general faith in science and the commitment to modernization led to the discrediting of indigenous knowledge.

Farming systems research and the "rediscovery" of farmers' knowledge have shown that "improved technology is a package of inputs and practices that usually comes from many sources". Field surveys have collected the key drivers which control farmer's options to mitigate salinity or to improve their family income.

Key deficiencies in the system which contribute to land degradation, waterlogging, salinity and poor productivity include poor water availability, structural shortcomings, planning gaps, and restricted institutional capacities. The net amount of water available in Tigris-Euphrates basin is limited and cannot be supplemented from any adjacent watershed. The structural shortcomings relate to irrigation channels which have significantly deviated from their original designs, regulatory structures which have been operating inefficiently, are damaged and out of use (or gone missing altogether), drainage channels which have been identified as insufficient in some parts, and existing drains which have been clogged and are out of action. As to the planning gaps, comprehensive plans to combat overarching issues such as climate change, land degradation, contraventions and enforcement of farmers' responsibilities do not exist. The institutions lack the capacity to enforce regulations and penalize offenders. There is severe scarcity of resources in terms of skilled manpower, equipment and funds to carry out many important functions. Capacity building and farmers' education at the institutional level does not exist.

During the process of this assessment, it was concluded that the existing status of irrigation and drainage infrastructure, current operations and maintenance setup, and on-farm irrigation practices are all directly responsible for increasing soil salinization and reducting land and water productivity in the project areas. Irrigation networks are old and have deteriorated to a large extent due to the lack of maintenance. There are large-scale farmer interventions, noncompliance of the rotational system, irrigation of unauthorized agricultural lands, and establishment of illegal fish ponds. All these factors lead to serious water allocation problems causing water scarcity in many regions of the projects. On the other hand, project areas with available water suffer from low irrigation efficiencies, causing waterlogging and soil salinity problems.

4 Adapting to salinity

4.1 Socio-economic factors influencing farming decisions (field level)

Surveys undertaken as part of the project have shown that farmers perceive that salinity has reduced productivity. Although all three sites where the project is located are considered to be salt affected, about 56%, 96% and 100% of farmers from the Mussayeb, Dujailah and Abulkhaseeb areas respectively mentioned that salinity is a severe problem for them.

The main sources of salinity according to farmers are:

- Long fallow. Due to shortage of water and other factors related to the abnormal security situation of Iraq, a significant number of farmers left their lands with no cultivation for years. This has increased the level of salinity due to shallow watertables;
- Water shortage. Water policies of the neighbor countries, Iran, Turkey and Syria in addition to the shortage of rainfall during the last 15 years have affected levels of water in the main rivers that leads farmers to use drainage water of substantially higher salinity for irrigation;
- No drainage. Some farms have no drains or drains that exist require rehabilitation; and
- Generally high water table levels where the shallow aquifer is of a very high salinity.

In addition to these specific sources of salinity, farmers face a range of constraints and limitations that increase the severity of the salinity problem that ultimately leads to a decrease in the productivity per unit of land.

These constraints and limitations are:

- Unavailability of fuel in adequate quantities or at suitable prices;
- Inflexible irrigation delivery system in terms of timing and distributed of water quantities;
- Shortage of machinery in general, particularly seeders and combine-harvesters;
- Reduction in subsidies on inputs and low output (production) prices. Farmers used to get subsidies from the State on the main inputs such as seeds and fertilizers, at the same time, governments used to support production prices in order to keep farmers able to compete in the market and overcome price damping. This change has reduced the terms of trade for individual farmers;
- Unavailability of inputs at the required time. Due to failures in administration some main inputs do not reach farmers in time for planting. Seed, fertilizer and machinery services are the main inputs that are subject to this delay;
- Lack of extension services or total absence of them at specific times. Agricultural extension services are generally not available. However, extension has a critical role in delivering the outputs of research and in promoting modern agricultural practices to farmers and the broader rural community.
- Transportation facilities are in need of rehabilitation. Roads were established in rural areas as part of a national development strategy during the 1970s and 1980s. An absence of maintenance (mainly because of sanctions and the oil embargo and other factors) has lead these assets becoming partly dysfunctional; and
- Problems with some legislation, regulations and policies. Farmers have mentioned the urgent need for legislation and regulations to be revised so that they are better aligned with national development goals. Behaviour, traditions and attitudes need to be aligned with national irrigation modernization goals. This requires amongst other things a large extension effort.

However, there may also be some socio-economic impediments that are also operative in the background.

