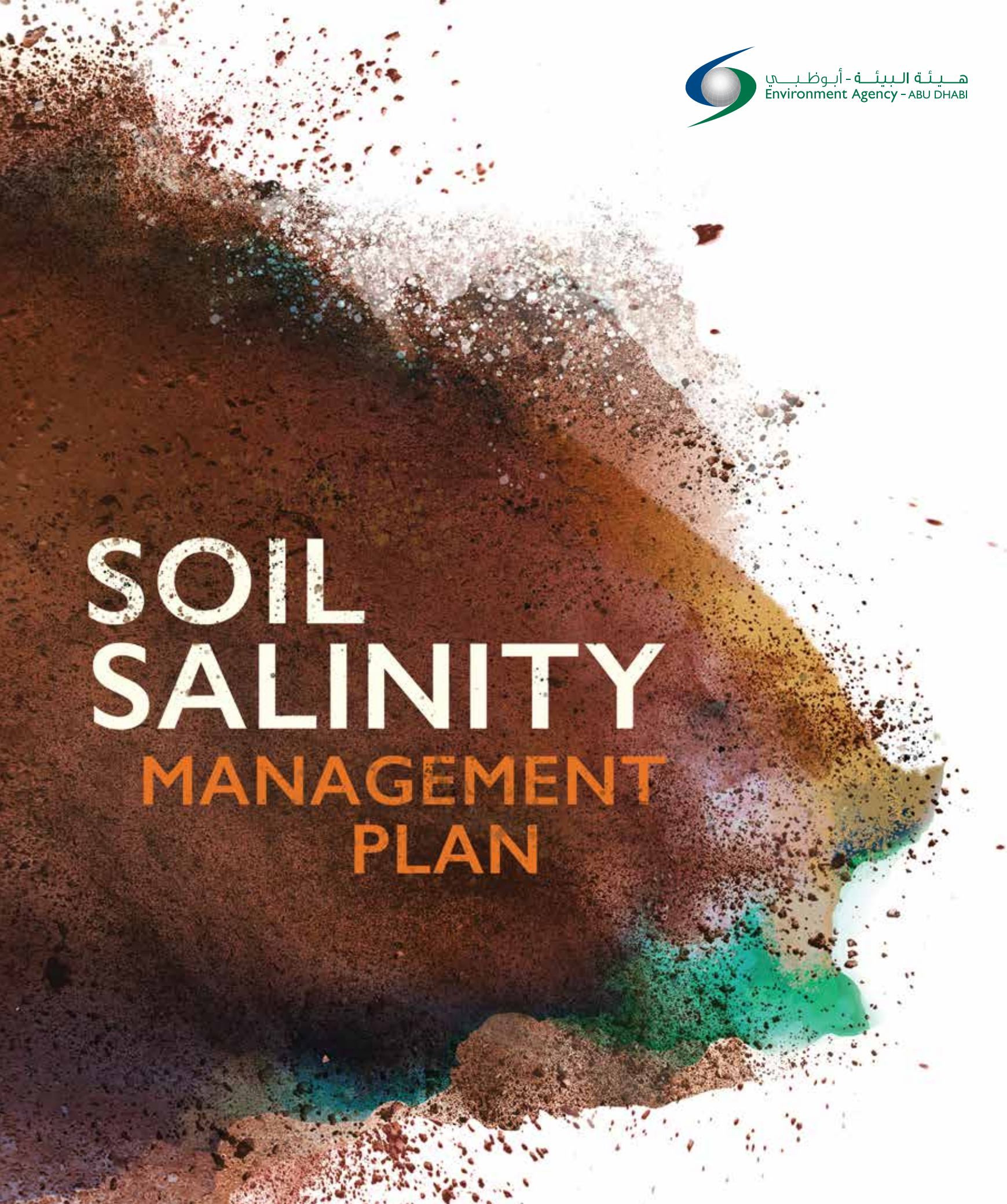
هـيـئـة الـبـيـئـة - أبـوظـبـي
Environment Agency - ABU DHABI



SOIL SALINITY MANAGEMENT PLAN

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SOIL SALINITY MANAGEMENT PLAN

FOREWORD

Soil is one of the most vital components of our environment. Without the many benefits that soils provide, human existence would be extremely difficult. As such, soil is a precious resource that needs protecting from the many natural and human activities that degrade it.

Arid climates with low precipitation and high evaporation, such as experienced here in the UAE, highlight the need to identify the characteristics of soils and develop land management plans to protect as well as optimise the economical use of those soils.

Worldwide, every day some 2 000 ha of farm soil is lost due to salt-induced degradation. Soil salinity is the most significant form of soil degradation in Abu Dhabi Emirate, particularly on agricultural land. More than 80 % of irrigated land in Abu Dhabi Emirate is affected negatively by salinity to various degrees, leading to reduced soil quality and crop production.

The Environment Agency – Abu Dhabi (EAD), in its Strategic Plan (2016-2020), made land and soil resources a strategic priority to ensure sustainable and integrated approaches to their protection. The strategic objectives of EAD aim at strengthening the policy and planning framework around soil quality, effectively influencing key stakeholder decisions, improving and enforcing the regulatory framework for soil quality, and ensuring land degradation management and restoration. In addition, EAD aims to ensure comprehensive understanding, knowledge and awareness building about soil quality in Abu Dhabi Emirate.

H.E. DR. SHEIKHA SALEM AL DHAHERI
Secretary General of Environment Agency - Abu Dhabi

Over the past three years, EAD conducted the Soil Salinity Inventory Project, surveying soil salinity in 4 000 farms. EAD also implemented a monitoring programme for salinity changes in 100 farms across the Emirate of Abu Dhabi. Data from this project is included within EAD's soil database providing decision-makers with up-to-date, accurate data on soil quality.

The primary outcome of this survey was the development of soil salinity maps, and an assessment of soil salinity management in the agricultural areas of Abu Dhabi Emirate. The evaluation showed that some of the farm area in Abu Dhabi region, Al Ain region, and Al Dhafra region had poorly managed salinity and which, if left unchecked, might significantly impact agricultural land sustainability. Therefore, and based on local Law Number 5 of 2016 on regulating the use of ground water in the emirate, EAD developed a Soil Salinity Management Plan to assist with managing and reclaiming salt-affected farms through its partner stakeholders to avoid further abandonment of agricultural farms.

The Soil Salinity Management Plan provides recommendations for each of the 16 Irrigation Districts in the Emirate of Abu Dhabi. Together with maps of soil suitability and groundwater quality data, the Soil Salinity Management Plan will enable us to optimise the use of available water resources and reduce the spread of agricultural land degradation due to soil salinity.

CONTRIBUTORS

The Soil Salinity Management Plan was developed by a multidisciplinary team comprising experts from EAD and local governmental stakeholders. The strategic direction, progress and high-level review process was overseen by the Technical Committee, with implementation supervised on a day-to-day basis by the Environment Agency – Abu Dhabi.

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Assistance from the following organisations is also gratefully acknowledged

Abu Dhabi Agriculture and Food Safety Authority (ADAFSA)
Abu Dhabi Municipality (ADM)
Abu Dhabi National Oil Company (ADNOC)
Al Ain Municipality (AAM)
Al Dhafra Region Municipality (DRM)
Department of Municipalities and Transport (DMT)
International Center for Biosaline Agriculture (ICBA)
Ministry of Climate Change and Environment (MOCCAE)
Statistics Centre Abu Dhabi (SCAD)

CONTENTS

OVERVIEW

This Soil Management Plan was developed to put the dynamics of farm soil salinity into perspective, specifically considering the deterioration of irrigation water quality. It aims to develop a nationwide model for the optimization of available water and soil resources, to provide farmers with a clear perspective, and to reinforce the role of farmers as suppliers of healthy local agricultural goods.

The monitoring programme conducted by EAD helps establish a baseline for soil behaviour throughout the seasons in order to identify key performance indicators for the implementation of a future management plan for agricultural soil.

Also, the development of a local comprehensive agricultural soil management plan in collaboration with ADAFSA should consider other aspects other than soil such as good agricultural and irrigation practices, pressure-optimized irrigation systems, optimal timing and irrigation quantities, appropriate leaching fractions, and the introduction and testing of salinity adapted crops.

The Soil Management Plan (SMP) presented in this document is divided into three subsections.

SECTION I

General principles for the best use of groundwater resources, and the maintenance and improvement of soil resources.This section includes a soil suitability classification for the Emirate of Abu Dhabi and identifies potential priority areas for agricultural activities.

SECTION II

Recommended actions are listed in separate tables for each of the 16 irrigation districts. A description is given of the existing conditions of irrigated soils and irrigation water, and specific recommendations are developed for each area (irrigation, crop selection, fertilization and other parameters). Properties and recommendations are tailored to be cross checked with the third section for the meaning and significance of their terms.

SECTION III

Terms, categories and classes of soil and irrigation water are explained as used in the characterization and recommendations produced for each individual irrigation district. Explanations and examples are also provided for crop water requirements and leaching requirements.

SECTION I

GENERAL RECOMMENDATIONS

FOR SOIL MANAGEMENT

SECTION I:
GENERAL RECOMMENDATIONS FOR SOIL MANAGEMENT

Comprehensive soil management goes beyond crop management recommendations to include integrated policy making and the consideration of soil, water resources, food security, and agricultural and general economic development, among others. For any nation to successfully and sustainably manage its natural resources, clear policies are essential.

On a national scale, farm soil resources (soil irrigation suitability) should match available water resources in both quality and quantity. The current soil survey on agricultural farms established a relevant information base that has been linked to, and complements, the EAD UAESIS System for non-agricultural areas.

As it stands, soils with restricted irrigation suitability (insufficient depth, imperfect drainage, high Gypsum or Calcium Carbonate content, topography, coarse texture) are being cultivated while other far more suitable soils are being overlooked. Figure 1 provides an overview of soil irrigation suitability in the Emirate of Abu Dhabi.

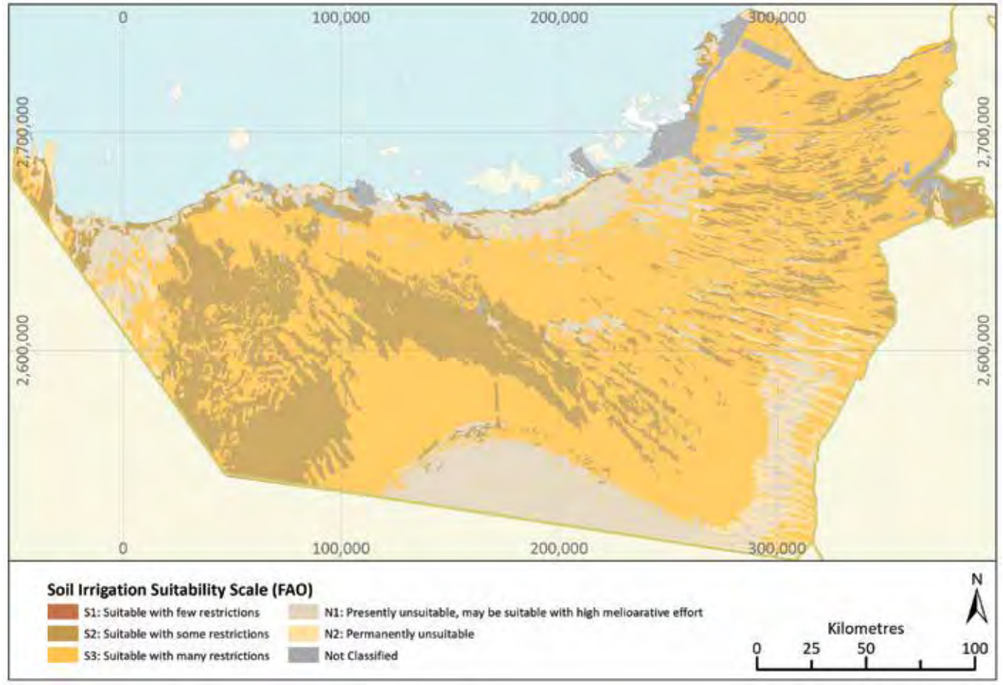


FIGURE 1: Soil Irrigation Suitability in the Emirate of Abu Dhabi

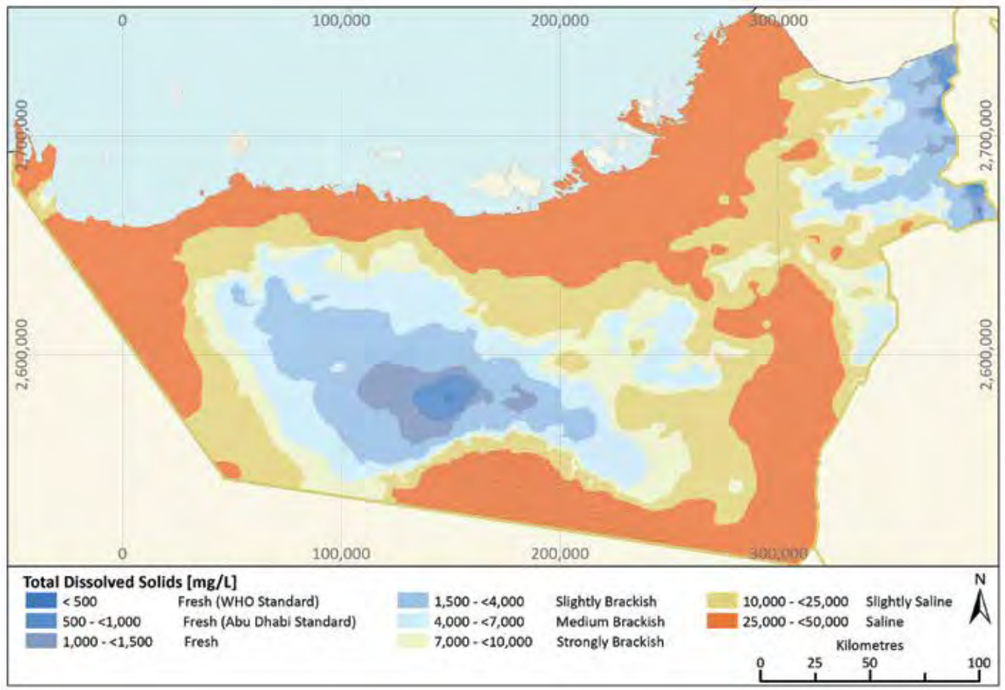


FIGURE 2: Groundwater Salinity in the Emirate of Abu Dhabi

Alternatively, land with suitable characteristics is being rendered useless due to the deterioration of water quality as over-extraction leads the soil to face severe degradation. Figure 2 shows groundwater quality in terms of Total Dissolved Solids.

SUITABLE AGRICULTURAL AREAS CAN BE IDENTIFIED THROUGH THE GROUNDWATER WELL INVENTORY, THE FARM SOIL SALINITY MAP, AND THE UAESIS DATABASE.

However, further water quality parameters and other factors such as infrastructure requirements, accessibility, etc. should be considered for this purpose. Dialogue with ADAFSA and other agricultural stakeholders will also help shape future regional agricultural policies.

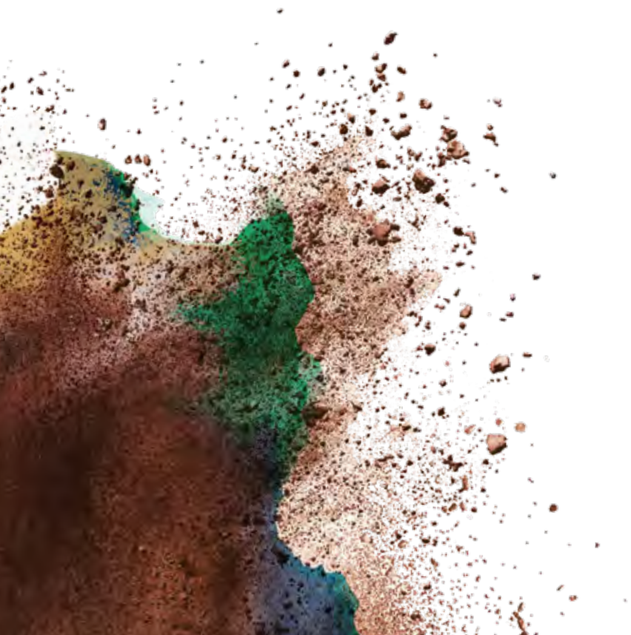
A long-term policy should match good quality water resources to the best available soils (Figure 1, Figure 2) by providing incentives to abandon locations with highly saline water and/or soil resources with severe restrictions. Farm soil survey mapping and UAESIS data from the Soil Map of the Emirate of Abu Dhabi should be leveraged as much as possible to shape future regional agricultural policies.

- Conducting rural planning reviews to determine if good soil resources match good water resources and vice versa.
- Reviewing the suitability of locations with highly saline water and/or soil resources with severe restrictions.
- If practical, reviewing the possibility of relocating agricultural properties and businesses.

FURTHER TO SUCH A POLICY, A STRATEGY TO DIRECT ABU DHABI'S THREE MAIN WATER RESOURCES (GROUNDWATER, DESALINATED WATER AND TREATED SEWAGE EFFLUENT/ TSE) SHOULD BE DEVELOPED TO ENSURE OPTIMAL USE.

For example, well water should be used for salinity resistant crops while desalinated water should be restricted to high value vegetable crops. Treated Sewage Effluent (TSE) use should be actively expanded wherever possible and directed to forestry, ornamentals and fruit trees (date palms) that do not come into direct contact with human consumption.

- In urban and rural planning, additional sewage treatment plants should be made available in proximity to potential users.



- The use of TSE should be enabled close to principal farming areas through a distribution infrastructure.
- TSE should be used for forestry, palm trees, ornamentals, lawn production, sports grounds, etc.
- The use of energy-intensive desalinated water should be encouraged and limited to high-value crops.
- Well water use should be limited to salinity and alkalinity resistant crops.

Furthermore, scientific approaches should be enlisted to improve the reasonable use of soil and water resources: applying water in appropriate quantities according to crop water requirements and leaching needs.

APPROACHES:

- Introducing water metering and allocating water according to climatic Crop Water Requirements.
- Encouraging the use of modern measuring instrumentation (soil EC and humidity) to improve water allocation.
- Supporting modern greenhouse technology, recycled evaporation water, and aquaponics.
- Supporting salinity resistant plant research.
- Continuous Salinity Monitoring.

It should be noted that, due to the elevated cost and energy requirements of desalinated water application, priority should be given in this regard to crops with a high monetary value. Meanwhile, the use of TSE for date palms and ornamentals should be increased, provided there is no direct contact with the water.

Therefore, urban and rural planning should consider placing sewage collection and treatment infrastructures near potential users such as agricultural farms, landscape greenery, and protective forests.

The calculation of Crop Water Requirements based on climatic conditions should be compared with the actual use of irrigation water. When necessary, farmers should be made aware of any excessive use of water. Moreover, modern measuring instruments for measuring soil EC and humidity can be leveraged to optimize irrigation timing and conserve irrigation water. As for modern greenhouse technology, it can be used in combination with desalinated water (recycled evaporation water) and aquaponics, to help reach successful outcomes in a desert environment.

Any management recommendations issued to control salinity and alkalinity need to deal with the principal factors influencing salinity: precipitation, leaching, ascending capillary action of dissolved salts, irrigation management, heavy texture and impermeable layers.

POSSIBLE MANAGEMENT RECOMMENDATIONS INCLUDE:

Using the cooler and wetter seasons to leach out salts accumulated during the summer through dedicated leaching irrigation.

Using the best quality irrigation water available. Soil salinity conditions are linked to the quality of irrigation water. The use of desalinated water should be optimized by applying it to salinity sensitive crops with high market value.

Leveraging crust breaking of the soil surface and mulch covering to prevent capillary action, evaporation and salt deposits on the surface.

Avoiding irrigation beyond crop water requirements during the summer to avoid salt deposition, perched water tables and the capillary rise of salts.

Leveraging the recognized positive effect of organic fertilizers to attenuate the impact of salinity and alkalinity.

For non-saline sodic soils, applying gypsum amendments according to the registered pH.

For annual crops, adopting crop rotation within the farm: leaving a proportion of the surface fallow for some years to give the soil a chance to revert to lower salinity levels.

SECTION 2

SPECIFIC RECOMMENDATIONS

FOR IRRIGATION DISTRICTS

SECTION 2: SPECIFIC RECOMMENDATIONS FOR IRRIGATION DISTRICTS

The below tables (tables 1 to 15) map out farm areas based on their unique combination of soil properties, soil salinity, and the availability of irrigation water, both in terms of quantity and quality. These areas are referred to as Irrigation Districts (Figure 3).

From these particular combinations common and specific restrictions and recommendations for each irrigation district with regard to soil, irrigation, and salinity management are presented.

Each table outlines existing conditions for soil and irrigation water in the relevant irrigation district. It further offers recommendations regarding irrigation, leaching (desalination), crop selection, fertilization, drainage control, alkalinity control, and melioration measure. These recommendations are provided for every major soil unit that makes up the irrigation district. As a rule, soil units covering less than 5% of the surface have been omitted but were still listed for the sake of comprehensiveness.

Section III (1.4) offers a detailed explanation of each existing condition and recommendation.

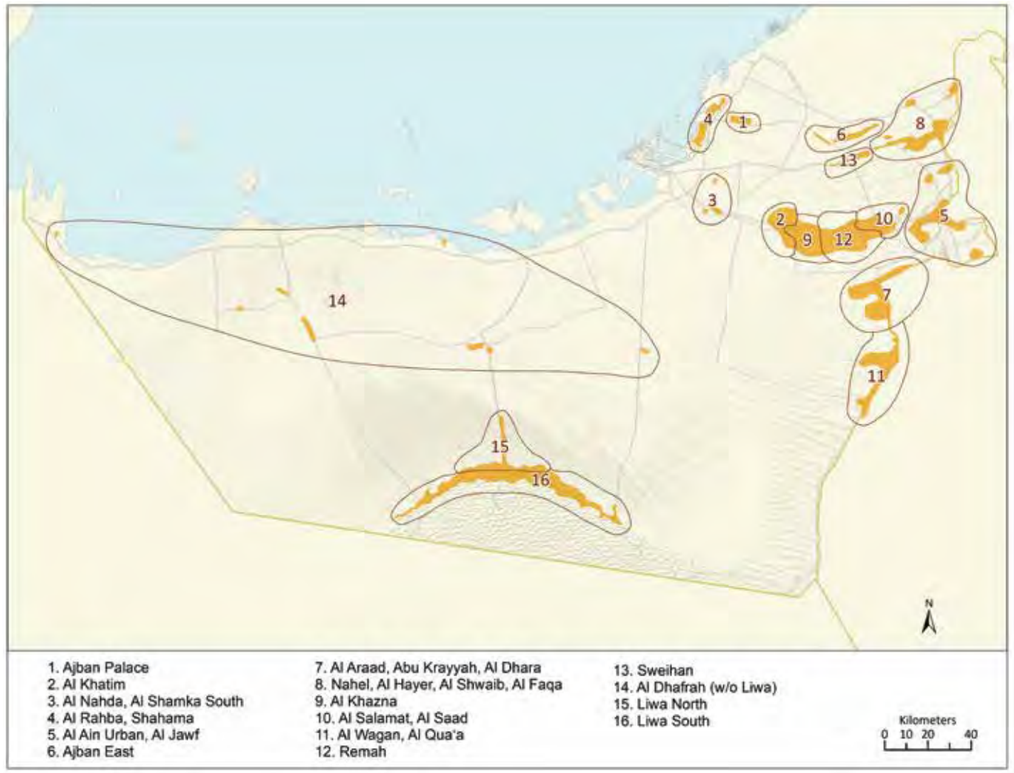


FIGURE 3: Main Irrigation Districts in the Emirate of Abu Dhabi

Ajban Palace

SOIL EXISTING CONDITIONS

Ajban Palace

TEXTURE
Loamy sand

GENERAL CHARACTERISTICS
Calcic/gypsic layers, lithic conditions

ROOTING DEPTH
Limited: 50-100 cm

SALINITY
ECe 2,000-4,000 µS/cm, low to moderate salinity

GROUNDWATER PRESENCE
By leakage or over-irrigation

FERTILITY
Moderate

DRAINAGE
Limited by hardpan/lithic layers

PERMEABILITY
Moderate

IRRIGATION WATER EXISTING CONDITIONS

Ajban Palace

ORIGIN
Desalinated

SALINITY
ECw 1,500 µS/cm, low

SAR
3, low

AVAILABLE QUANTITY
Limited

CURRENT AVERAGE USE M3/IRRIGATED HA
26,000 (estimated), insufficient

TABLE 1: Existing Conditions and Recommendations for Ajban Palace

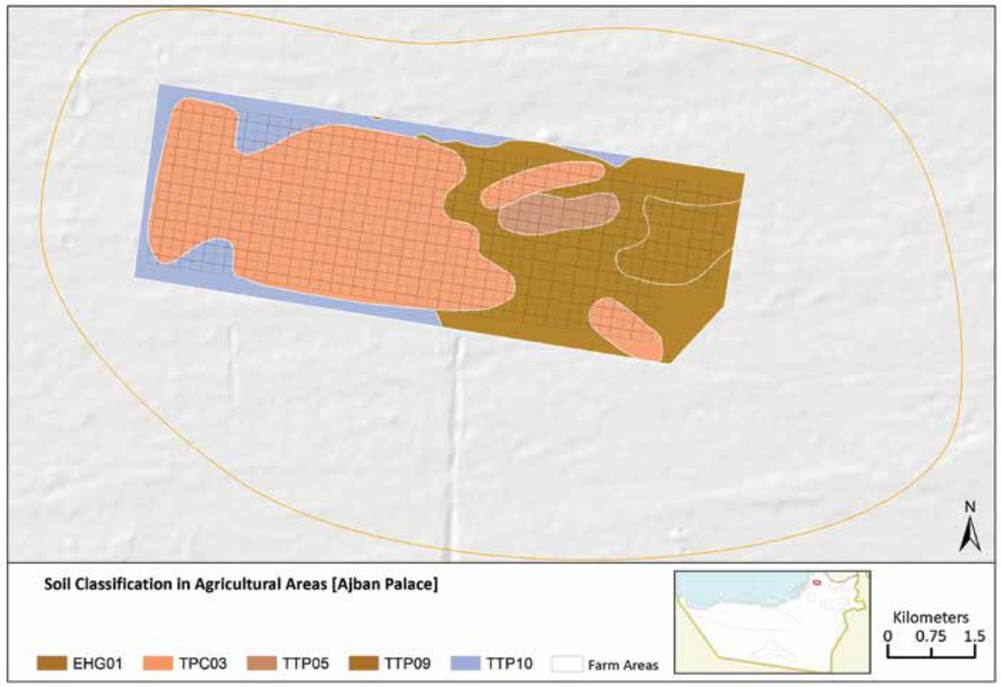


FIGURE 4: Soil Classification in Ajban Palace

Recommendations for Ajban Palace

Map Units	TPC03	TTP09
Total Farm Area	1,464.6 ha 78%	256.9 ha 14%

MAP UNITS	TPC03	TTP09
DESCRIPTION	Lithic Haplocalcids, Typic Haplocalcids, lithic Phase, Typic Petrocalcids consociation, shallow, deflation plain SUITABILITY S3 RESTR 1 m RESTR 2 k RESTR 3	Typic Torripsamments consociation, rolling plain and dunes SUITABILITY S3 RESTR 1 t RESTR 2 m RESTR 3
IRRIGATION	Avoid irrigation beyond crop water requirement: all-year crops with drip irrigation no more than 32,000 m3/ha. Switch from flood irrigation to sprinkler or drip.	Avoid irrigation beyond crop water requirement: all-year crops with drip irrigation no more than 32,000 m3/ha. Switch from flood irrigation to sprinkler or drip.
LEACHING (DESALINATION)	Not needed, only if ECe exceeds 2,000 µS/cm, equivalent to EC (1: 1) 590 µS/cm (local factor: 3.38). Use winter time for leaching.	Not needed, only if ECe exceeds 2,000 µS/cm, equivalent to EC (1: 1) 590 µS/cm (local factor: 3.38). Use winter time for leaching.
CROP SELECTION	Shallow rooting crops, otherwise in respect to salinity, suitable for all crops.	Shallow rooting crops, otherwise in respect to salinity, suitable for all crops
FERTILIZATION	Moderate level	Moderate level
DRAINAGE CONTROL	Avoid irrigation beyond crop water requirement	Avoid irrigation beyond crop water requirement
ALKALINITY CONTROL	Not needed	Not needed
MELIORATION MEASURE	None	None

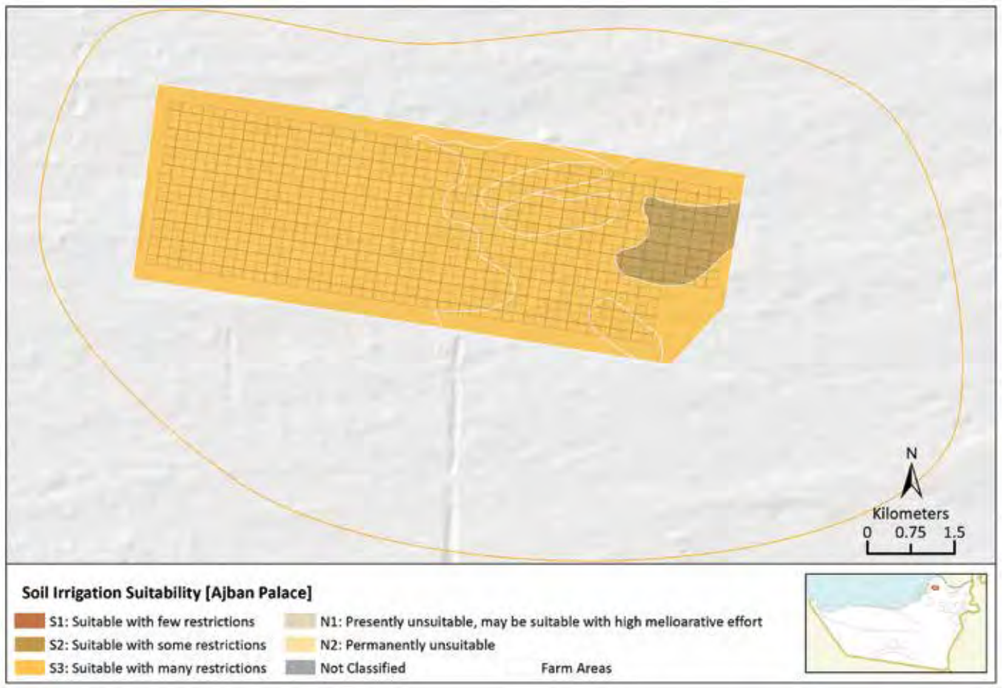


FIGURE 5: Soil Irrigation Suitability in Ajban Palace

Al Khatim

SOIL EXISTING CONDITIONS

Al Khatim

TEXTURE
Sand

GENERAL CHARACTERISTICS
Calcic, gypsic layers

ROOTING DEPTH
>150 cm

SALINITY
ECe 16,000-40,000 µS/cm, strongly saline

GROUNDWATER PRESENCE
None

FERTILITY
Low to moderate

DRAINAGE
Well drained

PERMEABILITY
Good to excessive

IRRIGATION WATER EXISTING CONDITIONS

Al Khatim

ORIGIN
Well water

SALINITY
ECw 18,000 µS/cm, very high

SAR
27, very high

AVAILABLE QUANTITY
Available

CURRENT AVERAGE USE M3/IRRIGATED HA
58,000, high

TABLE 2: Existing Conditions and Recommendations for Al Khatim

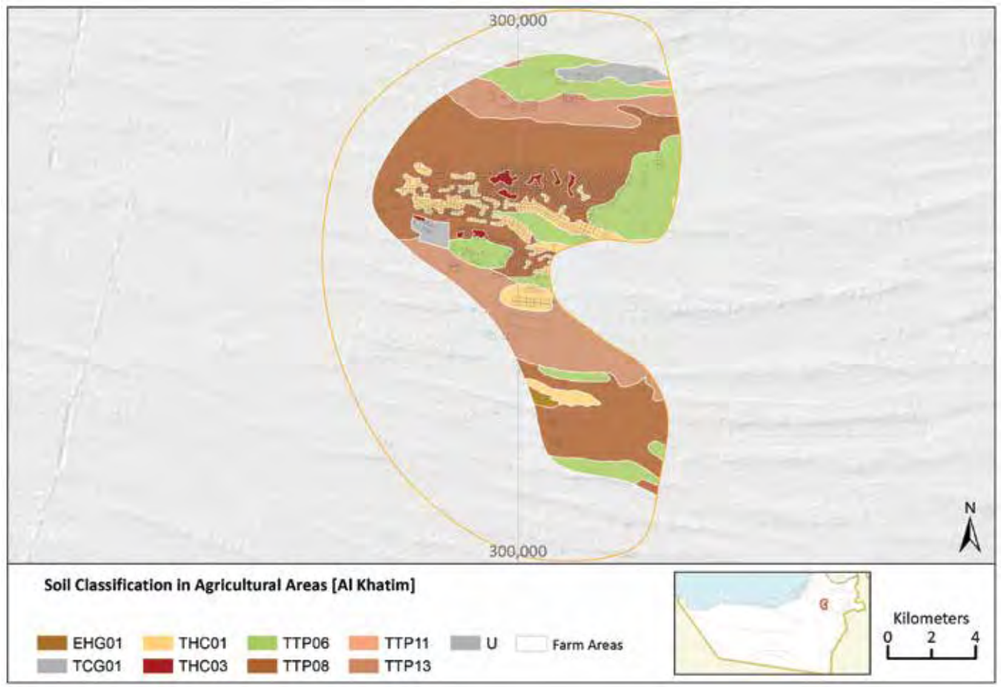


FIGURE 6: Soil Classification in Al Khatim

Recommendations for Al Khatim

Map Units	THC01	TTP08
Total Farm Area	663.6 ha 24%	1,592.8 ha 58%

MAP UNITS	THC01	TTP08
DESCRIPTION	Typic Haplocalcids - Typic Torripsamments association, almost level to gently undulating deflation plain SUITABILITY S2 RESTR 1 k RESTR 2 RESTR 3	Typic Torripsamments consociation, low to moderately high active dunes SUITABILITY S3 RESTR 1 t RESTR 2 z RESTR 3
IRRIGATION	All-year crops with drip irrigation no more than 32,000 m3/ha. Switch from flood irrigation to sprinkler or drip	All-year crops with drip irrigation no more than 32,000 m3/ha. Switch from flood irrigation to sprinkler or drip
LEACHING (DESALINATION)	Target salinity maximum 1.5 x of irrigation water salinity: apply leaching fraction 22% to crop water requirements for drip and sprinkler irrigation. No extra leaching needed for flood irrigation (high percolation losses). Use winter season for leaching.	Target salinity maximum 1.5 x of irrigation water salinity: apply leaching fraction 22% to crop water requirements for drip and sprinkler irrigation. No extra leaching needed for flood irrigation (high percolation losses). Use winter season for leaching
CROP SELECTION	Moderately salinity resistant crops: Alfalfa, Vegetables	Only extremely salt and alkalinity resistant crops: Date Palm, Rhodes Grass, Alfalfa
FERTILIZATION	Moderate level, apply organic fertilizer for binding salinity	Moderate level, apply organic fertilizer for binding salinity
DRAINAGE CONTROL	n.a.	n.a.
ALKALINITY CONTROL	Gypsum soil amendments when using desalinated water	Gypsum soil amendments when using desalinated water
MELIORATION MEASURE	None	Desalination plant

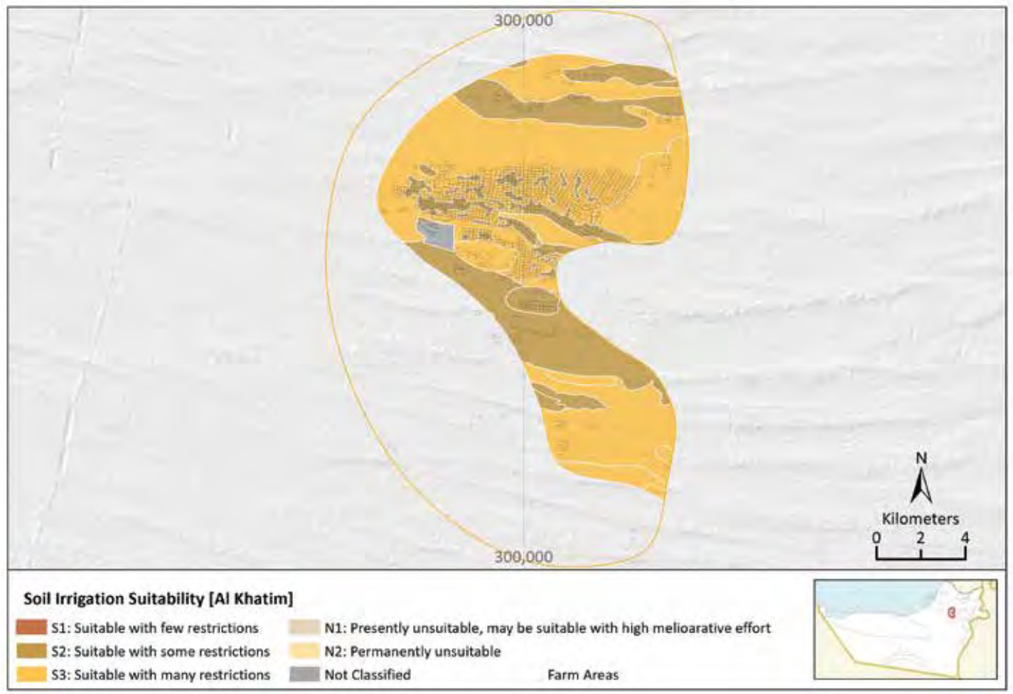


FIGURE 7: Soil Irrigation Suitability in Al Khatim

Al Nahda, Al Shamka South

SOIL EXISTING CONDITIONS

Al Nahda, Al Shamka South

TEXTURE
Sand

GENERAL CHARACTERISTICS
Calcic, gypsic layers

ROOTING DEPTH
>150 cm

SALINITY
ECe 2,000-8,000 µS/cm, low to moderate salinity

GROUNDWATER PRESENCE
By leakage or over-irrigation

FERTILITY
Low to moderate

DRAINAGE
Well drained

PERMEABILITY
Good to excessive

IRRIGATION WATER EXISTING CONDITIONS

Al Nahda, Al Shamka South

ORIGIN
Desalinated

SALINITY
ECw 3,300 µS/cm, low

SAR
8, medium

AVAILABLE QUANTITY
Available

CURRENT AVERAGE USE M3/IRRIGATED HA
27,000 (estimated), insufficient

TABLE 3: Existing Conditions and Recommendations for Al Nahda, Al Shamka South

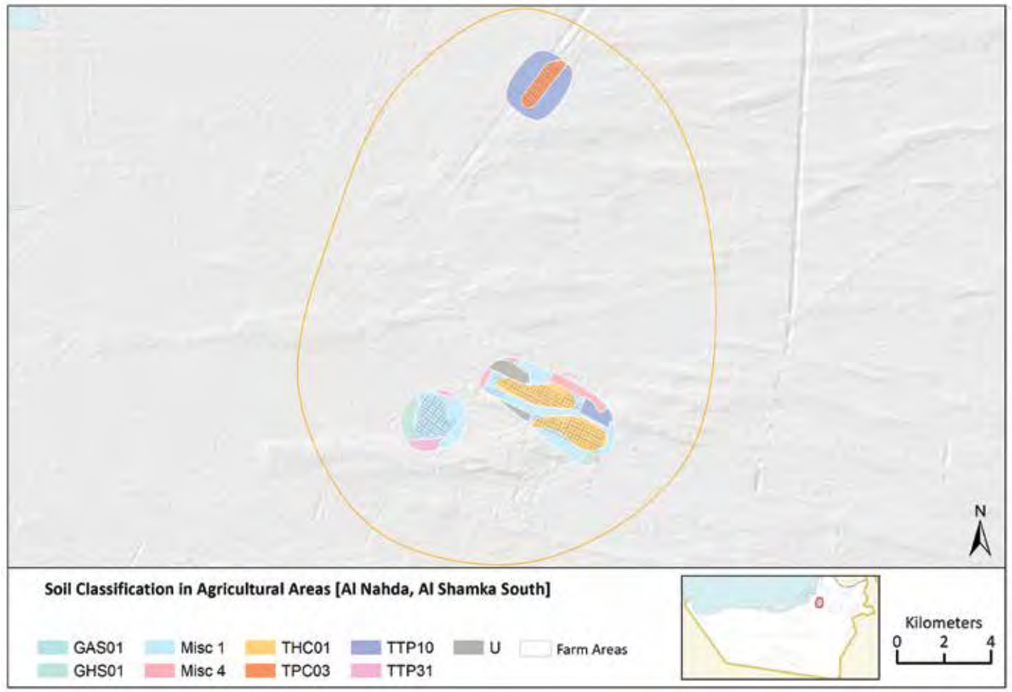


FIGURE 8: Soil Classification in Al Nahda, Al Shamka South

Recommendations for Al Nahda, Al Shamka South

Map Units	MISC 1	THC01	TPC03
Total Farm Area	221.7 ha 31%	351.3 ha 50%	124.5 ha 18%

MAP UNITS	MISC 1	THC01	TPC03
DESCRIPTION	Re-filled	Typic Haplocalcids - Typic Torripsamments association, almost level to gently undulating deflation plain SUITABILITY S2 RESTR 1 k RESTR 2 RESTR 3	Typic Haplocalcids - Typic Torripsamments association, almost level to gently undulating deflation plain SUITABILITY S3 RESTR 1 m RESTR 2 k RESTR 3
IRRIGATION	Non-classified	All-year crops with drip irrigation no more than 32,000 m3/ha. Switch from flood irrigation to sprinkler or drip	All-year crops with drip irrigation no more than 32,000 m3/ha. Switch from flood irrigation to sprinkler or drip
LEACHING (DESALINATION)		Not needed, only if ECe exceeds 2,000 µS/cm, equivalent to EC (1: 1) 580 µS/cm (local factor: 3.46). Use winter season for leaching	Not needed, only if ECe exceeds 2,000 µS/cm, equivalent to EC (1: 1) 580 µS/cm (local factor: 3.46). Use winter season for leaching
CROP SELECTION		In respect to salinity, suitable for all crops	Shallow rooting crops, otherwise in respect to salinity, suitable for all crops
FERTILIZATION		Moderate level	Moderate level
DRAINAGE CONTROL		n.a.	n.a.
ALKALINITY CONTROL		Not needed	Not needed
MELIORATION MEASURE		None	None