What is not well known is the economic loss due to salinity and how economic factors influence land use change. There has been no credible assessment undertaken in recent years of the cost of salinity to Iraqi agriculture, the livelihood patterns of farm families and the policy environment affecting water and soil salinity management.

Without understanding the baseline costs associated with salinity and the current agricultural situation, it is very difficult to understand the scale of benefits that might accrue from the implementation of changed agricultural practices. There is little existing information on the relative profitability at a farm level of proposed alternative land use options. To undertake such an analysis of costs and benefits, information is required on the nature and extent of salinity at the regional and district levels as well as at the farm level.

An assessment of the socio-economic costs of salinity at all levels is required as a basis to understand the benefits to be gained by changing irrigation practice.

4.2 Productivity on irrigated saline soils (field level)

The use of saline water in Iraq, to a large extent, is still confined to the growth of salt resistant grasses for fodder, bushes and trees. Because of their limited profitability, farmers are not very interested in adopting these practices and prefer to leave their salinised lands fallow and look for off-farm income and employment.

In areas where salt-affected soils exist and drainage waters are generated on a large scale, production systems based on salt-tolerant plant species are likely to be the key for future agricultural and economic growth. While doing so, the involvement of local communities and stakeholders such as industry and traders is of great importance in order to establish and strengthen markets for the products produced from salt-affected water and soils. Increasing the intensity of plant production per unit of area is also useful in reducing surface evaporation and the accumulation of salts at the soil surface. Maintaining soil moisture at a level that can reduce the salt stress is another way of coping with salinity. This can be done by changing the planting methods, e.g. by shifting the production of maize from basin to furrow irrigation.

In areas where salinity levels are extremely high, such as Al-Dujaila area in southern Iraq, and where installation of drainage systems is expensive or impractical, reclamation through the planting of different salt tolerant species could be a useful possibility. Plant species such as *Tamarix aphylla* and *Atriplex* species are considered effective in decreasing the salinity of surface soil. Other plants such as *Haloxylon aphyllum*, *Haloxylon persicum* and *Petropyrum euphratica* are also recommended for this purpose. Halophytes are usually considered useful for rangelands in saline areas and can be used as a fodder for grazing animals.

Problems of the disposal of saline drainage effluent can partly be solved by re-using drainage water for growing salt-tolerant crops. As well, there is scope to use blended water (fresh and saline water) to provide the required amount of irrigation water, particularly in areas suffering water shortages. Drainage waters can also be used for the promotion of aquaculture especially in those areas which are abandoned for conventional agricultural production systems. Such areas exist where sources of farm income can be diversified by exploiting unutilized resources and contributing to the remediation of waterlogging problems by removing excess water from the soil.

All farming systems in Iraq, including those that are irrigated, produce crops and livestock. Systems become more livestock-dominant as salinity increases, generally towards the Gulf. Different mixes of productive salt-tolerant crops and forages are needed to match farming systems in mildly, moderately and highly saline areas. The profitability of these systems may only be apparent in the whole farm context. The nutritive value of forages and their fit within existing, new, and evolving farming systems should be considered in the evaluation of existing and new forages. There is also a need to consider opportunities to integrate plants with lower water requirements or an ability to use groundwater, and consider the role of legumes within farming systems.

One unpalatable truth is that not all land is capable of economic use. Land and water needs to be classified in terms of its capability. Most investment needs to be focused on land and water of high capability. Some land and water will have such low capability that no investment in these areas will be the optimal solution.

One of the features of our study has been the demonstration of high levels of production from irrigated saline land in both the winter and summer growing seasons – see results from three trials conducted in the Al-Nassiriyah, Wasit and Basrah governorates (Figure 2: A-C). The levels of production seen in these trials are high for saline land (with wheat 3.0–5.3 t/ha, with summer forages 5.2–1.9 t/ha, and with halophytic grasses 6.1–12.5 t/ha after 2.5 months growth and 8.8–12.4 t/ha after a further 3 months growth). However, these levels of production are not surprising given the dual role that irrigation has in lowering the salinity of soil solution. Furthermore, these high levels of production are completely in accord with international examples from irrigated saline land.[1]

A second major theme that emerges from the field trials in Iraq is that in some cases, the currently used genotypes are relatively productive. In the summer forages trial, only one of the six imported pearl millet lines and one of the three imported sorghum lines had higher productivity than the best local variety (Fig. 1.B). Similarly, in the halophytic grasses trial, the locally adapted species (pearmoda grass) had higher productivity than the three imported lines (Fig. 1.C). However, this effect was not universal. With the wheat cultivar trial eight of the ten imported lines had higher yields than the best local variety (Fig. 1.A).