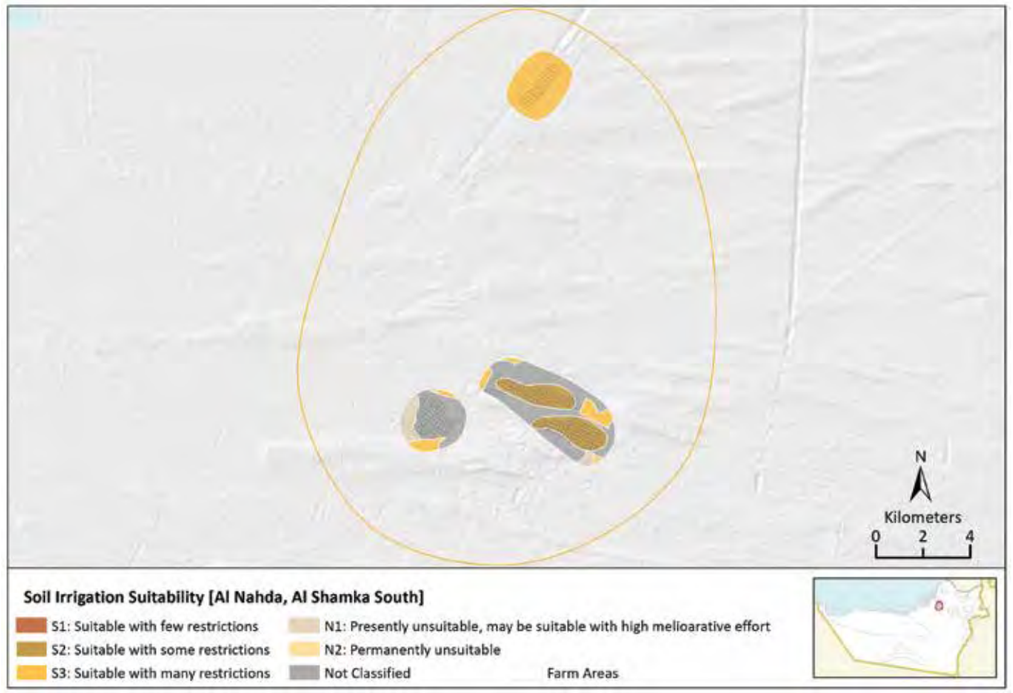


FIGURE 9: Soil Irrigation Suitability in Al Nahda, Al Shamka South

Al Rahba, Shahama

SOIL EXISTING CONDITIONS

Al Rahba, Shahama

TEXTURE
Loamy sand

GENERAL CHARACTERISTICS
Calcic/gypsic layers, lithic conditions

ROOTING DEPTH
50-100 cm

SALINITY
ECe 200-4,000 µS/cm, slightly saline

GROUNDWATER PRESENCE
By leakage or over-irrigation

FERTILITY
Moderate

DRAINAGE
Limited by hardpan/lithic layers

PERMEABILITY
Moderate

IRRIGATION WATER EXISTING CONDITIONS

Al Rahba, Shahama

ORIGIN
Desalinated

SALINITY
ECw 200 µS/cm, low

SAR
12, medium

AVAILABLE QUANTITY
Limited

CURRENT AVERAGE USE M3/IRRIGATED HA
26,000 (estimated), insufficient

TABLE 4: Existing Conditions and Recommendations for Al Rahba, Shahama

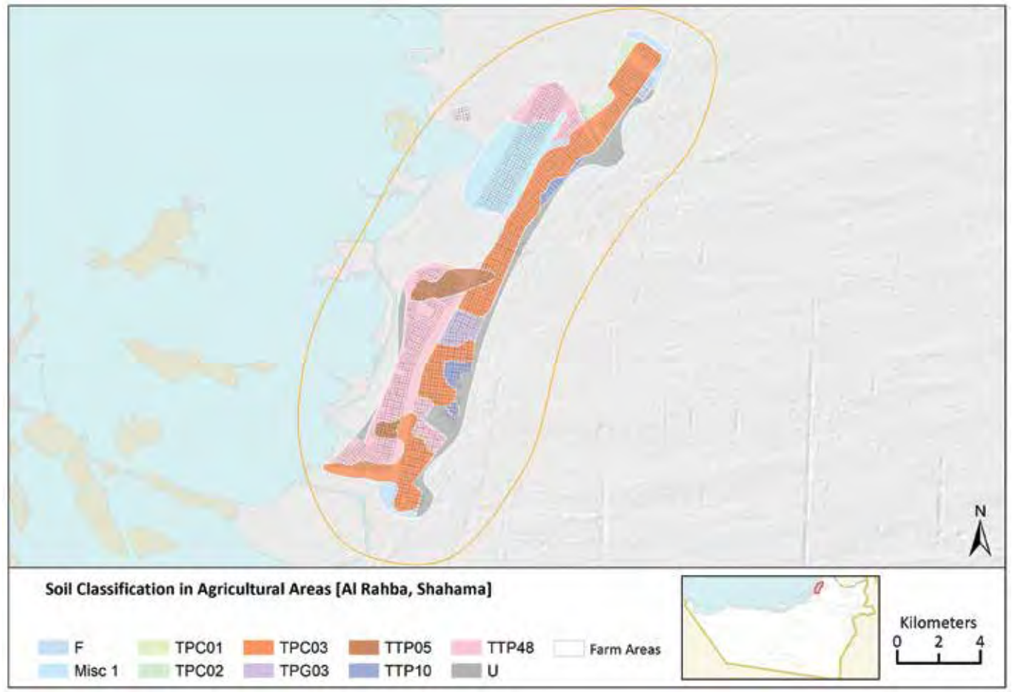


FIGURE 10: Soil Classification in Al Rahba, Shahama

Recommendations for Al Rahba, Shahama

Map Units	TPC03
Total Farm Area	2,144.0 ha 54%

MAP UNITS	TPC03
DESCRIPTION	Typic Haplocalcids, lithic phase, Typic Petrocalcids SUITABILITY S3 · RESTR 1 m · RESTR 2 k · RESTR 3
IRRIGATION	Avoid irrigation beyond crop water requirement. All-year crops with drip irrigation no more than 32,000 m3/ha. Switch from flood irrigation to sprinkler or drip.
LEACHING (DESALINATION)	Not needed, only if ECe exceeds 2,000 pS/cm, equivalent to EC (1:1) 560 pS/cm (local factor: 3.54). Use winter season for leaching
CROP SELECTION	Shallow rooting depths, otherwise in respect to salinity suitable for all crops. Avoid citrus, nuts avocado and other alkalinity susceptible crops.
FERTILIZATION	Moderate level
DRAINAGE CONTROL	Avoid irrigation beyond crop water requirement
ALKALINITY CONTROL	Not needed, avoid susceptible crops
MELIORATION MEASURE	None

Map Units	TTP05	TTP48
Total Farm Area	330.7 ha 8%	997.7 ha 25%

MAP UNITS	TTP05	TTP48
DESCRIPTION	Typic Torripsamments - Typic Aquisalids - Typic Haplosalids - Gypsic Haplosalids complex, gently undulating to rolling plains **SUITABILITY** S3 **RESTR 1** w **RESTR 2** z **RESTR 3**	Typic Torripsamments consociation, rolling plain and dunes **SUITABILITY** S2 **RESTR 1** t **RESTR 2** **RESTR 3**
IRRIGATION	Avoid irrigation beyond crop water requirement: all-year crops with drip irrigation no more than 32,000 m3/ha. Switch from flood irrigation to sprinkler or drip.	Avoid irrigation beyond crop water requirement: all-year crops with drip irrigation no more than 32,000 m3/ha. Switch from flood irrigation to sprinkler or drip
LEACHING (DESALINATION)	Not needed, only if ECe exceeds 2,000 µS/cm, equivalent to EC (1: 1) 560 µS/cm (local factor: 3.54). Use winter time for leaching.	Not needed, only if ECe exceeds 2,000 pS/cm, equivalent to EC (1: 1) 560 µS/cm (local factor: 3.54). Use winter time for leaching
CROP SELECTION	In respect to salinity suitable for all crops. Avoid citrus, nuts avocado and other alkalinity susceptible crops.	In respect to salinity suitable for all crops. Avoid citrus, nuts avocado and other alkalinity susceptible crops.
FERTILIZATION	Moderate level	Small but frequent doses
DRAINAGE CONTROL	Avoid irrigation beyond crop water requirement, improve drainage (ditches, underground pipe drainage)	Avoid irrigation beyond crop water requirement
ALKALINITY CONTROL	Not needed, avoid susceptible crops	Not needed, avoid susceptible crops
MELIORATION MEASURE	None	None

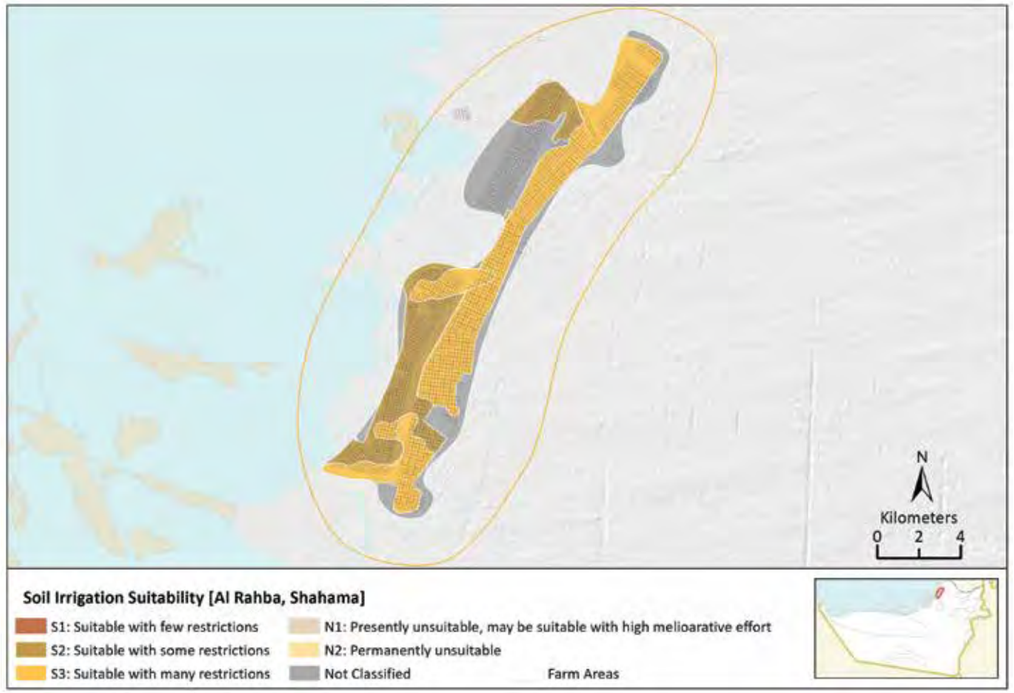


FIGURE 11: Soil Irrigation Suitability in Al Rahba, Shahama

Al Ain Urban, Al Jawf

SOIL EXISTING CONDITIONS

Al Ain Urban, Al Jawf

TEXTURE
Loamy sand

GENERAL CHARACTERISTICS
Calcic/gypsic layers, wadi gravels

ROOTING DEPTH
>150 cm

SALINITY
ECe 2,000-8,000 µS/cm, low to moderate salinity

GROUNDWATER PRESENCE
By leakage or over-irrigation

FERTILITY
Moderate to good

DRAINAGE
Moderate to good

PERMEABILITY
Good

IRRIGATION WATER EXISTING CONDITIONS

Al Ain Urban, Al Jawf

ORIGIN
Well water, falaj

SALINITY
ECw 5,000 µS/cm, medium

SAR
7, low

AVAILABLE QUANTITY
Available

CURRENT AVERAGE USE M3/IRRIGATED HA
28,000, insufficient

TABLE 5: Existing Conditions and Recommendations for Al Ain Urban, Al Jawf

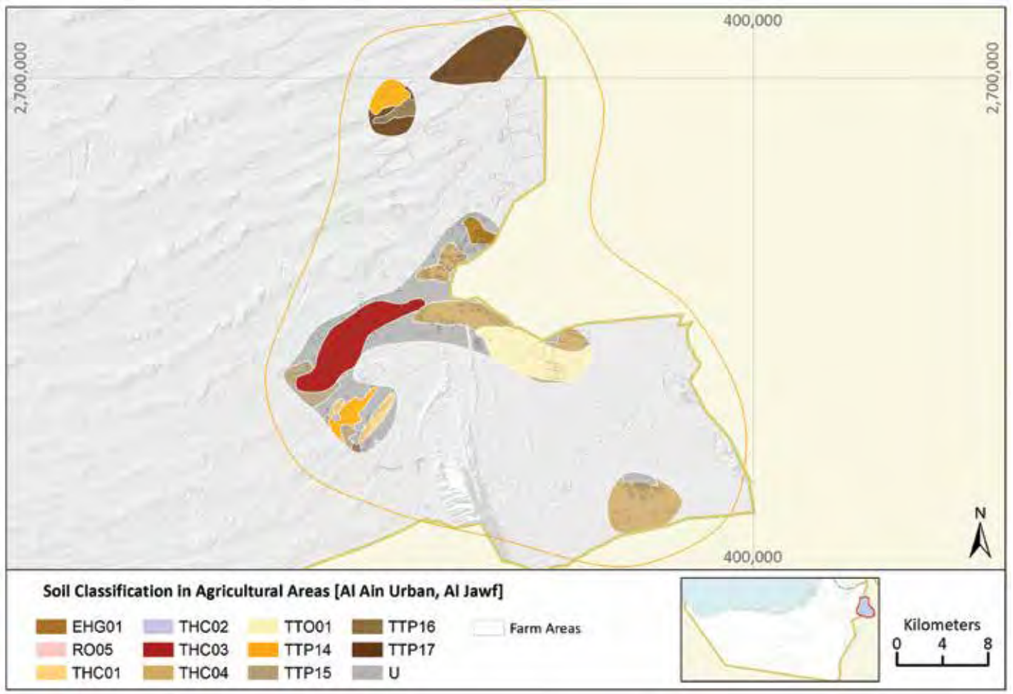
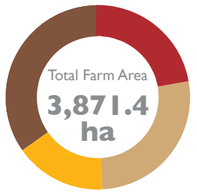


FIGURE 12: Soil Classification in Al Ain Urban, Al Jawf

Recommendations for Al Ain Urban, Al Jawf



Map Units	THC03	THC04
Total Farm Area	594.4 ha 15%	811.1 ha 21%

MAP UNITS	THC03	THC04
DESCRIPTION	Typic Haplocalcids - Typic Calcigypsids complex, deflation plains and low dunes **SUITABILITY** S2 **RESTR 1** k **RESTR 2** **RESTR 3**	Typic Haplocalcids, Typic Haplocambids, alluvial deposits **SUITABILITY** S2 **RESTR 1** k **RESTR 2** **RESTR 3**
IRRIGATION	All-year crops with drip irrigation no more than 36,000 m3/ha. Switch from flood irrigation to sprinkler or drip.	All-year crops with drip irrigation no more than 36,000 m3/ha. Switch from flood irrigation to sprinkler or drip.
LEACHING (DESALINATION)	Target salinity maximum 1.5x of irrigation water salinity, apply leaching 31% above the crop water requirements (drip irrigation). No extra leaching needed for flood irrigation (high percolation losses). Use winter season for leaching	Target salinity maximum 1.5x of irrigation water salinity, apply leaching 31% above the crop water requirements (drip irrigation). No extra leaching needed for flood irrigation (high percolation losses). Use winter season for leaching
CROP SELECTION	Moderately salinity resistant crops: alfalfa, vegetables	Moderately salinity resistant crops: alfalfa, vegetables
FERTILIZATION	High level to achieve optimum yields	Low but frequent doses
DRAINAGE CONTROL	Avoid irrigation beyond crop water requirement	Avoid irrigation beyond crop water requirement
ALKALINITY CONTROL	Not needed, avoid susceptible crops	Not needed, avoid susceptible crops
MELIORATION MEASURE	None	Ground levelling

Map Units	TTP14	TTP17
Total Farm Area	298.6 ha 8%	585.3 ha 15%

MAP UNITS	TTP14	TTP17
DESCRIPTION	Typic Torripsamments consociation, rolling to steep low hills SUITABILITY S3 · RESTR 1 r · RESTR 2 t · RESTR 3	Typic Torripsamments consociation, rolling to steep mixed dunes SUITABILITY S3 · RESTR 1 r · RESTR 2 t · RESTR 3
IRRIGATION	All-year crops with drip irrigation no more than 36,000 m3/ha. Switch from flood irrigation to sprinkler or drip.	All-year crops with drip irrigation no more than 36,000 m3/ha. Switch from flood irrigation to sprinkler or drip.
LEACHING (DESALINATION)	Target salinity maximum 1.5x of irrigation water salinity, apply leaching 31% above the crop water requirements (drip irrigation). No extra leaching needed for flood irrigation (high percolation losses). Use winter season for leaching	Target salinity maximum 1.5x of irrigation water salinity, apply leaching 31% above the crop water requirements (drip irrigation). No extra leaching needed for flood irrigation (high percolation losses). Use winter season for leaching
CROP SELECTION	Moderately salinity resistant crops: alfalfa, vegetables	Moderately salinity resistant crops: alfalfa, vegetables
FERTILIZATION	Low but frequent doses	Low but frequent doses
DRAINAGE CONTROL	None	None
ALKALINITY CONTROL	Not needed, avoid susceptible crops	Not needed, avoid susceptible crops
MELIORATION MEASURE	Ground levelling	Ground levelling

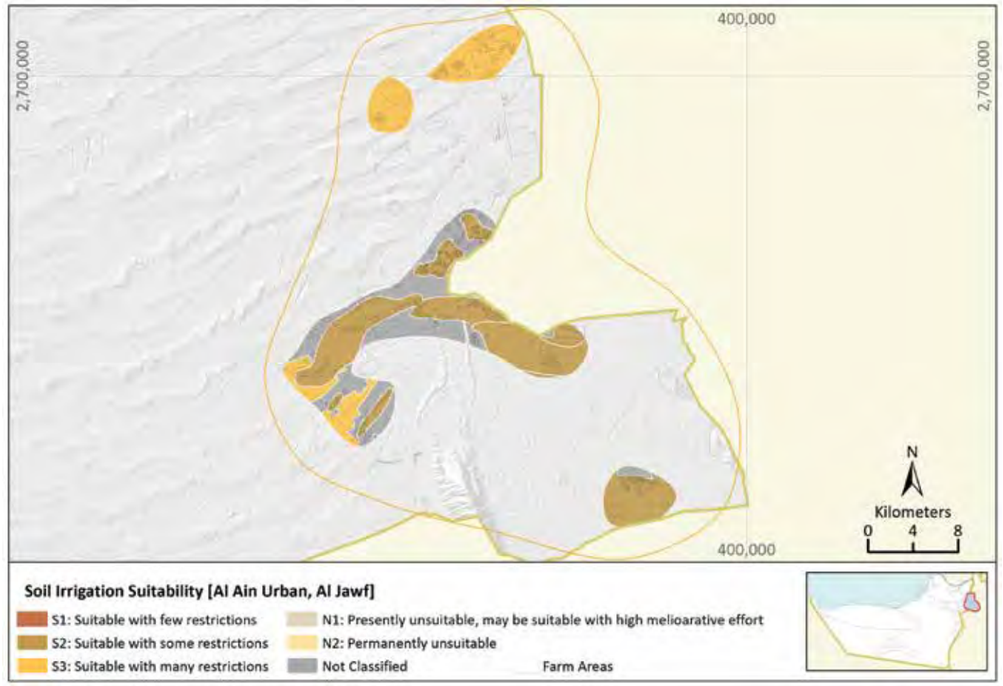


FIGURE 13: Soil Irrigation Suitability in Al Ain Urban, Al Jawf

Ajban East

SOIL EXISTING CONDITIONS

Ajban East

TEXTURE
Loamy sand

GENERAL CHARACTERISTICS
Petrogypsic, petrocalcic layers

ROOTING DEPTH
80 - 120 cm

SALINITY
ECe 8,000-40,000 µS/cm, medium to strongly saline

GROUNDWATER PRESENCE
By leakage or over-irrigation

FERTILITY
Moderate

DRAINAGE
Limited by hardpan

PERMEABILITY
Moderate

IRRIGATION WATER EXISTING CONDITIONS

Ajban East

ORIGIN
Well water

SALINITY
ECw 15,500 µS/cm, high

SAR
22, very high

AVAILABLE QUANTITY
Available

CURRENT AVERAGE USE M3/IRRIGATED HA
71,000, excessive

TABLE 6: Existing Conditions and Recommendations for Ajban East

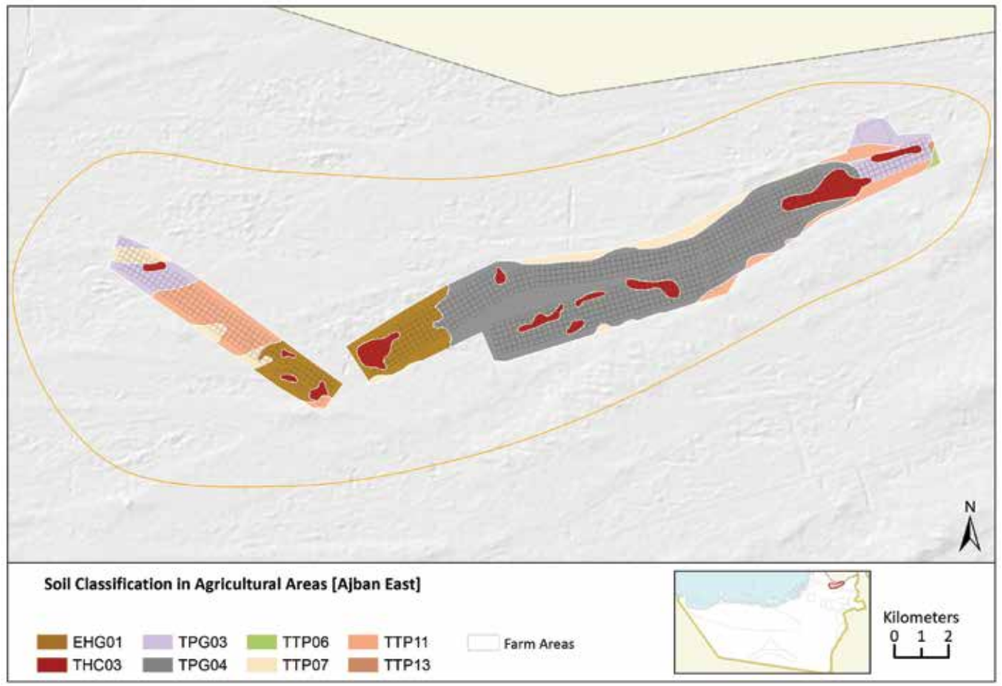


FIGURE 14: Soil Classification in Ajban East

Recommendations for Ajban East

Map Units	EHG01	THC03
Total Farm Area	389.3 ha 11%	506.9 ha 15%

MAP UNITS	EHG01	THC03
DESCRIPTION	Leptic Haplogypsids - Typic Torripsamments - Typic Petrogypsids complex, level to gently undulating inland plains **SUITABILITY** S2 **RESTR 1** y **RESTR 2** **RESTR 3**	Typic Haplocalcids - Typic Calcigypsids complex, deflation plains and low dunes **SUITABILITY** S2 **RESTR 1** k **RESTR 2** **RESTR 3**
IRRIGATION	All-year crops with drip irrigation no more than 36,000 m3/ha. Switch from flood irrigation to sprinkler or drip	All-year crops with drip irrigation no more than 36,000 m3/ha. Switch from flood irrigation to sprinkler or drip
LEACHING (DESALINATION)	Target salinity maximum 1.5 x of irrigation water salinity: apply leaching fraction 19% to crop water requirements for drip and sprinkler irrigation. No extra leaching needed for flood irrigation (high percolation losses). Use winter season for leaching	Target salinity maximum 1.5 x of irrigation water salinity: apply leaching fraction 19% to crop water requirements for drip and sprinkler irrigation. No extra leaching needed for flood irrigation (high percolation losses). Use winter season for leaching
CROP SELECTION	Moderately salinity resistant crops: alfalfa, vegetables	Moderately salinity resistant crops: alfalfa, vegetables
FERTILIZATION	Moderate level, apply organic fertilizer for binding salinity	Moderate level, apply organic fertilizer for binding salinity
DRAINAGE CONTROL	Avoid irrigation beyond crop water requirement	Avoid irrigation beyond crop water requirement
ALKALINITY CONTROL		Gypsum soil amendments when using desalinated water
MELIORATION MEASURE	Desalination plant	Desalination plant

Map Units	TPG04	TTP11
Total Farm Area	1,990.3 ha 59%	260.8 ha 8%

MAP UNITS	TPG04	TTP11
DESCRIPTION	Typic Petrogypsids - Leptic Haplogypsids - Typic Torripsamments complex, almost level to gently undulating SUITABILITY S3 RESTR 1 m RESTR 2 y RESTR 3	Typic Torripsamments consociation, low dunes and sand plains SUITABILITY S2 RESTR 1 t RESTR 2 z RESTR 3
IRRIGATION	All-year crops with drip irrigation no more than 36,000 m3/ha. Switch from flood irrigation to sprinkler or drip	All-year crops with drip irrigation no more than 36,000 m3/ha. Switch from flood irrigation to sprinkler or drip
LEACHING (DESALINATION)	Target salinity maximum 1.5 x of irrigation water salinity: apply leaching fraction 19% to crop water requirements for drip and sprinkler irrigation. No extra leaching needed for flood irrigation (high percolation losses). Use winter season for leaching	Target salinity maximum 1.5 x of irrigation water salinity: apply leaching fraction 19% to crop water requirements for drip and sprinkler irrigation. No extra leaching needed for flood irrigation (high percolation losses). Use winter season for leaching
CROP SELECTION	Only shallow rooting and extremely salt and alkalinity resistant crops:, Rhodes grass, Alfalfa	Salinity resistant crops: alfalfa, vegetables
FERTILIZATION	Moderate level, apply organic fertilizer for binding salinity	Moderate level, apply organic fertilizer for binding salinity
DRAINAGE CONTROL	Mid irrigation beyond crop water requirement	
ALKALINITY CONTROL		Gypsum soil amendments when using desalinated water
MELIORATION MEASURE	Breaking of hardpan, desalination plant	Desalination plant

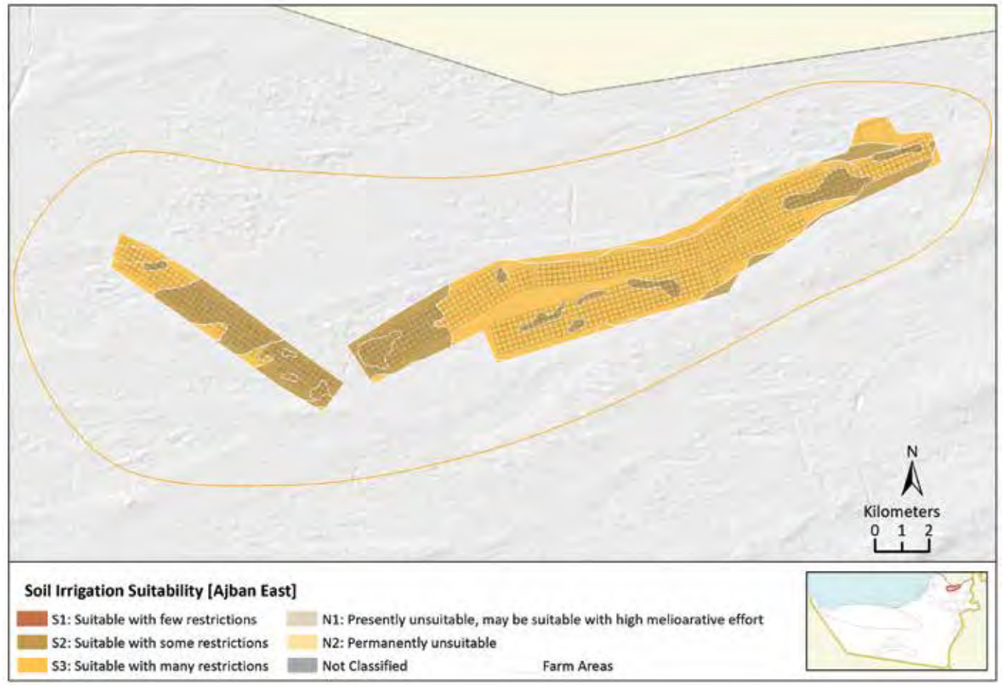


FIGURE 15: Soil Classification in Ajban East

Al Araad, Abu Krayyah, Al Dhahra

SOIL EXISTING CONDITIONS

Al Araad, Abu Krayyah, Al Dhahra

TEXTURE
Sand

GENERAL CHARACTERISTICS
Levelled dunes

ROOTING DEPTH
>150 cm

SALINITY
ECe 8,000-40,000 µS/cm, medium to strongly saline

GROUNDWATER PRESENCE
Absent

FERTILITY
Low

DRAINAGE
Excessive

PERMEABILITY
Very good

IRRIGATION WATER EXISTING CONDITIONS

Al Araad, Abu Krayyah, Al Dhahra

ORIGIN
Well water

SALINITY
ECw 13,000 µS/cm, high

SAR
18, high

AVAILABLE QUANTITY
Available

CURRENT AVERAGE USE M3/IRRIGATED HA
33,000, slightly insufficient

TABLE 7: Existing Conditions and Recommendations for Al Araad, Abu Krayyah, Al Dhahra

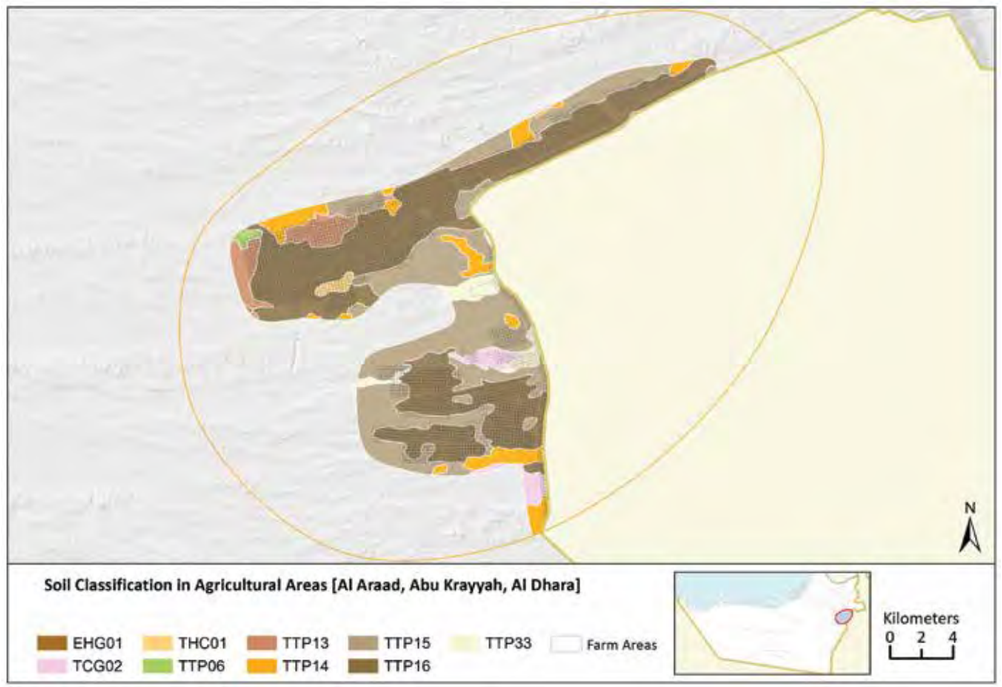


FIGURE 16: Soil Classification in Al Araad, Abu Krayyah, Al Dhahra

Recommendations for Al Araad, Abu Krayyah, Al Dhahra

Map Units	TTP15	TTP16
Total Farm Area	1,093 ha 11%	8,076.2 ha 78%

MAP UNITS	TTP15	TTP16
DESCRIPTION	Typic Torripsamments consociation, rolling to steep barchanoid dunes SUITABILITY S3 RESTR 1 r RESTR 2 t RESTR 3 z	Typic Torripsamments consociation, rolling to steep barchanoid dunes SUITABILITY S3 RESTR 1 r RESTR 2 t RESTR 3 z
IRRIGATION	Irrigation not above 36,000 m3/h for all year crops with drip irrigation. Switch from flood irrigation to sprinkler or drip	Irrigation not above 36,000 m3/h for all year crops with drip irrigation. Switch from flood irrigation to sprinkler or drip
LEACHING (DESALINATION)	Not needed with regular irrigation	Not needed with regular irrigation
CROP SELECTION	Only extremely salt and alkalinity resistant crops: Date Palm, Rhodes grass, Alfalfa	Only extremely salt and alkalinity resistant crops: Date Palm, Rhodes grass, Alfalfa
FERTILIZATION	Low fertilizer quantities in frequent doses, organic fertilizer	Low fertilizer quantities in frequent doses, organic fertilizer
DRAINAGE CONTROL	Not needed	Not needed
ALKALINITY CONTROL	Gypsum soil amendments when using desalinated water	Gypsum soil amendments when using desalinated water
MELIORATION MEASURE	Compost/manure, desalination plant	Compost/manure, desalination plant

FIGURE 17: Soil Irrigation Suitability in Al Araad, Abu Krayyah, Al Dhahra

Al Hayer, Nahel town, Al Shwaib, Al Faqa

SOIL EXISTING CONDITIONS

Al Hayer, Nahel town, Al Shwaib, Al Faqa

TEXTURE
Sand

GENERAL CHARACTERISTICS
Levelled dunes

ROOTING DEPTH
>150 cm

SALINITY
ECe 2,000-4,000 µS/cm, slightly saline

GROUNDWATER PRESENCE
Absent

FERTILITY
Low

DRAINAGE
Excessive

PERMEABILITY
Very good

IRRIGATION WATER EXISTING CONDITIONS

Al Hayer, Nahel town, Al Shwaib, Al Faqa

ORIGIN
Well water

SALINITY
ECw 4,000 µS/cm, low to medium

SAR
7, low

AVAILABLE QUANTITY
Limited

CURRENT AVERAGE USE M3/IRRIGATED HA
26,000, insufficient

TABLE 8: Existing Conditions and Recommendations for Al Hayer, Nahel town, Al Shwaib, Al Faqa

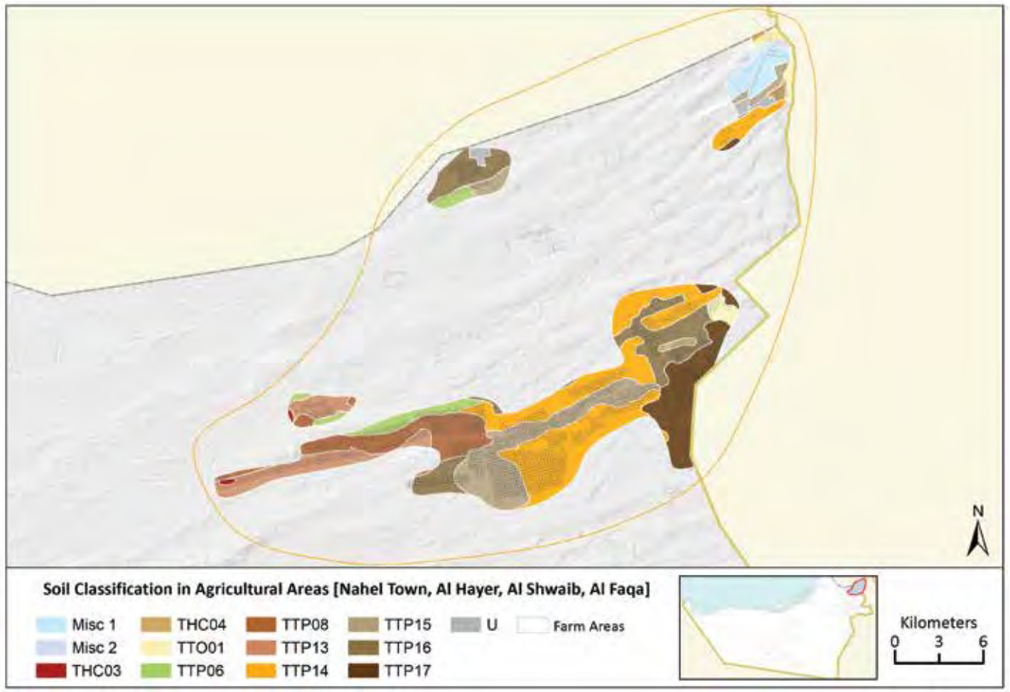


FIGURE 18: Soil Classification in Al Hayer, Nahel town, Al Shwaib, Al Faqa

Recommendations for Al Hayer, Nahel town, Al Shwaib, Al Faqa

Map Units	TTP08	TTP13	TTP14
Total Farm Area	962.2 ha 12%	599.2 ha 7%	2,037.4 ha 25%

MAP UNITS	TTP08	TTP13	TTP14
DESCRIPTION	Typic Torripsamments consociation, low to moderately high active dunes **SUITABILITY** S3 **RESTR 1** t **RESTR 2** z **RESTR 3**	Typic Torripsamments consociation, low dunes and inland plains **SUITABILITY** S2 **RESTR 1** t **RESTR 2** **RESTR 3**	Typic Torripsamments consociation, rolling to steep low hills **SUITABILITY** S3 **RESTR 1** r **RESTR 2** t **RESTR 3**
IRRIGATION	Due to lack of water apply to high value crops only. For drip irrigation of all year crops do not exceed 36,000 m3/ha. Switch from flood irrigation to sprinkler or drip	Due to lack of water apply to high value crops only. For drip irrigation of all year crops do not exceed 36,000 m3/ha. Switch from flood irrigation to sprinkler or drip	Due to lack of water apply to high value crops only. For drip irrigation of all year crops do not exceed 36,000 m3/ha. Switch from flood irrigation to sprinkler or drip
LEACHING (DESALINATION)	Not needed with regular irrigation	Not needed with regular irrigation	Not needed with regular irrigation
CROP SELECTION	Salinity resistant crops: vegetables	Moderately salinity resistant crops: vegetables, tomato, cucumber	Moderately salinity resistant crops: vegetables, tomato, cucumber
FERTILIZATION	Low fertilizer quantities in frequent doses, organic fertilizer	Low fertilizer quantities in frequent doses, organic fertilizer	Low fertilizer quantities in frequent doses, organic fertilizer
DRAINAGE CONTROL	Not needed	Not needed	Not needed
ALKALINITY CONTROL	Not needed, avoid susceptible crops	Not needed, avoid susceptible crops	Not needed, avoid susceptible crops
MELIORATION MEASURE	Compost/manure	Compost/manure	Compost/manure, ground levelling

Map Units	TTP15	TTP16	TTP17
Total Farm Area	1,737.1 ha 21%	1,047.0 ha 13%	547.7 ha 7%

MAP UNITS	TTP15	TTP16	TTP17
DESCRIPTION	Typic Torripsamments consociation, rolling to steep barchanoid dunes SUITABILITY S3 RESTR 1 r RESTR 2 t RESTR 3 z	Typic Torripsamments consociation, rolling rises and flats SUITABILITY S3 RESTR 1 r RESTR 2 t RESTR 3 z	Typic Torripsamments consociation, low to moderately high active dunes SUITABILITY S3 RESTR 1 r RESTR 2 t RESTR 3
IRRIGATION	Due to lack of water apply to high value crops only. For drip irrigation of all year crops do not exceed 36,000 m3/ha. Switch from flood irrigation to sprinkler or drip	Due to lack of water apply to high value crops only. For drip irrigation of all year crops do not exceed 36,000 m3/ha. Switch from flood irrigation to sprinkler or drip	Due to lack of water apply to high value crops only. For drip irrigation of all year crops do not exceed 36,000 m3/ha. Switch from flood irrigation to sprinkler or drip
LEACHING (DESALINATION)	Not needed with regular irrigation	Not needed with regular irrigation	Not needed with regular irrigation
CROP SELECTION	Salinity resistant crops: vegetables	Salinity resistant crops: vegetables	Moderately salinity resistant crops: vegetables, tomato, cucumber
FERTILIZATION	Low fertilizer quantities in frequent doses, organic fertilizer	Low fertilizer quantities in frequent doses, organic fertilizer	Low fertilizer quantities in frequent doses, organic fertilizer
DRAINAGE CONTROL	Not needed	Not needed	Not needed
ALKALINITY CONTROL	Not needed, avoid susceptible crops	Not needed, avoid susceptible crops	Not needed, avoid susceptible crops
MELIORATION MEASURE	Compost/manure, ground levelling	Compost/manure	Compost/manure, ground levelling

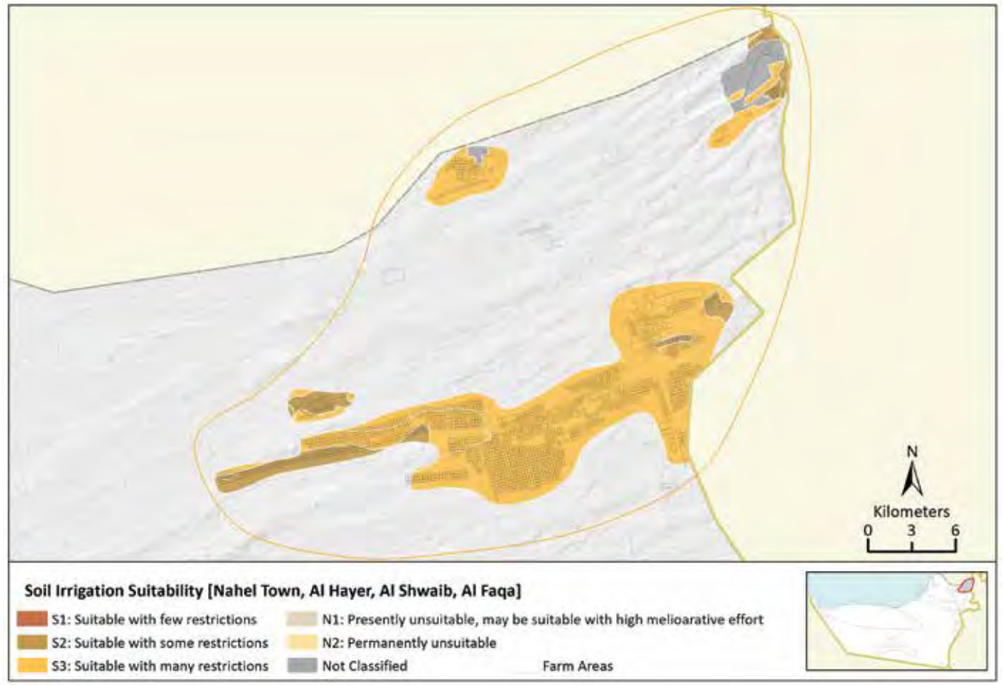


FIGURE 19: Soil Irrigation Suitability in Nahel Town, Al Hayer, Al Shwaib, Al Faqa

Al Khazna

SOIL EXISTING CONDITIONS

Al Khazna

TEXTURE
Sand

GENERAL CHARACTERISTICS
Calcic, gypsic layers

ROOTING DEPTH
>150 cm

SALINITY
ECe 4,000-8,000 µS/cm, moderate salinity

GROUNDWATER PRESENCE
By leakage or over-irrigation

FERTILITY
Low to moderate

DRAINAGE
Well drained

PERMEABILITY
Good to very good

IRRIGATION WATER EXISTING CONDITIONS

Al Khazna

ORIGIN
Well water

SALINITY
ECw 13,000 µS/cm, moderate

SAR
24, very high

AVAILABLE QUANTITY
Available

CURRENT AVERAGE USE M3/IRRIGATED HA
40,000, slightly high

TABLE 9: Existing Conditions and Recommendations for Al Khazna

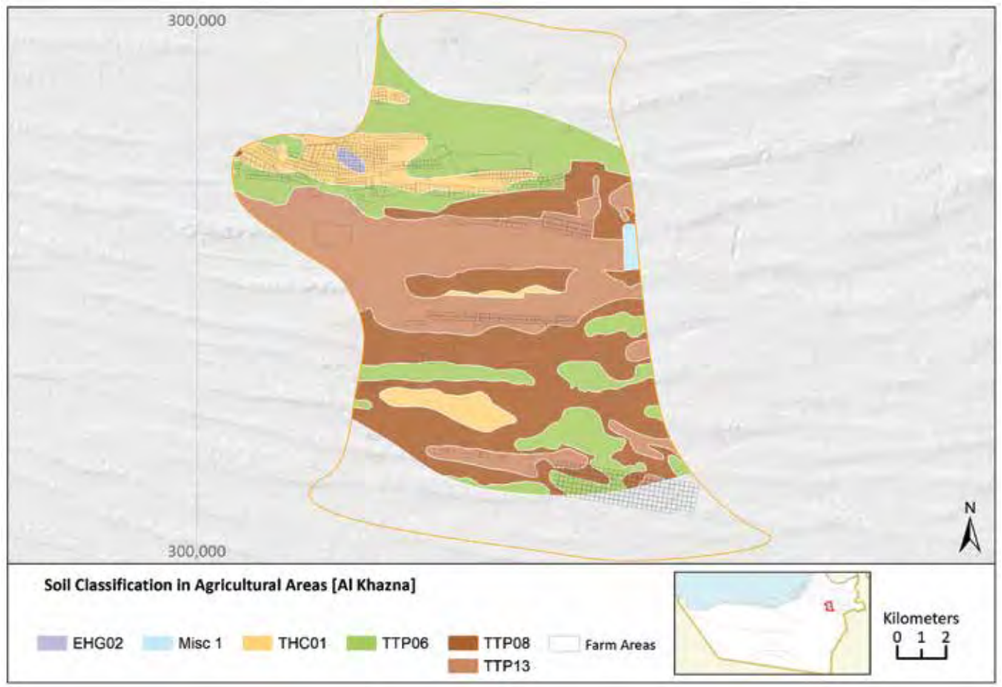


FIGURE 20: Soil Classification in Al Khazna

Recommendations for Al Khazna

Map Units	THC01	TTP06	TTP13
Total Farm Area	880.8 ha 47%	350.5 ha 19%	506.7 ha 27%