The implications of these results are clear. Research to compare imported and local plant varieties for salt tolerance and adaptation needs to continue, with the best plants being demonstrated on-farm to growers.

With forages, there needs to be a focus on plant nutritive value as well as biomass production. All plants need to be evaluated in the context of farming systems: benefits may not necessarily relate directly to the amount produced, but when it is produced (in the case of fodder plants filling feed gaps) or how much other resource (like water, fertilizer, etc.) can be saved for other parts of the productive system.

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[1] For example, with *Atriplex* species under non-irrigated conditions in southern Australia (330–370 mm of annual rainfall per annum), annual leaf yields are commonly around 0.4–0.7 t DM/ha. In contrast, under irrigated conditions annual leaf yields of 10–20 t DM/ha have been achieved with *Atriplex* species irrigated with water of salinity of 9–10 and □55 dS/m. Similar differences in production also occur with halophytic grasses. Under conditions of dryland salinity in southern Australia, grasses typically have an annual production of 0.2 to 1.0 t DM/ha. In contrast, the annual production of halophytic grasses can reach 40 t DM/ha when irrigated with water of 9.5 dS/m (reviewed by Norman *et al*. 2013).

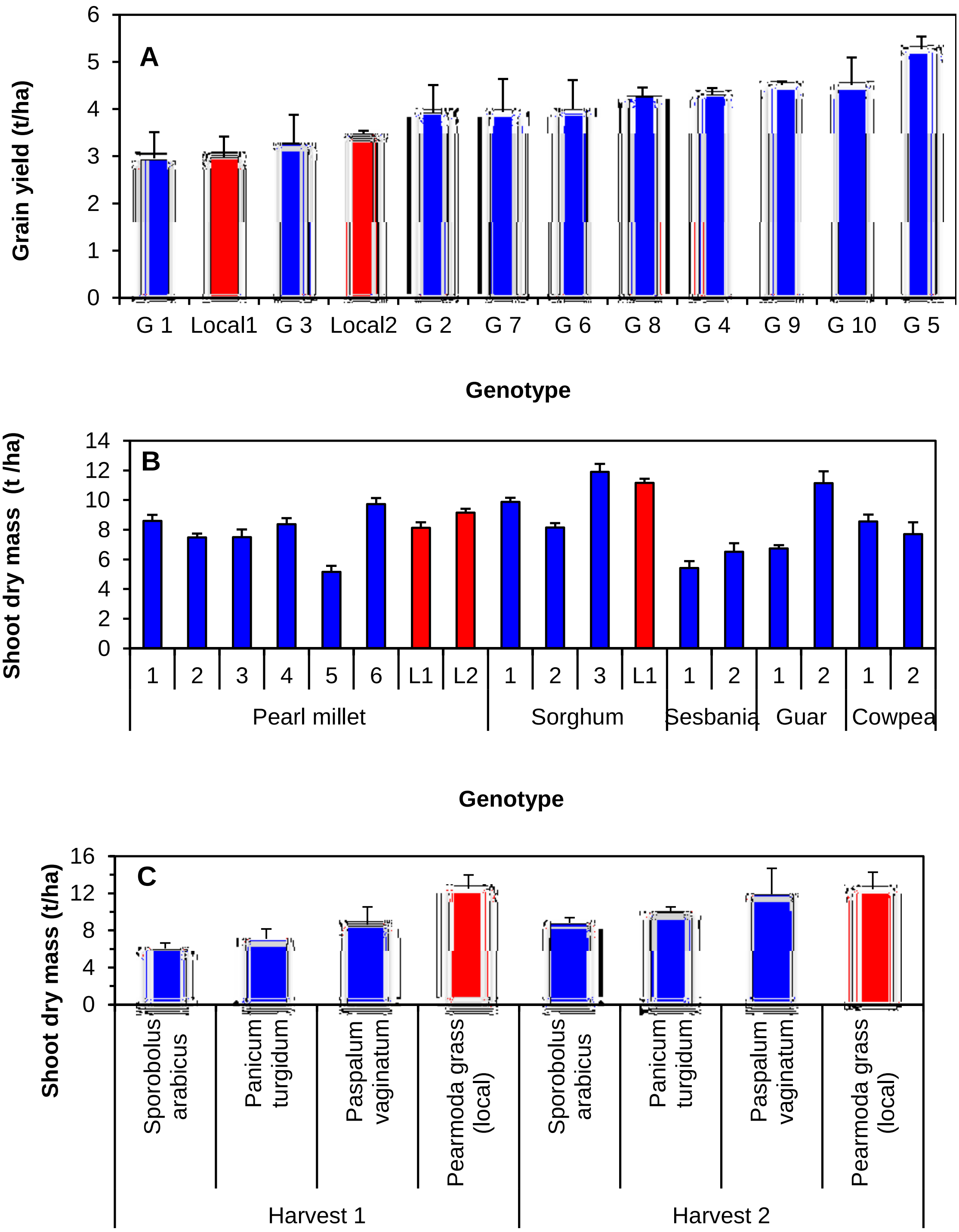

Figure 2: Variation in yields of: (A) wheat cultivars[2] (B), summer forages, and (C) halophytic grasses under irrigated conditions in Central and Southern Iraq. Each value is the mean ± SEM of 3-4 replicates. Red columns are local varieties.

Experimental information and land capability data for the three trials shown in Figure 2 was as follows:

- Site A (in the Al-Gharraf project area, Al-Nassiriyah Governorate) had a silty clay texture, initial and final EC_e values (0–25 cm) of 16.2 and 10.8 dS/m, groundwater of EC_w 35-42 dS/m

[2] Trial conducted as part of Italian project.

at a depth of 125–130 cm, and an average salinity of the irrigation water of 2.5 dS/m. There were significant effects of cultivar on yield ($P < 0.05$). The trial was planted on 16 December 2011. Plots were 5 x 2 m in size and consisted of rows planted 20 cm apart. Plants received ~450 mm of irrigation over 6 applications.

- Site B (in Al-Dujaila irrigation project area, Wasit Governorate) had a clay texture, initial and final EC_e values (0–50 cm) of 18.0 and 13.0 dS/m, groundwater of EC_w 19-44 dS/m at a depth of 84–166 cm, and an average salinity of the irrigation water of 2.5 dS/m. Species varied significantly in yield ($P < 0.001$). The trial was planted on 25 May 2011 and harvested on 13 October 2011. Plants were grown in rows 9 m long, spaced 0.6 m apart. Plants received 1980 mm of irrigation over 25 applications.