MAP UNITS	THC01	TTP06	TTP13
DESCRIPTION	Typic Haplocalcids - Typic Torripsamments association, almost level to gently undulating deflation plain SUITABILITY S2 RESTR 1 k RESTR 2 RESTR 3	Typic Torripsamments consociation, rolling dunes SUITABILITY S3 RESTR 1 r RESTR 2 RESTR 3	Typic Torripsamments consociation, low dunes and inland plains SUITABILITY S2 RESTR 1 t RESTR 2 RESTR 3
IRRIGATION	Avoid irrigation beyond crop water requirement: all-year crops with drip irrigation no more than 36,000 m3/ha. Switch from flood irrigation to sprinkler or drip	All-year crops with drip irrigation no more than 36,000 m3/ha. Switch from flood irrigation to sprinkler or drip	All-year crops with drip irrigation no more than 36,000 m3/ha. Switch from flood irrigation to sprinkler or drip
LEACHING (DESALINATION)	Apply in winter months. Target salinity maximum 1.5 x of irrigation water salinity, apply 37% above crop water requirements (drip irrigation). No extra leaching needed for flood irrigation (high percolation losses)	Apply in winter months. Target salinity maximum 1.5 x of irrigation water salinity, apply 37% above crop water requirements (drip irrigation). No extra leaching needed for flood irrigation (high percolation losses)	Apply in winter months. Target salinity maximum 1.5 x of irrigation water salinity, apply 37% above crop water requirements (drip irrigation). No extra leaching needed for flood irrigation (high percolation losses)
CROP SELECTION	Moderately salinity resistant crops: vegetables, tomato, cucumber, avoid alkalinity susceptible nuts, avocado, citrus, beans	Moderately salinity resistant crops: vegetables, tomato, cucumber, avoid alkalinity susceptible nuts, avocado, citrus, beans	Moderately salinity resistant crops: vegetables, tomato, cucumber, avid alkalinity susceptible nuts, avocado, citrus, beans
FERTILIZATION	Moderate level, apply organic fertilizer for binding salinity	Moderate level, apply organic fertilizer for binding salinity	Apply in small but frequent doses
DRAINAGE CONTROL	Avoid irrigation beyond crop water requirement		
ALKALINITY CONTROL	Gypsum soil amendments when using desalinated water	Gypsum soil amendments when using desalinated water	Gypsum soil amendments when using desalinated water
MELIORATION MEASURE	Compost/manure	Compost/manure, ground levelling	Compost/manure

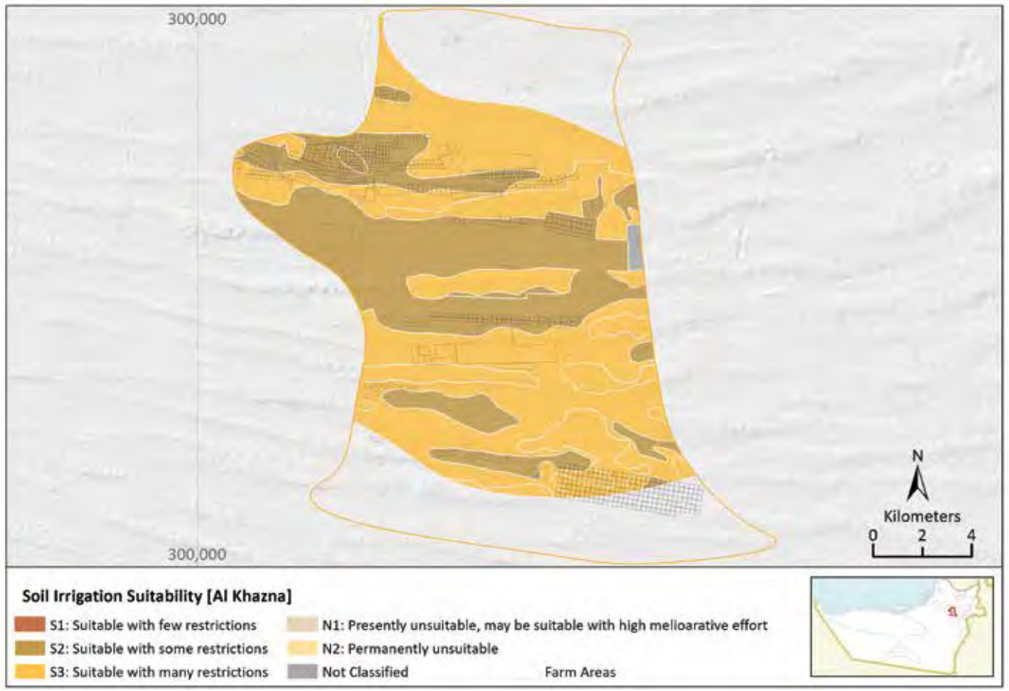


FIGURE 21: Soil Irrigation Suitability in Al Khazna

Al Salamat, Al Saad

SOIL EXISTING CONDITIONS

Al Salamat, Al Saad

TEXTURE
Loamy sand

GENERAL CHARACTERISTICS
Calcic, gypsic layers

ROOTING DEPTH
>150 cm

SALINITY
ECe 4,000-8,000 µS/cm, moderate salinity

GROUNDWATER PRESENCE
By leakage or over-irrigation

FERTILITY
Moderate

DRAINAGE
Well drained

PERMEABILITY
Good

IRRIGATION WATER EXISTING CONDITIONS

Al Salamat, Al Saad

ORIGIN
Well water

SALINITY
ECw 7,500 µS/cm, moderate

SAR
12, medium

AVAILABLE QUANTITY
Available

CURRENT AVERAGE USE M3/IRRIGATED HA
25,000, insufficient

TABLE 10: Existing Conditions and Recommendations for Al Salamat, Al Saad

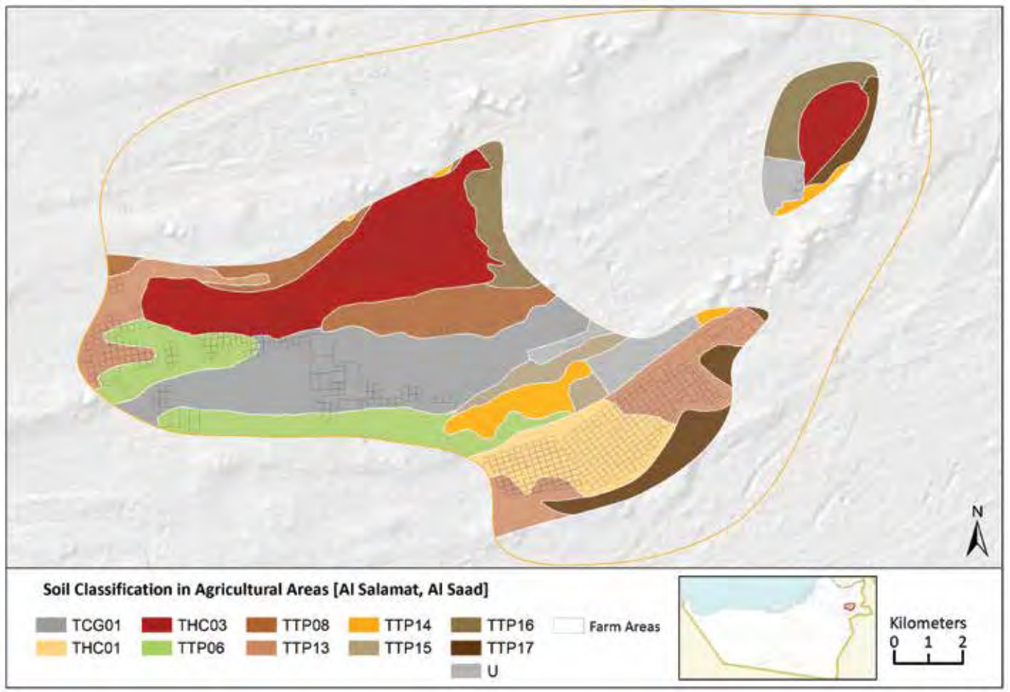


FIGURE 22: Soil Classification in Al Salamat, Al Saad

Recommendations for Al Salamat, Al Saad

Map Units	TCG01	THC01
Total Farm Area	343.9 ha 11%	648.3 ha 21%

MAP UNITS	TCG01	THC01
DESCRIPTION	Typic Calcigypsids - Typic Torripsamments complex, almost level to gently undulating SUITABILITY S2 RESTR 1 y RESTR 2 k RESTR 3	Typic Haplocalcids - Typic Torripsamments association, almost level to gently undulating deflation plain SUITABILITY S2 RESTR 1 k RESTR 2 RESTR 3
IRRIGATION	All-year crops with drip irrigation no more than 36,000 m3/ha. Switch from flood irrigation to sprinkler or drip	All-year crops with drip irrigation no more than 36,000 m3/ha. Switch from flood irrigation to sprinkler or drip
LEACHING (DESALINATION)	Not needed with regular irrigation	Not needed with regular irrigation
CROP SELECTION	Moderately salinity resistant crops: alfalfa, vegetables	Moderately salinity resistant crops: alfalfa, vegetables
FERTILIZATION	Moderate level, apply organic fertilizer for binding salinity	Moderate level, apply organic fertilizer for binding salinity
DRAINAGE CONTROL	Avoid irrigation beyond crop water requirement	Avoid irrigation beyond crop water requirement
ALKALINITY CONTROL		Gypsum soil amendments when using desalinated water
MELIORATION MEASURE	Compost/manure	Compost/manure

Map Units	THC03	TTP13
Total Farm Area	1,119.2 ha 37%	635.8 ha 21%

MAP UNITS	THC03	TTP13
DESCRIPTION	Typic Haplocalcids - Typic Calcigypsids complex, deflation plains and low dunes SUITABILITY S2 · RESTR 1 k · RESTR 2 · RESTR 3	Typic Torripsamments consociation, low dunes and inland plains SUITABILITY S2 · RESTR 1 t · RESTR 2 · RESTR 3
IRRIGATION	All-year crops with drip irrigation no more than 36,000 m3/ha. Switch from flood irrigation to sprinkler or drip	All-year crops with drip irrigation no more than 36,000 m3/ha. Switch from flood irrigation to sprinkler or drip
LEACHING (DESALINATION)	Not needed with regular irrigation	Not needed with regular irrigation
CROP SELECTION	Moderately salinity resistant crops: vegetables, tomato, cucumber, avoid alkalinity susceptible nuts, avocado, citrus, beans	Moderately salinity resistant crops: vegetables, tomato, cucumber, avoid alkalinity susceptible nuts, avocado, citrus, beans
FERTILIZATION	Moderate level, apply organic fertilizer for binding salinity	Apply in small but frequent doses
DRAINAGE CONTROL	Avoid irrigation beyond crop water requirement	Avoid irrigation beyond crop water requirement
ALKALINITY CONTROL		Gypsum soil amendments when using desalinated water
MELIORATION MEASURE	Compost/manure	Compost/manure, ground levelling

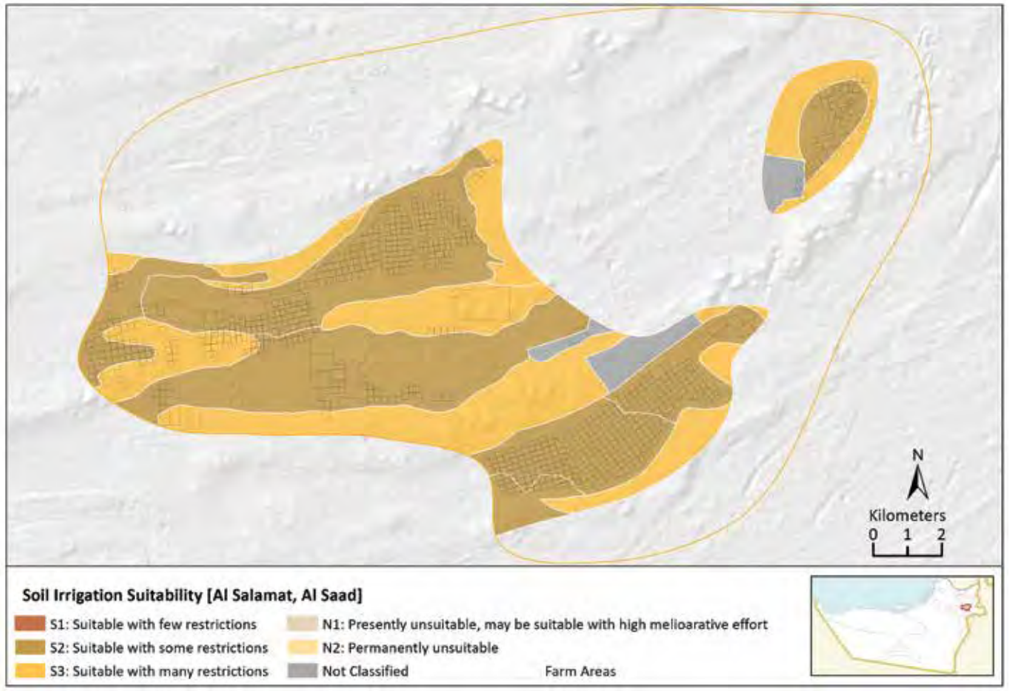


FIGURE 23: Soil Irrigation Suitability in Al Salamat, Al Saad

Al Wagan, Al Qua'a

SOIL EXISTING CONDITIONS

Al Wagan, Al Qua'a

TEXTURE
Sand

GENERAL CHARACTERISTICS
Calcic, gypsic layers levelled dunes

ROOTING DEPTH
>150 cm

SALINITY
ECe 8,000-16,000 µS/cm, medium saline

GROUNDWATER PRESENCE
Absent/by leakage or over-irrigation

FERTILITY
Low to moderate

DRAINAGE
Excessive/well drained

PERMEABILITY
Good to very good

IRRIGATION WATER EXISTING CONDITIONS

Al Wagan, Al Qua'a

ORIGIN
Well water

SALINITY
ECw 9,000 µS/cm, moderate

SAR
14, high

AVAILABLE QUANTITY
Available

CURRENT AVERAGE USE M3/IRRIGATED HA
36,000, good

TABLE 11: Existing Conditions and Recommendations for Al Wagan, Al Qua'a

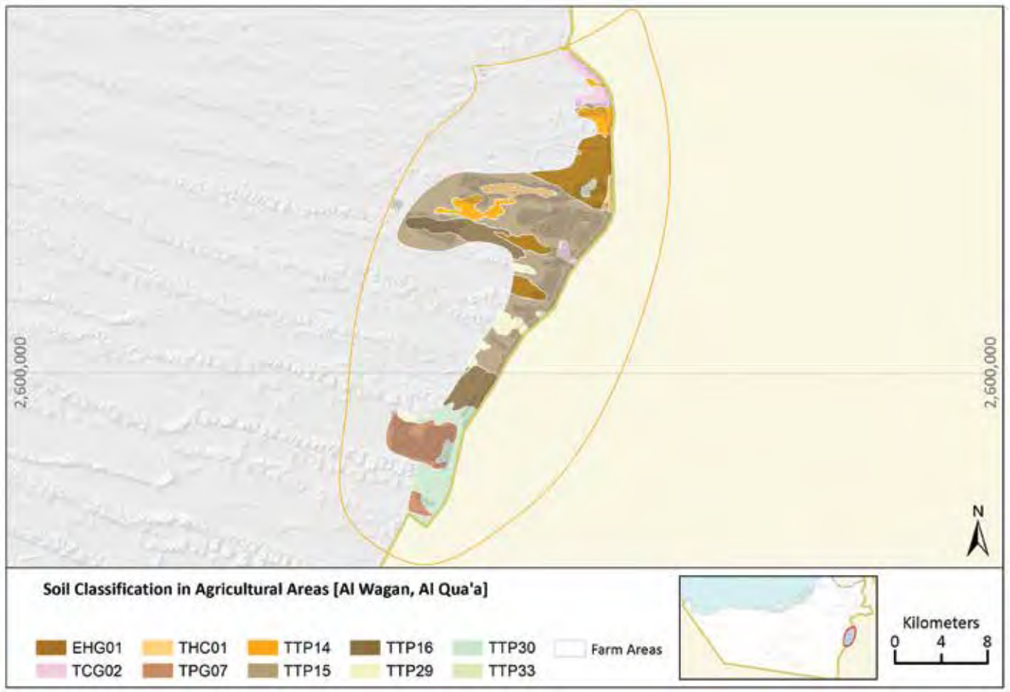


FIGURE 24: Soil Classification in Al Wagan, Al Qua'a

Recommendations for Al Wagan, Al Qua'a

Map Units	EHG01	TPG07
Total Farm Area	559.1 ha 9%	493.9 ha 8%

MAP UNITS	EHG01	TPG07
DESCRIPTION	Leptic Haplogypsids - Typic Torripsamments - Typic Petrogypsids complex, level to gently undulating inland plains **SUITABILITY** S2 **RESTR 1** y **RESTR 2** **RESTR 3**	Typic Petrogypsids - Petrogypsic Haplosalids complex, almost level to gently undulating **SUITABILITY** S3 **RESTR 1** m **RESTR 2** y **RESTR 3**
IRRIGATION	All-year crops with drip irrigation no more than 32,000 m3/ha. Switch from flood irrigation to sprinkler or drip	All-year crops with drip irrigation no more than 32,000 m3/ha. Switch from flood irrigation to sprinkler or drip
LEACHING (DESALINATION)	Target salinity maximum 1.5 x of irrigation water salinity: apply leaching fraction 28% above the crop water requirements for drip and sprinkler irrigation. No extra leaching needed for flood irrigation (high percolation losses). Use winter season for leaching	Target salinity maximum 1.5 x of irrigation water salinity: apply leaching fraction 28% above the crop water requirements for drip and sprinkler irrigation. No extra leaching needed for flood irrigation (high percolation losses). Use winter season for leaching
CROP SELECTION	Moderately salinity and alkalinity resistant crops: alfalfa, vegetables	Shallow rooting, moderately salinity and alkalinity resistant crops: alfalfa, vegetables
FERTILIZATION	Moderate level, apply organic fertilizer for binding salinity	Moderate level, apply organic fertilizer for binding salinity
DRAINAGE CONTROL	Not needed	Not needed
ALKALINITY CONTROL		
MELIORATION MEASURE	Compost/manure	Compost/manure, breaking of hardpan

Map Units	TTP15	TTP16
Total Farm Area	3,003.6 ha 50%	650.6 ha 11%

MAP UNITS	TTP15	TTP16
DESCRIPTION	Typic Torripsamments consociation, rolling to steep barchanoid dunes SUITABILITY S3 · RESTR 1 r · RESTR 2 t · RESTR 3 z	Typic Torripsamments consociation, rolling to steep barchanoid dunes SUITABILITY S3 · RESTR 1 r · RESTR 2 t · RESTR 3 z
IRRIGATION	All-year crops with drip irrigation no more than 36000 m3/ha. Switch from flood irrigation to sprinkler or drip	All-year crops with drip irrigation no more than 36000 m3/ha. Switch from flood irrigation to sprinkler or drip
LEACHING (DESALINATION)	Target salinity maximum 1.5 x of irrigation water salinity: apply leaching fraction 28% above the crop water requirements for drip and sprinkler irrigation. No extra leaching needed for flood irrigation (high percolation losses). Use winter season for leaching	Target salinity maximum 1.5 x of irrigation water salinity: apply leaching fraction 28% above the crop water requirements for drip and sprinkler irrigation. No extra leaching needed for flood irrigation (high percolation losses). Use winter season for leaching
CROP SELECTION	Moderately salinity and alkalinity resistant crops: alfalfa, vegetables	Moderately salinity and alkalinity resistant crops: alfalfa, vegetables
FERTILIZATION	Apply in small but frequent doses	Apply in small but frequent doses
DRAINAGE CONTROL	Not needed	Not needed
ALKALINITY CONTROL		
MELIORATION MEASURE	Compost/manure, ground levelling	Compost/manure, ground levelling

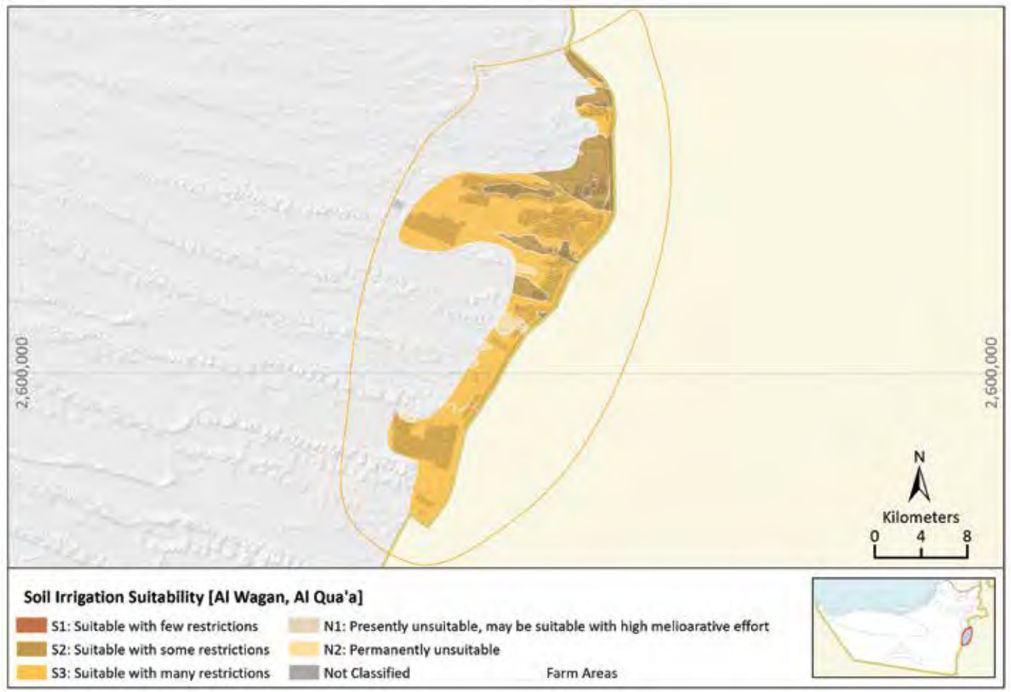


FIGURE 25: Soil Irrigation Suitability in Al Wagan, Al Qua'a

Remah

SOIL EXISTING CONDITIONS

Remah

TEXTURE
Sand

GENERAL CHARACTERISTICS
Levelled dunes

ROOTING DEPTH
>150 cm

SALINITY
ECe 2,000-8,000 µS/cm, low to moderate

GROUNDWATER PRESENCE
Absent

FERTILITY
Low

DRAINAGE
Excessive

PERMEABILITY
Very good

IRRIGATION WATER EXISTING CONDITIONS

Remah

ORIGIN
Well water

SALINITY
ECw 7,700 µS/cm, moderate

SAR
14, high

AVAILABLE QUANTITY
Available

CURRENT AVERAGE USE M3/IRRIGATED HA
32,000, slightly insufficient

TABLE 12: Existing Conditions and Recommendations for Remah

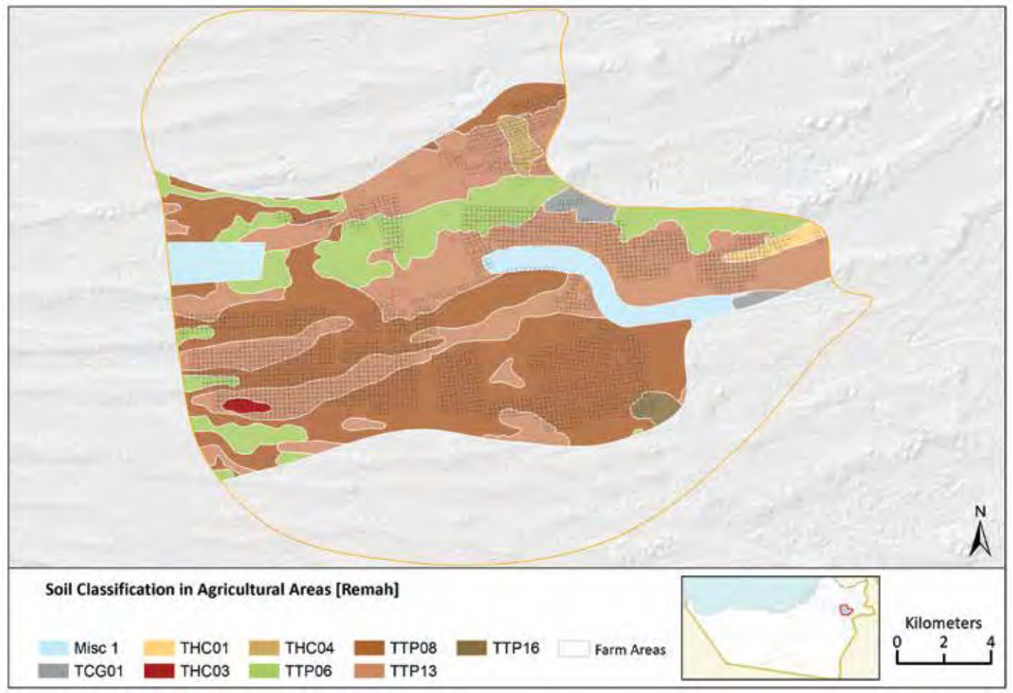


FIGURE 26: Soil Classification in Remah

Recommendations for Remah

Map Units	TTP06	TTP08	TTP13
Total Farm Area	511.0 ha 6%	3,950.4 ha 46%	3,493.1 ha 41%

MAP UNITS	TTP06	TTP08	TTP13
DESCRIPTION	Typic Torripsamments consociation, rolling dunes SUITABILITY S3 RESTR 1 r RESTR 2 RESTR 3	Typic Torripsamments consociation, low to moderately high active dunes SUITABILITY S3 RESTR 1 t RESTR 2 RESTR 3 z	Typic Torripsamments consociation, low dunes and inland plains SUITABILITY S2 RESTR 1 t RESTR 2 RESTR 3
IRRIGATION	All-year crops with drip irrigation no more than 36,000 m3/ha. Switch from flood irrigation to sprinkler or drip	All-year crops with drip irrigation no more than 36,000 m3/ha. Switch from flood irrigation to sprinkler or drip	All-year crops with drip irrigation no more than 36,000 m3/ha. Switch from flood irrigation to sprinkler or drip
LEACHING (DESALINATION)	Not needed with regular irrigation	Not needed with regular irrigation	Not needed with regular irrigation
CROP SELECTION	In respect to salinity suitable for all crops, not suitable for alkalinity susceptible plants: nuts, citrus avocado, beans	Suitable for moderately salt tolerant crops, not suitable for alkalinity susceptible plants: nuts, citrus avocado, beans	In respect to salinity suitable for all crops, not suitable for alkalinity susceptible plants: nuts, citrus avocado, beans
FERTILIZATION	Low fertilizer quantities in frequent doses, organic fertilizer	Low fertilizer quantities in frequent doses, organic fertilizer	Low fertilizer quantities in frequent doses, organic fertilizer
DRAINAGE CONTROL	Not needed	Not needed	Not needed
ALKALINITY CONTROL	Gypsum soil amendments when using desalinated water, avoid susceptible crops	Gypsum soil amendments when using desalinated water, avoid susceptible crops	Gypsum soil amendments when using desalinated water, avoid susceptible crops
MELIORATION MEASURE	Compost/manure, ground levelling	Compost/manure	Compost/manure

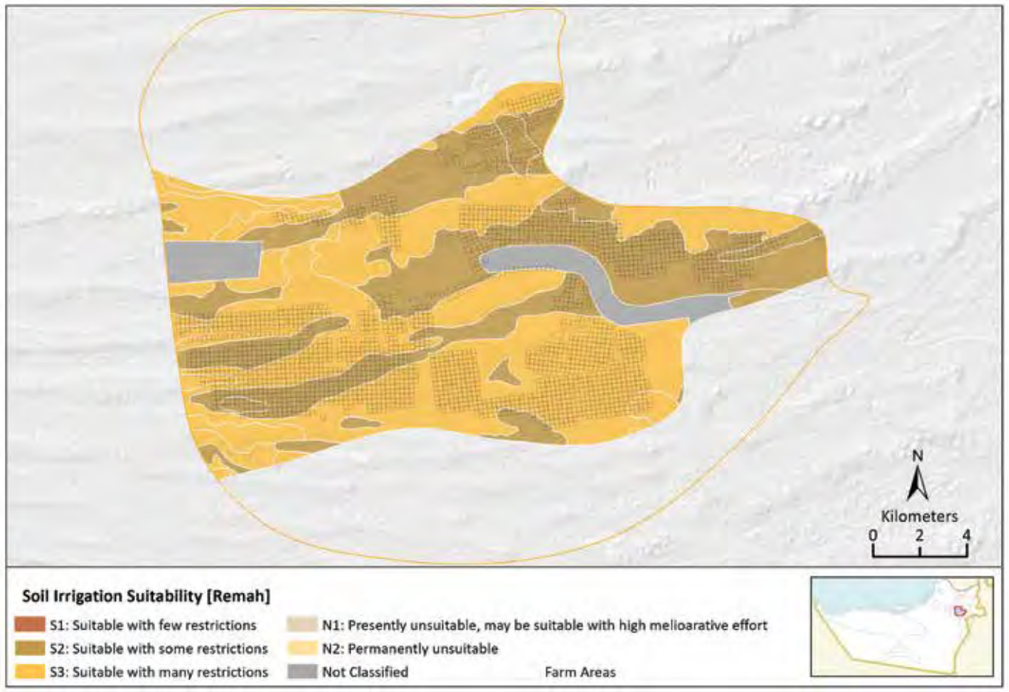


FIGURE 27: Soil Irrigation Suitability in Remah

Sweihan

SOIL EXISTING CONDITIONS

Sweihan

TEXTURE
Loamy sand

GENERAL CHARACTERISTICS
Petrogypsic, petrocalcic layers

ROOTING DEPTH
80 - 120 cm

SALINITY
ECe 8,000-40,000 µS/cm, medium to very high salinity

GROUNDWATER PRESENCE
By leakage or over-irrigation

FERTILITY
Moderate

DRAINAGE
Limited by hardpan

PERMEABILITY
Moderate

IRRIGATION WATER EXISTING CONDITIONS

Sweihan

ORIGIN
Well water

SALINITY
ECw 11,000 µS/cm, medium to high

SAR
24, very high

AVAILABLE QUANTITY
Available

CURRENT AVERAGE USE M3/IRRIGATED HA
34,000, good

TABLE 13: Existing Conditions and Recommendations for Sweihan

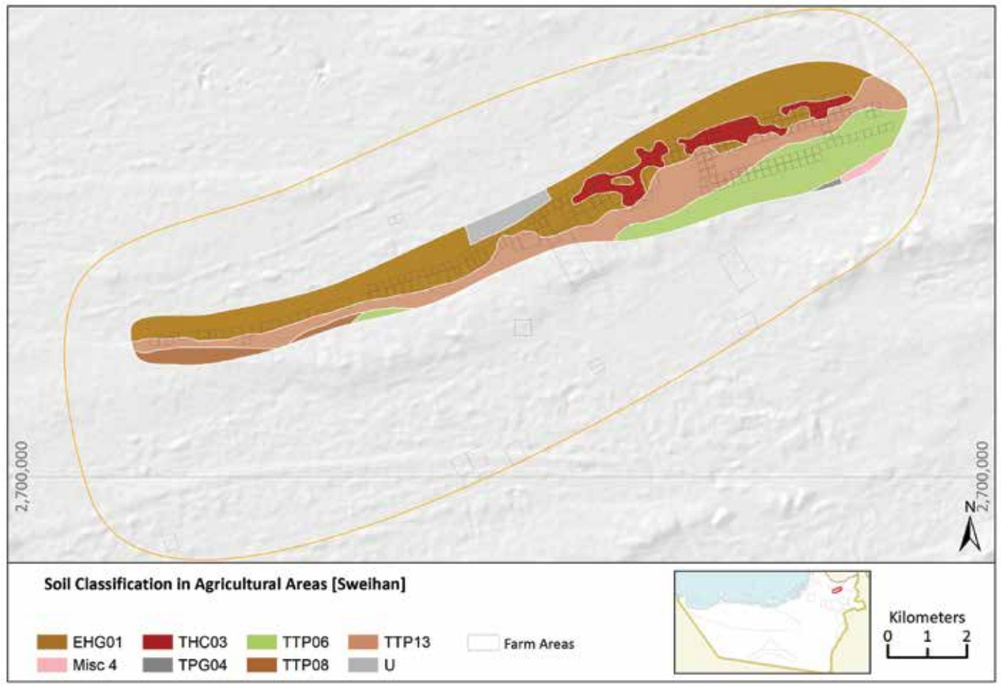


FIGURE 28: Soil Classification in Sweihan

Recommendations for Sweihan

Map Units	EHG01	THC03
Total Farm Area	530.0 ha 45%	237.8 ha 20%

MAP UNITS	EHG01	THC03
DESCRIPTION	Leptic Haplogypsids - Typic Torripsamments - Typic Petrogypsids complex, level to gently undulating inland plains SUITABILITY S2 RESTR 1 y RESTR 2 RESTR 3	Leptic Haplogypsids - Typic Torripsamments - Typic Petrogypsids complex, level to gently undulating inland plains SUITABILITY S2 RESTR 1 k RESTR 2 RESTR 3
IRRIGATION	All-year crops with drip irrigation no more than 36,000 m3/ha. Switch from flood irrigation to sprinkler or drip	All-year crops with drip irrigation no more than 36,000 m3/ha. Switch from flood irrigation to sprinkler or drip
LEACHING (DESALINATION)	Target salinity maximum 1.5 x of irrigation water salinity: apply leaching fraction 14% to crop water requirements for drip and sprinkler irrigation. No extra leaching needed for flood irrigation (high percolation losses). Use winter season for leaching	Target salinity maximum 1.5 x of irrigation water salinity: apply leaching fraction 14% to crop water requirements for drip and sprinkler irrigation. No extra leaching needed for flood irrigation (high percolation losses). Use winter season for leaching
CROP SELECTION	Only extremely salt and alkalinity resistant crops: Rhodes grass, Alfalfa, shallow rooting	Only extremely salt and alkalinity resistant crops: Rhodes grass, Alfalfa, shallow rooting
FERTILIZATION	Moderate level, apply organic fertilizer for binding salinity	Moderate level, apply organic fertilizer for binding salinity
DRAINAGE CONTROL	Avoid irrigation beyond crop water requirement	Avoid irrigation beyond crop water requirement
ALKALINITY CONTROL		Gypsum soil amendments when using desalinated water
MELIORATION MEASURE	Desalination plant, compost/manure, breaking of hardpan	Desalination plant, compost/manure, breaking of hardpan

Map Units	TTP06	TTP13
Total Farm Area	173.5 ha 15%	233.8 ha 20%

MAP UNITS	TTP06	TTP13
DESCRIPTION	Typic Torripsamments consociation, rolling dunes SUITABILITY S3 · RESTR 1 r · RESTR 2 · RESTR 3	Typic Torripsamments consociation, low dunes and inland plains SUITABILITY S2 · RESTR 1 t · RESTR 2 · RESTR 3
IRRIGATION	All-year crops with drip irrigation no more than 36,000 m3/ha. Switch from flood irrigation to sprinkler or drip	All-year crops with drip irrigation no more than 36,000 m3/ha. Switch from flood irrigation to sprinkler or drip
LEACHING (DESALINATION)	Target salinity maximum 1.5 x of irrigation water salinity: apply leaching fraction 14% to crop water requirements for drip and sprinkler irrigation. No extra leaching needed for flood irrigation (high percolation losses). Use winter season for leaching	Not needed
CROP SELECTION	Only extremely salt and alkalinity resistant crops: Rhodes grass, Alfalfa, shallow rooting	Moderately salinity and alkalinity resistant crops: alfalfa, vegetables
FERTILIZATION	Moderate level, apply organic fertilizer for binding salinity	Apply in low but frequent doses
DRAINAGE CONTROL		
ALKALINITY CONTROL	Gypsum soil amendments when using desalinated water	Gypsum soil amendments when using desalinated water
MELIORATION MEASURE	Desalination plant, compost/manure, terrain levelling	Desalination plant, compost/manure

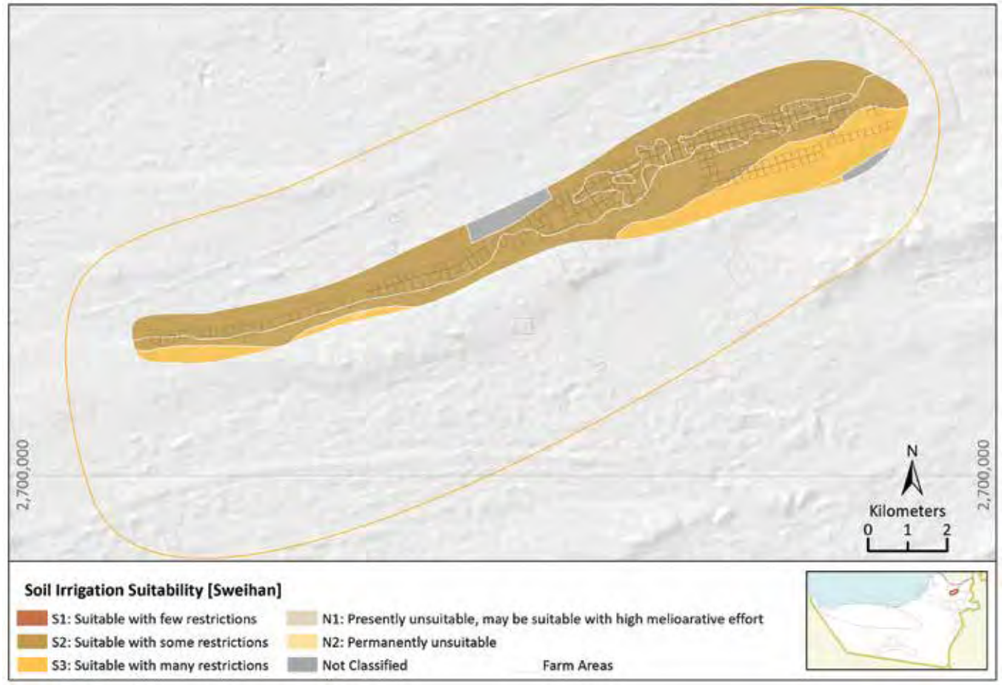


FIGURE 29: Soil Irrigation Suitability in Sweihan

Al Dhafra (without Liwa): Silah, Al Marfa, Madinat Zayed, Ghayathi, Al Fadhiya

SOIL EXISTING CONDITIONS

Al Dhafra (without Liwa): Silah, Al Marfa, Madinat Zayed, Ghayathi, Al Fadhiya

TEXTURE
Sand

GENERAL CHARACTERISTICS
Calcic, gypsic layers

ROOTING DEPTH
>150 cm

SALINITY
ECe 4,000-40,000 µS/cm, moderate to very high

GROUNDWATER PRESENCE
By leakage or over-irrigation

FERTILITY
Low to medium

DRAINAGE
Well drained

PERMEABILITY
Good

IRRIGATION WATER EXISTING CONDITIONS

Al Dhafra (without Liwa): Silah, Al Marfa, Madinat Zayed, Ghayathi, Al Fadhiya

ORIGIN
Well water/desalinated water

SALINITY
ECw 12,500 µS/cm high/low if desalinated

SAR
17, high

AVAILABLE QUANTITY
Available

CURRENT AVERAGE USE M3/IRRIGATED HA
39,000, slightly high

TABLE 14: Existing Conditions and Recommendations for Al Dhafra (without Liwa): Silah, Al Marfa, Madinat Zayed, Ghayathi, Al Fadhiya

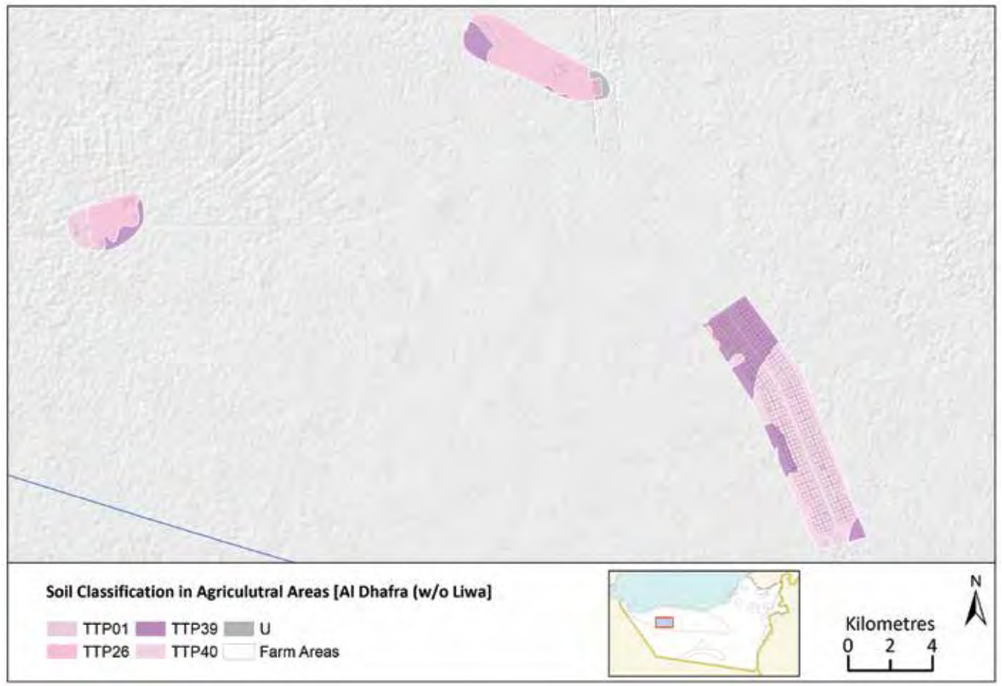


FIGURE 30: Soil Classification in Al Dhafra (I)

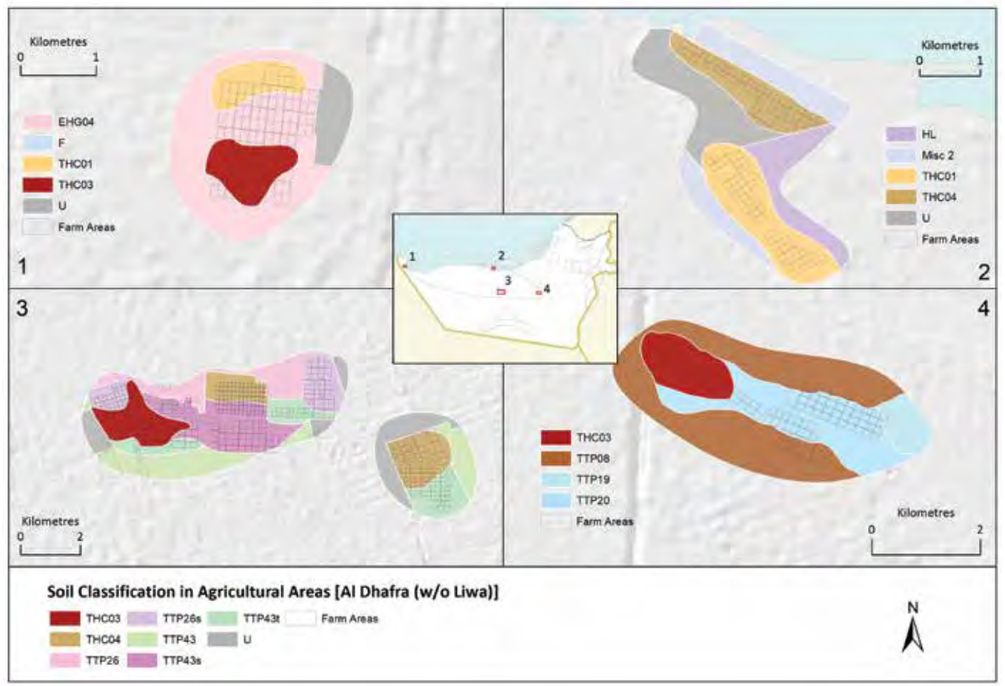


FIGURE 31: Soil Classification in Al Dhafra (II)