- Site C (in Abu-Alkhaseeb project, Basrah Governorate) had a loamy texture, initial and final EC_e values (0–25 cm) of 22.3 and 18.2 dS/m, groundwater of EC_w ~62 dS/m at a depth of ~1.0 m, and an average salinity of the irrigation water of 3.1 dS/m. Species varied significantly in shoot dry mass production at the first ($P < 0.05$) but not the second harvest. The trial was planted on 31 March 2012. The first harvest was taken on 18 June 2012 and the second harvest was taken on 18 September 2012. Plants were grown in plots 2 m x 2 m in size. Plants received 1990 mm of irrigation over 21 applications.

Waterlogging

Another potential driver of plant survival and growth in saline landscapes is waterlogging. Waterlogging causes oxygen deficiency – and therefore energy deficiency – in plants. In saline landscapes, this leads to rapid increases in the uptake of sodium and chloride, which concentrate in plant tissues, leading to decreased growth and survival.

Waterlogging occurs when the watertable rises to within 10-30 cm of the soil surface. It may have critical effects on the germination of seeds on saline soils if these soils are irrigated immediately after planting. An example of such an effect occurred in our trial with barley. This trial was planted on soils near the wheat experiment in Fig. 1.A. However, in this case, the trial was sown one day before the application of ~70 mm of irrigation water. This water application caused a very patchy establishment of barley (Fig. 2), and the overall average yield of barley was only ~30% of the overall average yield of wheat.

The case for waterlogging being a strong constraint to productivity in Iraq is not clear, and further data to support or refute the case need to be gathered. All field trials should be routinely monitored for depth to water-table at every visit.

Furthermore, care should be taken in the design of trials to ensure that sites are watered after germination has occurred. Seeds are especially prone to waterlogging damage during germination.

Figure 3: Barley plots at Al-Nassiriyah showing patchy establishment: this may have been caused by waterlogging of the seeds (due to irrigation) one day after sowing.[3] .

4.3 The role of livestock and salt tolerant forages in saline landscapes (field level)

The growth of salt-tolerant forage species for ruminant production offers the only opportunity to use land and water resources that are too saline for conventional crops and forages.

Ruminant production, primarily sheep, is already a component of farming systems in the irrigated zone of Iraq, so changing production from crops and forages to halophytic forages will not require as much farming systems change as would be required for development of entirely new farming systems. This is a major advantage. Markets exist for livestock products; it is estimated that there are 9.3 million small ruminants (80 % sheep, 20% goats) in Iraq and livestock production accounts for roughly 24% of the value of agriculture (FAOSTAT: http://faostat.fao.org/). There are significant opportunities to use halophytic forages to improve productivity of livestock systems. Opportunities also exist for the development of markets and trading of halophytic fodders as a product in their own right. Hay cut from halophytic grasses may be attractive to farmers unaffected by salinity in the irrigated zone and shepherds in sedentary systems.