Recommendations for Al Dhafra (without Liwa): Silah, Al Marfa, Madinat Zayed, Ghayathi, Al Fadhiya

Map Units	THC03	THC04
Total Farm Area	343.4 ha 9%	352.4 ha 9%

MAP UNITS	THC03	THC04
DESCRIPTION	Typic Haplocalcids - Typic Calcigypsids complex, deflation plains and low dunes SUITABILITY S2 RESTR 1 k RESTR 2 RESTR 3	Typic Haplocalcids, Typic Haplocambids, alluvial deposits SUITABILITY S2 RESTR 1 k RESTR 2 RESTR 3
IRRIGATION	All-year crops with drip irrigation no more than 32,000 m3/ha. Switch from flood irrigation to sprinkler or drip	All-year crops with drip irrigation no more than 32,000 m3/ha. Switch from flood irrigation to sprinkler or drip
LEACHING (DESALINATION)	Target salinity maximum 1.5 x of irrigation water salinity: apply leaching fraction 16% to crop water requirements for drip and sprinkler irrigation. No extra leaching needed for flood irrigation (high percolation losses). Use winter season for leaching	Target salinity maximum 1.5 x of irrigation water salinity: apply leaching fraction 16% to crop water requirements for drip and sprinkler irrigation. No extra leaching needed for flood irrigation (high percolation losses). Use winter season for leaching
CROP SELECTION	Salinity and alkalinity resistant crops: Date palm, Rhodes Grass, Alfalfa. With good water quality vegetables, except alkalinity susceptible (citrus, beans, avocado, nuts)	Salinity and alkalinity resistant crops: Date palm, Rhodes Grass, Alfalfa. With good water quality vegetables, except alkalinity susceptible (citrus, beans, avocado, nuts)
FERTILIZATION	Moderate level, apply organic fertilizer for binding salinity	Moderate level, apply organic fertilizer for binding salinity
DRAINAGE CONTROL	Avoid irrigation beyond crop water requirement	Avoid irrigation beyond crop water requirement
ALKALINITY CONTROL	Gypsum soil amendments when using desalinated water	Gypsum soil amendments when using desalinated water
MELIORATION MEASURE	Desalination plant. Apply compost/manure	Desalination plant. Apply compost/manure

Map Units	TTP39	TTP40
Total Farm Area	511.4 ha 14%	1,228.2 ha 33%

MAP UNITS	TTP39	TTP40
DESCRIPTION	Typic Torripsamments consociation, undulating plains and rises SUITABILITY S2 RESTR 1 t RESTR 2 RESTR 3	Typic Torripsamments consociation, undulating plains and rises SUITABILITY S3 RESTR 1 t RESTR 2 RESTR 3 m
IRRIGATION	All-year crops with drip irrigation no more than 32,000 m3/ha. Switch from flood irrigation to sprinkler or drip	All-year crops with drip irrigation no more than 32,000 m3/ha. Switch from flood irrigation to sprinkler or drip
LEACHING (DESALINATION)	Target salinity maximum 1.5 x of irrigation water salinity: apply leaching fraction 16% to crop water requirements for drip and sprinkler irrigation. No extra leaching needed for flood irrigation (high percolation losses). Use winter season for leaching	Target salinity maximum 1.5 x of irrigation water salinity: apply leaching fraction 16% to crop water requirements for drip and sprinkler irrigation. No extra leaching needed for flood irrigation (high percolation losses). Use winter season for leaching
CROP SELECTION	Salinity and alkalinity resistant crops: Date palm, Rhodes Grass, Alfalfa. With good water quality vegetables, except alkalinity susceptible (citrus, beans, avocado, nuts)	Salinity and alkalinity resistant crops: Date palm, Rhodes Grass, Alfalfa. With good water quality vegetables, except alkalinity susceptible (citrus, beans, avocado, nuts)
FERTILIZATION	Apply in low but frequent doses	Apply in low but frequent doses
DRAINAGE CONTROL	Avoid irrigation beyond crop water requirement	Avoid irrigation beyond crop water requirement
ALKALINITY CONTROL	Gypsum soil amendments when using desalinated water	Gypsum soil amendments when using desalinated water
MELIORATION MEASURE	Desalination plant, apply compost/manure	Desalination plant, breaking of hardpan, apply compost/manure

Map Units	TTP43s
Total Farm Area	334.4 ha 9%

MAP UNITS	TTP43s
DESCRIPTION	Typic Torripsamments consociation, undulating to rolling rises and dunes, high salinity. Typic Torripsamments consociation, undulating to rolling rises and dunes, high salinity **SUITABILITY** S3 · **RESTR 1** t · **RESTR 2** r · **RESTR 3** z
IRRIGATION	All-year crops with drip irrigation no more than 32,000 m3/ha. Switch from flood irrigation to sprinkler or drip
LEACHING (DESALINATION)	Target salinity maximum 1.5 x of irrigation water salinity: apply leaching fraction 16% to crop water requirements for drip and sprinkler irrigation. No extra leaching needed for flood irrigation (high percolation losses). Use winter season for leaching
CROP SELECTION	Salinity and alkalinity resistant crops: Date palm, Rhodes Grass, Alfalfa. With good water quality vegetables, except alkalinity susceptible (citrus, beans, avocado, nuts)
FERTILIZATION	Apply in low but frequent doses
DRAINAGE CONTROL	Avoid irrigation beyond crop water requirement
ALKALINITY CONTROL	Gypsum soil amendments when using desalinated water
MELIORATION MEASURE	Desalination plant, ground levelling, apply compost/manure

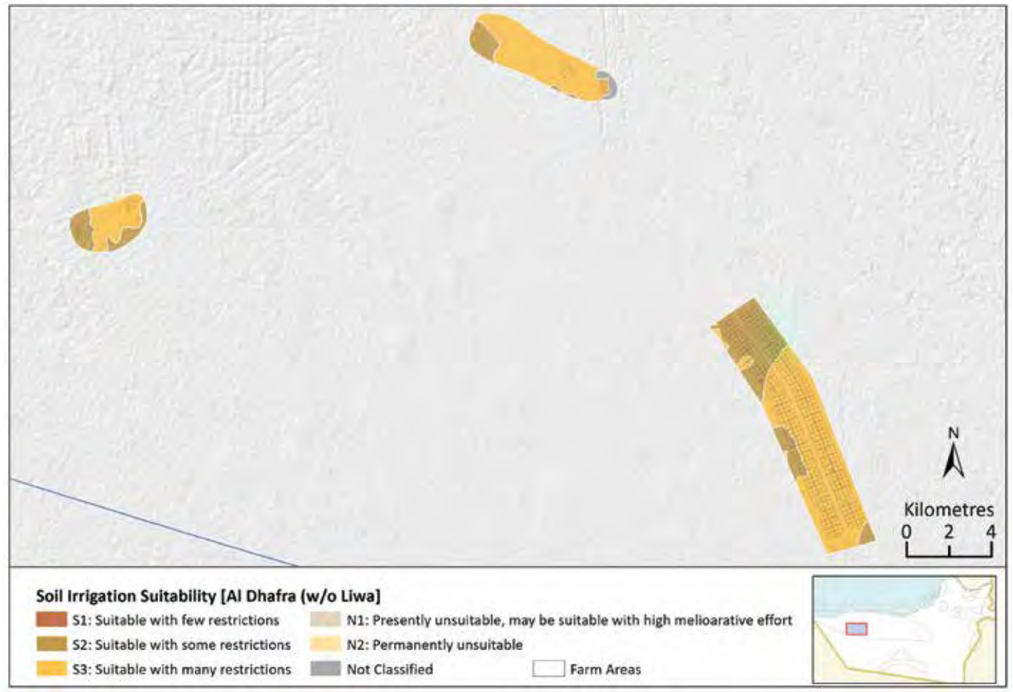


FIGURE 32: Soil Irrigation Suitability in Al Dhafra (I)

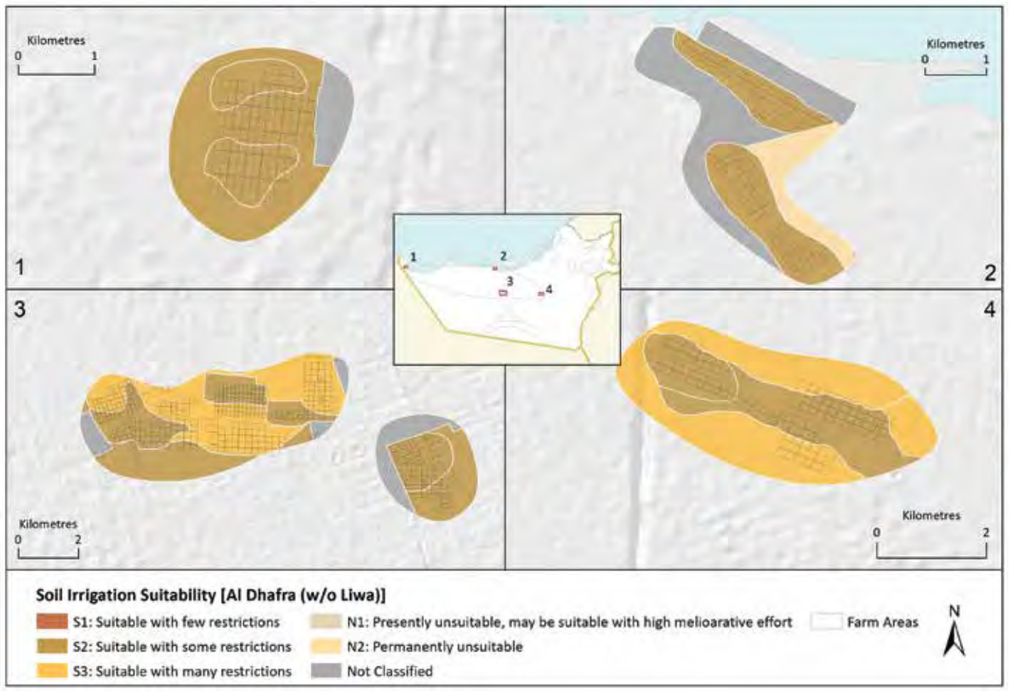


FIGURE 33: Soil Irrigation Suitability in Al Dhafra (II)

Liwa North

SOIL EXISTING CONDITIONS

Liwa North

TEXTURE
Sand

GENERAL CHARACTERISTICS
Levelled dunes

ROOTING DEPTH
>150 cm

SALINITY
ECe 4,000-8,000 µS/cm, moderate

GROUNDWATER PRESENCE
Absent

FERTILITY
Low

DRAINAGE
Excessive

PERMEABILITY
Very good

IRRIGATION WATER EXISTING CONDITIONS

Liwa North

ORIGIN
Well water

SALINITY
ECw 7,000 µS/cm, low to medium

SAR
12, medium

AVAILABLE QUANTITY
Available

CURRENT AVERAGE USE M3/IRRIGATED HA
52,000, high

TABLE 15: Existing Conditions and Recommendations for Liwa North

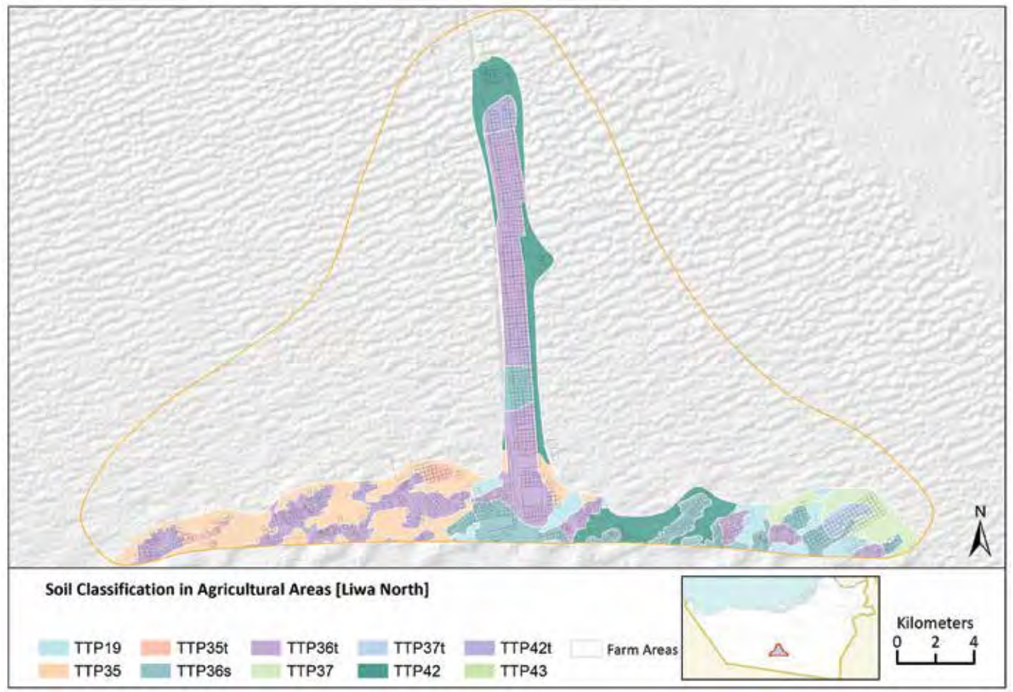


FIGURE 34: Soil Classification in Liwa North

Recommendations for Liwa North

Map Units	TTP36s	TTP36t	TTP42
Total Farm Area	1,159.5 ha 20%	3,263.6 ha 56%	397.7 ha 7%

MAP UNITS	TTP36s	TTP36t	TTP42
DESCRIPTION	Typic Torripsamments consociation, undulating rises and valleys, agricultural use, high salinity SUITABILITY S3 RESTR 1 r RESTR 2 t RESTR 3 z	Typic Torripsamments consociation, undulating rises and valleys, agricultural use, low salinity SUITABILITY S2 RESTR 1 r RESTR 2 t RESTR 3	Typic Torripsamments consociation, undulating rises and valleys, agricultural use, low salinity SUITABILITY S3 RESTR 1 t RESTR 2 r RESTR 3
IRRIGATION	All-year crops no more than 32,000 m3/ha for drip and sprinkler irrigation. Switch from flood irrigation to sprinkler or drip	All-year crops with drip irrigation no more than 32,000 m3/ha. Switch from flood irrigation to sprinkler or drip	All-year crops with drip irrigation no more than 32,000 m3/ha. Switch from flood irrigation to sprinkler or drip
LEACHING (DESALINATION)	Not needed with regular irrigation	Not needed with regular irrigation	Not needed with regular irrigation
CROP SELECTION	Salinity resistant crops, vegetables, except alkalinity susceptible awcado, nuts, citrus	Moderately salinity resistant crops, vegetables, except alkalinity susceptible avocado, nuts, citrus	Moderately salinity resistant crops, vegetables, except alkalinity susceptible avocado, nuts, citrus
FERTILIZATION	Low fertilizer quantities in frequent doses, organic fertilizer	Low fertilizer quantities in frequent doses, organic fertilizer	Low fertilizer quantities in frequent doses, organic fertilizer
DRAINAGE CONTROL	Not needed	Not needed	Not needed
ALKALINITY CONTROL	Gypsum soil amendments when using desalinated water	Gypsum soil amendments when using desalinated water	Gypsum soil amendments when using desalinated water
MELIORATION MEASURE	Compost/manure, ground levelling	Compost/manure, ground levelling	Compost/manure, ground levelling

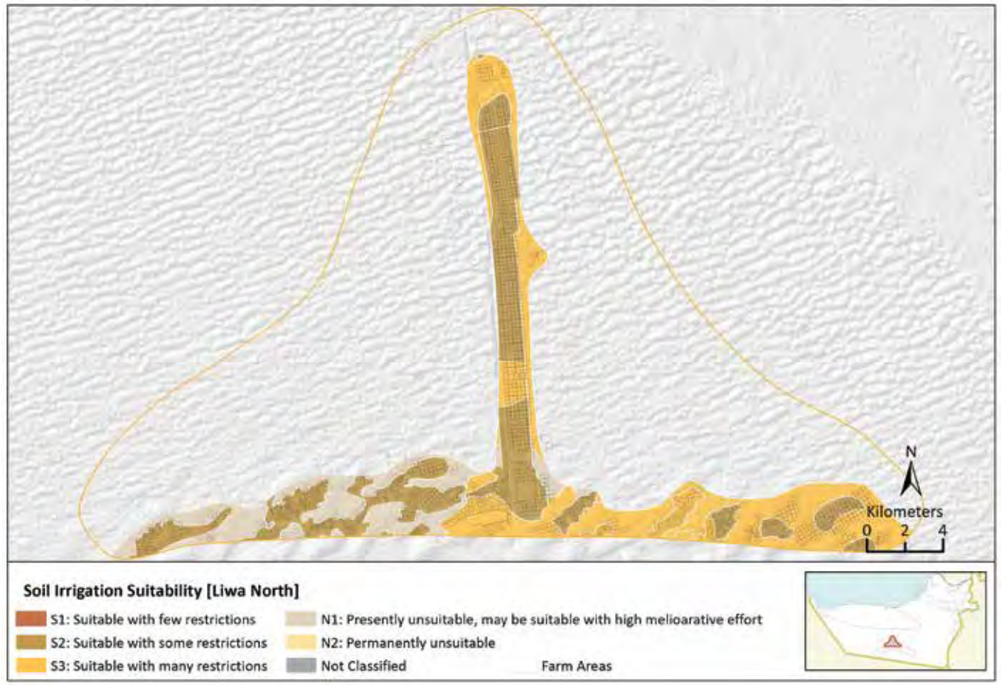


FIGURE 35: Soil Irrigations Suitability in Liwa North

Liwa South

SOIL EXISTING CONDITIONS

Liwa South

TEXTURE
Sand

GENERAL CHARACTERISTICS
Levelled dunes

ROOTING DEPTH
>150 cm

SALINITY
ECe 8,000-40,000 µS/cm, medium to very high

GROUNDWATER PRESENCE
By over-irrigation or leakage

FERTILITY
Low

DRAINAGE
Excessive

PERMEABILITY
Very good

IRRIGATION WATER EXISTING CONDITIONS

Liwa South

ORIGIN
Well water

SALINITY
ECw 22,000 µS/cm, high

SAR
22, high

AVAILABLE QUANTITY
Available

CURRENT AVERAGE USE M3/IRRIGATED HA
57,000, high

TABLE 16: Existing Conditions and Recommendations for Liwa South

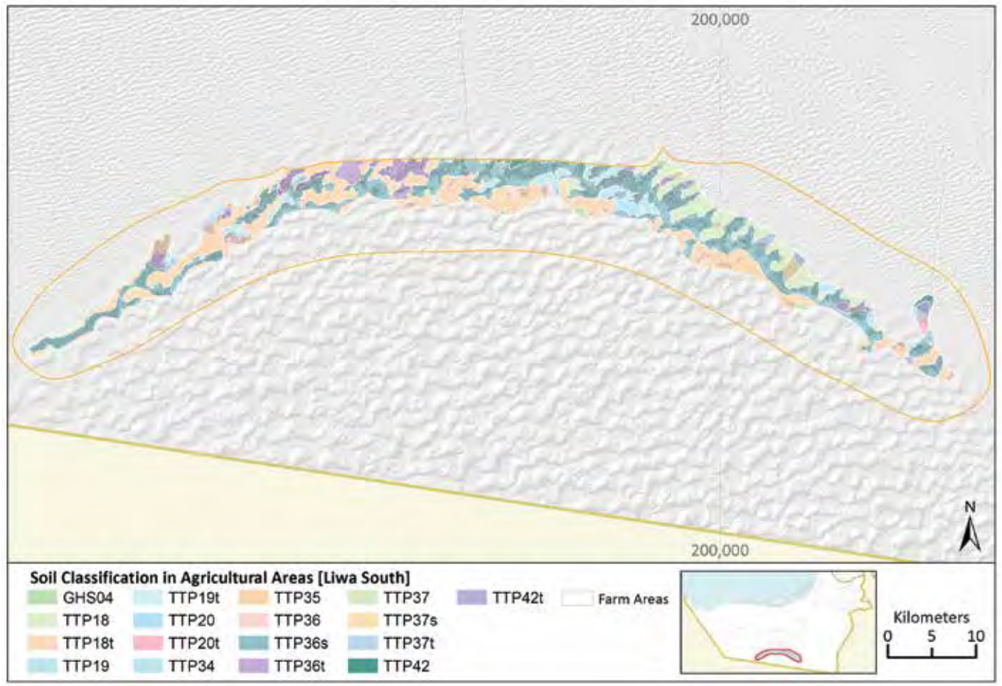


FIGURE 36: Soil Classification in Liwa South

Recommendations for Liwa South

Map Units	TTP36s	TTP36t
Total Farm Area	7,550.7 ha 68%	1,652.2 ha 15%

MAP UNITS	TTP36s	TTP36t
DESCRIPTION	Typic Torripsamments consociation, undulating rises and valleys, agricultural use, high salinity SUITABILITY S3 RESTR 1 r RESTR 2 t RESTR 3 z	Typic Torripsamments consociation, undulating rises and valleys, agricultural use, low salinity SUITABILITY S2 RESTR 1 r RESTR 2 t RESTR 3
IRRIGATION	All-year crops with drip irrigation no more than 32,000 m3/ha. Switch from flood irrigation to sprinkler or drip	All-year crops with drip irrigation no more than 32,000 m3/ha. Switch from flood irrigation to sprinkler or drip
LEACHING (DESALINATION)	Apply in winter months. Target salinity maximum 1.5 x of irrigation water salinity, apply 27% above crop water requirements for drip and sprinkler irrigation. No extra leaching needed for flood irrigation (high percolation losses)	Apply in winter months. Target salinity maximum 1.5 x of irrigation water salinity, apply 27% above crop water requirements for drip and sprinkler irrigation. No extra leaching needed for flood irrigation (high percolation losses)
CROP SELECTION	Salinity and alkalinity resistant crops: Date palm, Rhodes grass, Alfalfa	Moderately salinity resistant crops, vegetables, except alkalinity susceptible avocado, nuts, citrus
FERTILIZATION	Low fertilizer quantities in frequent doses, organic fertilizer	Low fertilizer quantities in frequent doses, organic fertilizer
DRAINAGE CONTROL	Not needed	Not needed
ALKALINITY CONTROL	Gypsum soil amendments when using desalinated water	Gypsum soil amendments when using desalinated water
MELIORATION MEASURE	Desalination plant, terrain levelling, compost/manure	Compost/manure, terrain levelling