Opportunities exist for (1) highly productive halophytic grasses and forages that require regular irrigation and fertilizing, and (2) halophytic chenopods that are relatively drought tolerant and able to persist when irrigation water is scarce. The first group of plants may be highly productive but require significant inputs to optimise growth and nutritive value. The halophytic chenopods are less productive but represent an inexpensive risk-management strategy and can be reliable source of scarce nutrients. Halophytic grasses differ from chenopods in their method of osmotic adjustment, which impacts particularly on the mineral contents in the edible biomass. In the grasses, tolerance to salinity is based primarily on maintaining low salt concentrations in the leaves, while for the chenopods tolerance to salinity is based more on the uptake of sodium and chloride, and the compartmentalization of these ions in vacuoles. Consequently halophytic grass biomass contains approximately 5-9 % salt while the chenopods can have 15-35 % salt in the dry matter.

In the Mediterranean-climate areas of Australia, halophytic forages are often used to fill nutrient gaps within farming systems. In Iraq there are similar feed gaps; analysis of ruminant production systems (Report 1) indicates that halophytes offer an opportunity to provide a protein and mineral

[3] Trial conducted as part of Italian project

supplement to animals grazing cereal stubbles in summer. In autumn and early winter, feed is relatively scarce so summer-active halophytes would have a relatively high value within systems. Key issues for small ruminant production in Iraq include reproductive inefficiencies (less than one lamb/kid per female) and failure of offspring to reach optimal slaughter weights. There are opportunities to use some of the unique properties of halophytes to improve the productivity and health of females and their offspring. Examples include provision of protein and sulphur during lactation in autumn and the supply of essential minerals and vitamins (vitamins E and A).

While halophytic forages represent a key opportunity for salinised areas of Iraq, these plants tend to have greater biochemical complexity than standard forages, partially due to the need to osmoregulate and partially due to lack of agronomic selection for low toxins and higher digestibility. Factors influencing voluntary feed intake and nutritive value must be considered. It is critical that the strengths and limitation of the halophytic forages are identified and suitable management strategies are communicated to farmers. For example, halophytic grasses tend to have relatively low energy values and pregnant and lactating females will need significant energy (and possibly) protein supplements. The chenopods accumulate salt at such high levels that animals cannot eat enough to maintain liveweight, again supplements are required. Mineral toxicities and induced mineral deficiencies are also possible but easily overcome through management. Figure 3 shows the range of factors after biomass production that impact on the real productivity and profitability of the system.

Halophytes have strengths and weaknesses as forages; farming systems incorporating halophytes need to focus strongly on livestock performance rather than on biomass production alone.

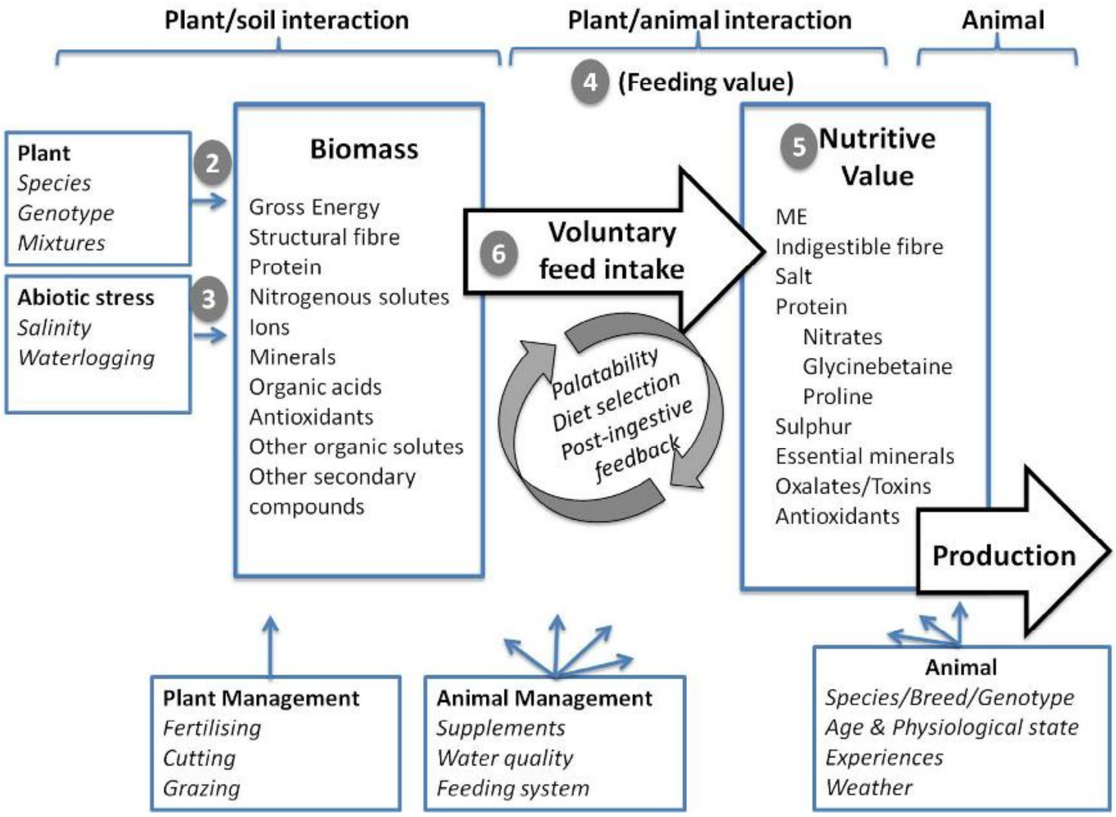

Figure 4: Framework for thinking about the use of halophytes for livestock production. Livestock production depends on the utilisation of biomass. The quantity and chemical composition of biomass is a function of plant genotype, abiotic environment and management. Biomass has no value unless it is eaten and its chemical composition influences both voluntary feed intake and nutritive value. Feedback loops between the stomach and brain regulate diet selection and intake. Livestock production is also influenced by animal genotype and husbandry factors.

5 Analysis of the government perspective

This report analyses the agricultural sector of Iraq and in particular the salinity problem, from a government perspective. A SWOT (Strengths, Weaknesses, Opportunities, and Threats) methodology has been used for the analysis in this section. SWOT analysis is a strategic method that can be used to identify the internal and external factors that are favourable and unfavourable for the Ministry of Agriculture and other stakeholders to achieve effective policies to control the salinity problem in Iraq.

The Government of Iraq, through the Ministry of Agriculture, faces a number of opportunities and challenges when it comes to managing salinity – a problem affecting many farming activities in Iraq.

Error! Reference source not found. shows the outputs of a **SWOT** analysis of irrigated agriculture in Iraq. The **Strengths**, from an agricultural policy viewpoint, are the natural resources, knowledge and experience in management and reclamation of saline soils, existing water policies for water and salinity control, existing legislation related to irrigation and salinity control, and experience with programs and projects for soil salinity control and water management.

The **Weaknesses** are the management of natural resources, agricultural practices, soil salinity and saline waters, water scarcity impacting on agriculture and irrigation, and institutional issues.

The **Opportunities** are new programs, already identified potential of the agricultural sector, involvement of the private sector in agricultural activities, agriculture seen as a value for social and rural development, the possibility of synergy among agricultural initiatives shown by region, and knowing the viewpoints and plans of policy makers.

The **Threats** are water scarcity, dependence on water resources from other countries, general threats to the agricultural sector, and internal threats as identified by the Ministry of Agriculture.

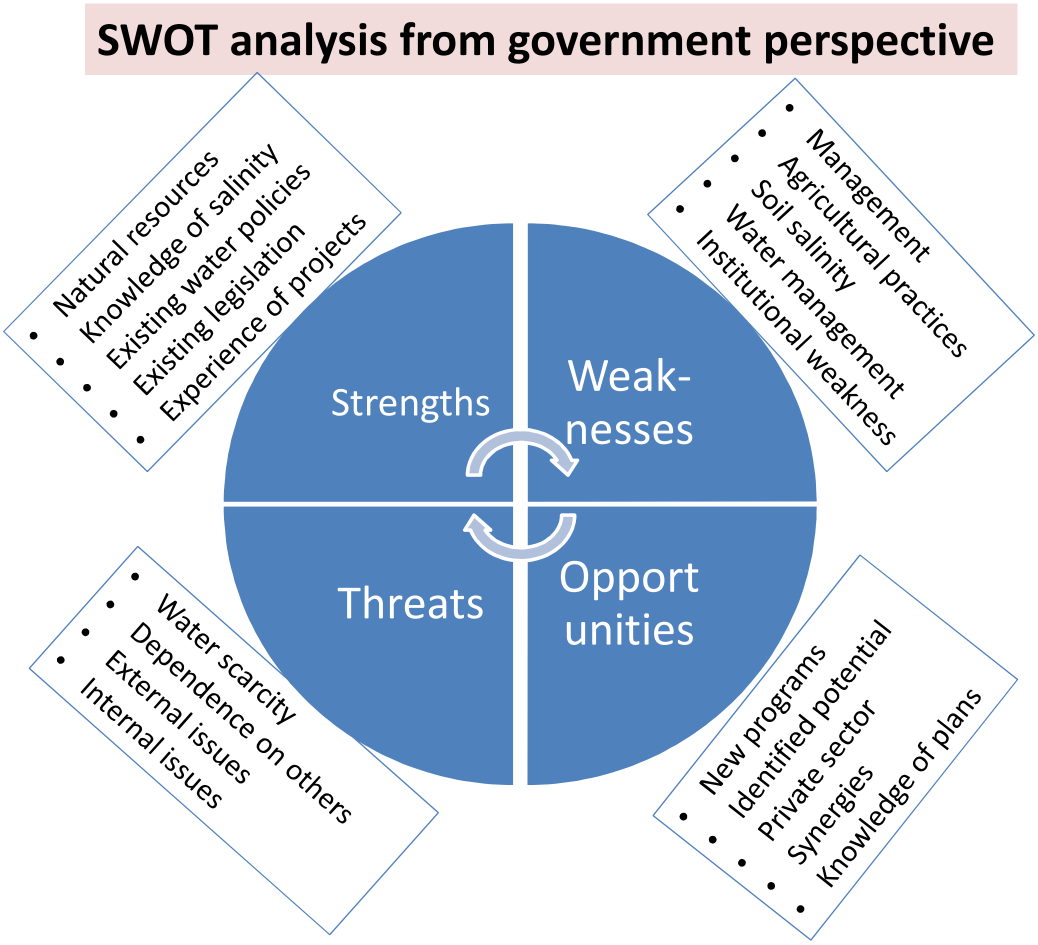

Figure 5: Summary of outputs of SWOT analysis. (Source: Authors' own elaboration)

In general, institutional issues refer to all impediments that affect the management of water and land resources, provoke environmental recklessness, and diminish investments in agricultural land.

It is not easy to implement sustainable farming systems. For example, the Ministry of Water Resources has developed a strategy to reclaim 3.73 Mha (Hassan 2011), of which 0.54 Mha are going to be used in supplementary irrigation projects and 3.19 Mha are to be rehabilitated.

The estimated cost of reclaiming 400,000 ha per year is up to 5,000 billion dinars (equivalent to 4,300 million USD as of February 2013). It is unclear (but very important) – who will take on the monumental tasks of implementing such large areas of land reclamation? Who will fund it? Which institution in Iraq is capable of handling 5000 billion dinars per year?

Policies and goals have been formulated in Iraq to ensure that water of sufficient quality and quantity is available to boost the intensification and expansion of agriculture. The following points summarize the National Development Plan (2009) that includes the water, irrigation, and salinity policies in Iraq:

1) Reach an agreement with the upstream countries of the Tigris and Euphrates Rivers and their tributaries (i.e. Turkey, Syria, and Iran) for appropriate apportionment of water according to international agreements and conventions. This will ensure access to an agreed share of water, in terms of its quantity and quality;
2) Speed up the completion of the second phase of the water budget (strategic study of water resources and land) by the Ministry of Water Resources for various sectors, beneficiaries and consumers, including agriculture, electricity, transport, marshes, drinking, health, and other industrial needs;
3) Apply management methods to integrate water resources, in coordination with all other bodies responsible for the optimal use of water resources and conservation. This would include sewage and industrial waters not being discharged into rivers without treatment, and studying the possibilities of reuse;
4) Dam projects should preferably operate centrally;
5) Complete the links between the drainage systems all over the country into the Main Drain channel;
6) Support and activate extension activities to publish results of the application of agricultural research, including use of water and land resources. Outreach programs to educate water users should be expanded to show the importance of water conservation and optimal utilization, with the participation of relevant ministries;
7) Account for the limited water resources in the process of developing future agricultural policies, using rational consumption and available alternatives in applying modern irrigation methods; and encourage cultivation of alternative crops that require less water and that are tolerant to salt and drought;
8) The Ministry of Agriculture should take steps towards rehabilitating irrigated lands through the provision of technical support and access to production inputs such as irrigation facilities, fuel for operations, and on-farm agricultural pest management;
9) Continue maintenance of dams and reservoirs to optimize operation of water resources;
10) Establish a national project that deals with studies of global climate change and its impact on Iraq's water share should be considered anticipating possible shortage scenarios;
11) Direct research studies in relevant ministries and universities to raise the efficiency of irrigation and reduce water losses. Research on the use of unconventional water, such as sanitation and water recycling (grey waters), shoud be explored. The application of research pilot projects can allow advances on innovative ways to improve water efficiency. The strengthening of existing research stations and water centers will be needed; and
12) Establish new technologies to utilize the saline water available.

6 Recommended solutions

Irrigation water in Iraq is not being used to its full potential because of the poor state of the country's irrigation infrastructure and soil salinity. Tackling these problems is a priority if the country is to make best use of its water supplies.

Iraq's irrigation systems will have to be modernized, but the country also needs farm-level water-management strategies, improved salinity control and irrigation management, and enabling water-use policies and institutions. Previous attempts to cope with or mitigate the effects of salinity have focused almost exclusively on field drainage, which is a highly expensive and technical proposition. The use of field drainage must be prioritized within a comprehensive framework that analyzes the costs and benefits of this and other approaches and the upstream/downstream impacts of interventions.

Addressing land salinity:

Investment in salinity management at the farm scale needs a strategic focus. Salinity in central and southern Iraq is so pervasive and severe that impacts on farming systems will be inevitable. To policy makers, the situation may appear overwhelming. Investment of human and financial resources will appear to be required everywhere, funding and human resources will probably never be available to address all the problems, and focusing equally in all areas where there are problems is unlikely to give the best long-term outcomes.

We suggest that there should be a strategic focusing of the limited resources available in Iraq to areas where they will achieve the greatest good as soon as possible. Moderately saline irrigated land will benefit strongly from investment in better drainage infrastructure and from improvements in the salt tolerance of the currently grown crop species. In the more highly saline irrigated areas, we expect that mixed production of vegetables, cereals, and high-value fodder will be replaced by growing salt-tolerant forages and that the farming systems will be dominated by livestock production. Investment for this kind of land needs to focus on issues related to the transition towards livestock production, e.g., on the development of extension packages focusing on ways to maximize animal performance using salt-tolerant forages and fodders, and research and development on the introduction and development of forage with higher nutritive value that complement existing feeding systems. Finally, there will be some landscapes that are severely saline: these should not receive investment for reclamation. This land is not likely to be ever recovered for irrigated farming, and investment should be targeted to identification of drought-tolerant halophytic shrubs that can prevent this land from becoming desertified and that can provide feed for livestock. Australian experience would indicate that these areas may in time partially rehabilitate and salt-sensitive plant species will eventually return if grazing is managed.

Highly saline land is still capable of growing high yields of forages. In highly saline areas agriculture will become increasingly dominated by the production of forages for the use of livestock. In severely salinized regions, vegetables and grain may have to be imported from other regions and farmers may need help in developing new skills in forage conservation and improved livestock management. Farmers vary in their ability to obtain production from saline landscapes. Management practices are important in achieving production from saline land and these can be communicated to other farmers.

Effective solutions to soil salinity require changes to land-use practices and production activities over whole districts. In order to improve farm water productivity under saline agriculture, it will be necessary to address rehabilitation priorities as they relate to soil- and water-salinity problems, create mechanisms for direct farmer participation in the development, evaluation, extension, and monitoring of technologies, and highlight livelihood-enhancing and employment-generating opportunities for farm families. This needs to include planning for livestock production associated with irrigated areas and saline lands. Livestock production can be a major source of income for the poor and thus rehabilitation systems that aim to integrate irrigated cropping and livestock production may have major benefits for disadvantaged people in areas with declining cropping systems.

Addressing river salinity:

It is critically important to reduce the salinity in the Tigris and Euphrates rivers, especially in the lower reaches. This is critical not only for agriculture but also for the communities that rely on these rivers for their drinking water and other needs. Most of the increase in the salinity of these rivers occurs within Iraq; the salinity of water entering Iraq appears to have been stable since the 1980s. This provides excellent opportunities for the Government of Iraq to invest in measures that will halt and even reverse the salinity trends in these rivers. These actions need to be undertaken soon and within a comprehensive framework that prioritizes those measures that result in the greatest benefit for least cost.

Future investment:

The Government of Iraq needs to invest in key areas: research, management frameworks, policy development, infrastructure, and education/training and extension. This project will work on developing aspects of these investment requirements in the next 12 months with a view to determining key investment decisions for future effective management of salinity in Iraq.