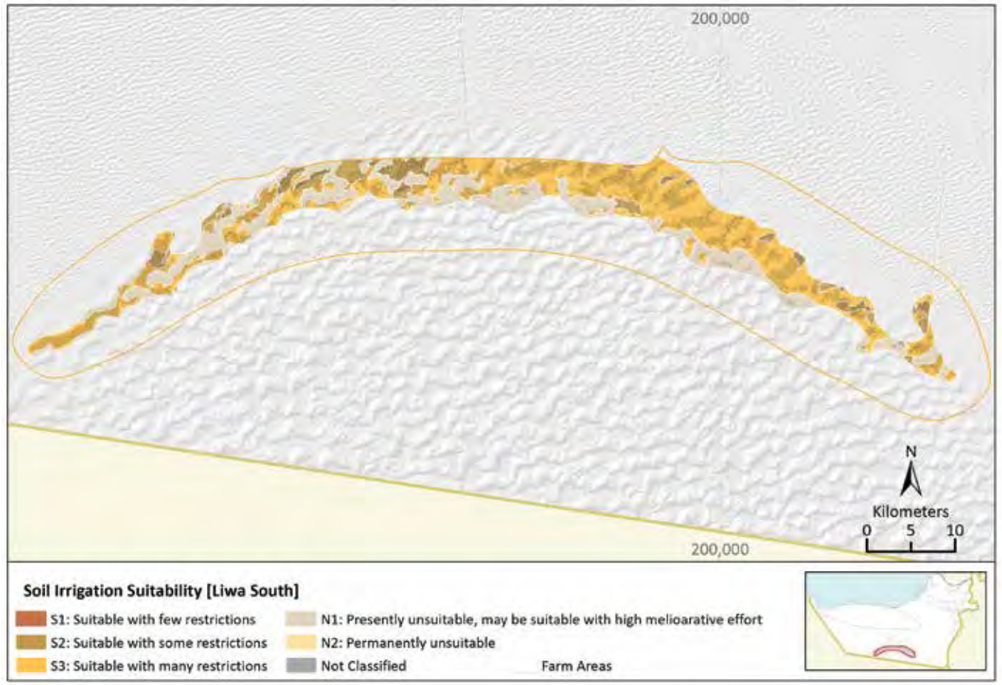


FIGURE 37: Soil Irrigation Suitability in Liwa South

SECTION 3

TERMS OF SOIL, WATER AND CROP MANAGEMENT

SECTION 3:
TERMS OF SOIL, WATER AND CROP MANAGEMENT

This section provides definitions for terms and expressions considered necessary to understand water and soil conditions. It further presents management recommendations for specific agricultural areas identified in the Emirate of Abu Dhabi.

LEACHING OF SALINITY

Ideally, salinity should be reduced to the level that secures optimum crop production. However, in practice, limitations are often imposed by the quality of irrigation water. To reduce salinity in the soil and to maintain its recommended levels – i.e. maximum 1.2 to 1.5 times the salinity of available irrigation water – an excess amount of irrigation water is needed:

SURFACE IRRIGATION

Surface Irrigation: The Leaching Requirement (LR) for surface irrigation is estimated using the following formula:

The Leaching Requirement is calculated using the equation of Rhoades (1974) and Rhoades and Merrill (1976), FAO (1985):

$$LR\ (\%) = \frac{ECe}{5(ECe)-ECw}$$

LR (%) = The minimum additional leaching requirement needed in % beyond normal net irrigation to control salts within the soil target (ECe) with ordinary surface methods of irrigation

ECe = Salinity of the applied irrigation water in µS/cm

ECw = Average soil salinity achievable with used irrigation water as measured on a soil saturation extract (µS/cm).

Example:
ECw: 10,000
Required: ECe: 12,000 (1.2 times the salinity of irrigation water)

$$LR\ (\%) = \frac{12{,}000}{5\ *(12{,}000)-10{,}000} = 24\%$$

or expressed as a fraction: 0.24

DRIP IRRIGATION

Drip Irrigation: Calculating the Leaching Requirement percentage for a Drip Irrigation System requires data on the electric conductivity of irrigation water (ECw) and the actual soil EC by saturation extract measured in the soil (ECe).

The Leaching Requirement is calculated using the equation of Rhoades (1974) and Rhoades and Merrill (1976), FAO (1985):

$$LR\ (\%) = \frac{ECw}{2*ECe}$$

Where, **ECw** is the EC of the irrigation water, and a factor of 2 is obtained from **ECsw** (EC soil water), which is assumed to be equal to 2*ECe (EC saturation extract).

Example:
ECw: 10 000
Actual (measured) Soil Salinity ECe: 24,000

$$LR\ (\%) = \frac{10{,}000}{2\ *(24{,}000)} = 20.8\%$$

or expressed as Leaching Fraction: 0.208

APPLICATION OF THE LEACHING REQUIREMENT

Once the desired leaching requirement (LR) and evapotranspiration (ET) demand of the crop becomes known, the net water required for such crop can be calculated (Ayers and Westcot 1985):

$$\text{Net water requirement (including leaching)} = \frac{\text{ET}}{\text{(1-Leaching Fraction)}}$$

Where **net water requirement** equals depth of applied water (mm per year), **ET** equals total annual crop water demand (mm per year), and **LR** represents the leaching requirement expressed as a fraction (leaching fraction).

Example:
Al Ain:
Net plant requirement for date palms: 29,000 m^3/ha annually
Required leaching percentage: 20% (or leaching fraction 0.2)

Net water requirement incl. leaching $= \frac{29{,}000}{1 - 0.2} = \frac{29{,}000}{0.8} = 36{,}250$ m3/ha

Effectively, an additional 7250 m3/ha need to be applied during the year.
This percentage, or fraction, is applicable alongside the net normal irrigation water quantity on a yearly average. The winter season has a much lower irrigation requirement than the summer season. This can be leveraged to apply excess water for leaching during the winter to compensate for the lack of leaching during the summer.

The leaching requirement depends on the type of irrigation applied, while considering associated losses by infiltration, evaporation and transport.

For drip irrigation, where losses are reduced to a minimum, the chance of percolation and washing out of salts is reduced. The leaching fraction must therefore be applied in full.

For sprinkler irrigation, and in order to have sufficient levels of water to percolate through the root zone, additional water must be applied in proportion to evaporation losses (30% of the leaching fraction).

For flood irrigation, where infiltration losses during field application are great (30 to 50%), especially considering the sandy soils of the Emirate of Abu Dhabi, no additional leaching water is needed to supplement the regular irrigation quantity. Percolation losses are sufficient to leach the salts.

IRRIGATION WATER QUALITY

The quality of irrigation water is detailed in the scale below. According to international norms issued by the Food and Agriculture Organization (FAO), water quality (Ayers RS, Westcot DW, 1985) beyond an EC of 3,000 µS/cm, (2,000 mg/l) progressively restricts crop growth.

THE MOST SALINITY RESISTANT CROPS SUCH AS RHODES GRASS OR DATE PALMS ARE THEREFORE REDUCED TO LESS THAN 50% OF PRODUCTION BEYOND A SALINITY OF EC 25,000 µS/CM. (SEE CROP TOLERANCE AND YIELD REDUCTION IN THE TABLE BELOW).

CATEGORIES	µS/cm	SALINITY LEVEL	FAO RESTRICTION FOR CROPS
I	0-2,000	Non-saline	Salinity effects are negligible
II	2,000-4,000	Very slightly saline	Yields of sensitive crops may be restricted
III	4,000-8,000	Moderately saline	Yields of many crops are restricted
IV	8,000-16,000	Strongly saline	Only tolerant crops yield satisfactorily
V	16,000-40,000	Very strongly saline	Only a few very tolerant crops yield satisfactorily
VI	> 40,000	Extremely saline	Unsuitable for any crops

TABLE 17: Salinity Levels and Crop Restriction

The Sodium Adsorption Rate (SAR) of Irrigation water (the content of Sodium) affects susceptible plants beyond a value of 9%. Sodium susceptible plants are typically fruit trees, vegetables and pulses.

CLASS	MAGNITUDE	SAR	SODIUM HAZARD SUSCEPTIBLE PLANTS
S1	Low	0-3	No hazard
S1	Low	3-9	Slight to moderate
S1	Low	> 9	Severe
S2	Medium	10-18	Severe
S3	High	18-26	Severe
S4	Very High	> 26	Severe

TABLE 18: SAR Classes and Sodium Hazard (James et al., 1982)

The tolerance of various crops to Exchangeable-Sodium Percentage (ESP approx. equivalent to SAR, James et al., 1982) is highlighted below:

Extremely Sensitive
ESP = 2 - 10
Deciduous fruits: nuts, citrus, avocado.
Sodium toxicity symptoms

Sensitive
ESP = 10 - 20
Beans.
Stunted growth at low ESP values even if the physical condition of the soil is good

Moderately Tolerant
ESP = 20 - 40
Clover, oats, tall fescue, rice, dallis grass.
Stunted growth due to both adverse nutritional and soil conditions

Tolerant
ESP = 40 - 60
Wheat, cotton, alfalfa, barley, tomatoes, beets.
Stunted growth, usually due to adverse physical soil conditions

Most Tolerant
ESP = > 60
Crested and fairway wheatgrass, tall wheatgrass, Rhodes grass.
Stunted growth, usually due to adverse physical soil conditions

CROP SELECTION ACCORDING TO WATER QUALITY

The table below details the expected yield decrease for selected plants according to variations in the quality of applied irrigation water. As a farmer selects crops, the available quality of irrigation water should be taken into account. The table is based on: Ayers & Westcot (1994): Crop tolerance and yield potential of selected crops as influenced by irrigation water salinity (ECw) or soil salinity (ECe) - Water Quality for Agriculture; FAO.

EC_e: Average root zone salinity, measured as electrical conductivity of the saturation extract of the soil, reported in µS per centimeter (µS/cm) at 25°C.

EC_w: Electrical conductivity of irrigation water in µS per centimeter (µS/cm).

The relationship between soil salinity and water salinity (ECe = 1.5 ECw) assumes a 15 - 20% leaching fraction and a 40 - 30 - 20 - 10% water use pattern for the upper to lower quarters of the root zone.

The zero-yield potential or maximum ECe indicates the theoretical soil salinity (ECe) at which crop growth ceases.

CEREALS

FIELD CROPS	100%		90%		75%		50%		0% No Yield	
	EC_e	EC_w	EC_e	EC_w	EC_e	EC_w	EC_e	EC_w	EC_e	EC_w
Barley (Hordeum vulgare)	8.0	5.3	10	6.7	13	8.7	18	12	28	19
Cotton (Gossypium hirsutum)	7.7	5.1	9.6	6.4	13	8.4	17	12	27	18
Sugarbeet (Beta vulgaris)	7.0	4.7	8.7	5.8	11	7.5	15	10	24	16
Sorghum (Sorghum bicolor)	6.8	4.5	7.4	5.0	8.4	5.6	9.9	6.7	13	8.7
Wheat (Triticum aestivum)	6.0	4.0	7.4	4.9	9.5	6.3	13	8.7	20	13
Wheat, durum (Triticum turgidum)	5.7	3.8	7.6	5.0	10	6.9	15	10	24	16
Soybean (Glycine max)	5.0	3.3	5.5	3.7	6.3	4.2	7.5	5.0	10	6.7
Cowpea (Vigna unguiculata)	4.9	3.3	5.7	3.8	7.0	4.7	9.1	6.0	13	8.8
Groundnut (Peanut) (Arachis hypogaea)	3.2	2.1	3.5	2.4	4.1	2.7	4.9	3.3	6.6	4.4
Rice (paddy) (Oriza sativa)	3.0	2.0	3.8	2.6	5.1	3.4	7.2	4.8	11	7.6
Sugarcane (Saccharum officinarum)	1.7	1.1	3.4	2.3	5.9	4.0	10	6.8	19	12
Corn (maize) (Zea mays)	1.7	1.1	2.5	1.7	3.8	2.5	5.9	3.9	10	6.7
Flax (Linum usitatissimum)	1.7	1.1	2.5	1.7	3.8	2.5	5.9	3.9	10	6.7
Broadbean (Vicia faba)	1.5	1.1	2.6	1.8	4.2	2.0	6.8	4.5	12	8.0
Bean (Phaseolus vulgaris)	1.0	0.7	1.5	1.0	2.3	1.5	3.6	2.4	6.3	4.2

VEGETABLE CROPS

FIELD CROPS	100%		90%		75%		50%		0% No Yield	
	EC_e	EC_w	EC_e	EC_w	EC_e	EC_w	EC_e	EC_w	EC_e	EC_w
Squash, zucchini (courgette) (Cucurbita pepo melopepo)	4.7	3.1	5.8	3.8	7.4	4.9	10	6.7	15	10
Beet, red (Beta vulgaris)	4.0	2.7	5.1	3.4	6.8	4.5	9.6	6.4	15	10
Squash, scallop (Cucurbita pepo melopepo)	3.2	2.1	3.8	2.6	4.8	3.2	6.3	4.2	9.4	6.3
Broccoli (Brassica oleracea botrytis)	2.8	1.9	3.9	2.6	5.5	3.7	8.2	5.5	14	9.1
Tomato (Lycopersicon esculentum)	2.5	1.7	3.5	2.3	5.0	3.4	7.6	5.0	13	8.4
Cucumber (Cucumis sativus)	2.5	1.7	3.3	2.2	4.4	2.9	6.3	4.2	10	6.8
Spinach (Spinacia oleracea)	2.0	1.3	3.3	2.2	5.3	3.5	8.6	5.7	15	10
Celery (Apium graveolens)	1.8	1.2	3.4	2.3	5.8	3.9	9.9	6.6	18	12
Cabbage (Brassica oleracea capitata)	1.8	1.2	2.8	1.9	4.4	2.9	7.0	4.6	12	8.1
Potato (Solanum tuberosum)	1.7	1.1	2.5	1.7	3.8	2.5	5.9	3.9	10	6.7
Corn, sweet (maize) (Zea mays)	1.7	1.1	2.5	1.7	3.8	2.5	5.9	3.9	10	6.7
Sweet potato (Ipomoea batatas)	1.5	1.0	2.4	1.6	3.8	2.5	6.0	4.0	11	7.1
Pepper (Capsicum annuum)	1.5	1.0	2.2	1.5	3.3	2.2	5.1	3.4	8.6	5.8
Lettuce (Lactuca sativa)	1.3	0.9	2.1	1.4	3.2	2.1	5.1	3.4	9.0	6.0
Radish (Raphanus sativus)	1.2	0.8	2.0	1.3	3.1	2.1	5.0	3.4	8.9	5.9
Onion (Allium cepa)	1.2	0.8	1.8	1.2	2.8	1.8	4.3	2.9	7.4	5.0
Carrot (Daucus carota)	1.0	0.7	1.7	1.1	2.8	1.9	4.6	3.0	8.1	5.4
Bean (Phaseolus vulgaris)	1.0	0.7	1.5	1.0	2.3	1.5	3.6	2.4	6.3	4.2

VEGETABLE CROPS

FIELD CROPS	100%		90%		75%		50%		0% No Yield	
	EC_e	EC_w	EC_e	EC_w	EC_e	EC_w	EC_e	EC_w	EC_e	EC_w
Turnip (Brassica rapa)	0.9	0.6	2.0	1.3	3.7	2.5	6.5	4.3	12	8.0
Wheatgrass, tall (Agropyron elongatum)	7.5	5.0	9.9	6.6	13	9.0	19	13	31	21
Wheatgrass, fairway crested (Agropyron cristatum)	7.5	5.0	9.0	6.0	11	7.4	15	9.8	22	15
Bermuda grass (Cynodon dactylon)	6.9	4.6	8.5	5.6	11	7.2	15	9.8	23	15
Barley (forage) (Hordeum vulgare)	6.0	4.0	7.4	4.9	9.5	6.4	13	8.7	20	13
Ryegrass, perennial (Lolium perenne)	5.6	3.7	6.9	4.6	8.9	5.9	12	8.1	19	13
Trefoil, narrowleaf birdsfoot (Lotus corniculatus tenuifolium)	5.0	3.3	6.0	4.0	7.5	5.0	10	6.7	15	10
Harding grass (Phalaris tuberosa)	4.6	3.1	5.9	3.9	7.9	5.3	11	7.4	18	12
Fescue, tall (Festuca elatior)	3.9	2.6	5.5	3.6	7.8	5.2	12	7.8	20	13
Wheatgrass, standard crested (Agropyron sibiricum)	3.5	2.3	6.0	4.0	9.8	6.5	16	11	28	19
Vetch, common (Vicia angustifolia)	3.0	2.0	3.9	2.6	5.3	3.5	7.6	5.0	12	8.1
Sudan grass (Sorghum sudanense)	2.8	1.9	5.1	3.4	8.6	5.7	14	9.6	26	17
Wildrye, beardless (Elymus triticoides)	2.7	1.8	4.4	2.9	6.9	4.6	11	7.4	19	13
Cowpea (forage) (Vigna unguiculata)	2.5	1.7	3.4	2.3	4.8	3.2	7.1	4.8	12	7.8
Trefoil, big (Lotus uliginosus)	2.3	1.5	2.8	1.9	3.6	2.4	4.9	3.3	7.6	5.0
Sesbania (Sesbania exaltata)	2.3	1.5	3.7	2.5	5.9	3.9	9.4	6.3	17	11

VEGETABLE CROPS

FIELD CROPS	100%		90%		75%		50%		0% No Yield	
	EC_e	EC_w	EC_e	EC_w	EC_e	EC_w	EC_e	EC_w	EC_e	EC_w
Sphaerophysa (Sphaerophysa salsula)	2.2	1.5	3.6	2.4	5.8	3.8	9.3	6.2	16	11
Alfalfa (Medicago sativa)	2.0	1.3	3.4	2.2	5.4	3.6	8.8	5.9	16	10
Lovegrass (Eragrostis sp.)	2.0	1.3	3.2	2.1	5.0	3.3	8.0	5.3	14	9.3
Corn (forage) (maize) (Zea mays)	1.8	1.2	3.2	2.1	5.2	3.5	8.6	5.7	15	10
Clover, berseem (Trifolium alexandrinum)	1.5	1.0	3.2	2.2	5.9	3.9	10	6.8	19	13
Orchard grass (Dactylis glomerata)	1.5	1.0	3.1	2.1	5.5	3.7	9.6	6.4	18	12
Foxtail, meadow (Alopecurus pratensis)	1.5	1.0	2.5	1.7	4.1	2.7	6.7	4.5	12	7.9
Clover, red (Trifolium pratense)	1.5	1.0	2.3	1.6	3.6	2.4	5.7	3.8	9.8	6.6
Clover, alsike (Trifolium hybridum)	1.5	1.0	2.3	1.6	3.6	2.4	5.7	3.8	9.8	6.6
Clover, ladino (Trifolium repens)	1.5	1.0	2.3	1.6	3.6	2.4	5.7	3.8	9.8	6.6
Clover, strawberry (Trifolium fragiferum)	1.5	1.0	2.3	1.6	3.6	2.4	5.7	3.8	9.8	6.6

FRUIT CROPS

FIELD CROPS	100%		90%		75%		50%		0% No Yield	
	EC_e	EC_w	EC_e	EC_w	EC_e	EC_w	EC_e	EC_w	EC_e	EC_w
Date palm (phoenix dactylifera)	4.0	2.7	6.8	4.5	11	7.3	18	12	32	21
Grapefruit (Citrus paradisi)	1.8	1.2	2.4	1.6	3.4	2.2	4.9	3.3	8.0	5.4
Orange (Citrus sinensis)	1.7	1.1	2.3	1.6	3.3	2.2	4.8	3.2	8.0	5.3
Peach (Prunus persica)	1.7	1.1	2.2	1.5	2.9	1.9	4.1	2.7	6.5	4.3
Apricot (Prunus armeniaca)	1.6	1.1	2.0	1.3	2.6	1.8	3.7	2.5	5.8	3.8
Grape (Vitus sp.)	1.5	1.0	2.5	1.7	4.1	2.7	6.7	4.5	12	7.9
Almond (Prunus dulcis)	1.5	1.0	2.0	1.4	2.8	1.9	4.1	2.8	6.8	4.5
Plum, prune (Prunus domestica)	1.5	1.0	2.1	1.4	2.9	1.9	4.3	2.9	7.1	4.7
Blackberry (Rubus sp.)	1.5	1.0	2.0	1.3	2.6	1.8	3.8	2.5	6.0	4.0
Boysenberry (Rubus ursinus)	1.5	1.0	2.0	1.3	2.6	1.8	3.8	2.5	6.0	4.0
Strawberry (Fragaria sp.)	1.0	0.7	1.3	0.9	1.8	1.2	2.5	1.7	4	2.7

TABLE 19: Decreasing Crop Yield Levels as Salinity Increases

CRUST BREAKING, MULCHING, ORGANIC FERTILIZER

Salt dissolved in the soil, and carried in irrigation water, has a tendency to move upwards by capillary action (similar to coffee rising in a cube of sugar) to the soil surface. Breaking the soil layers of the surface crust disrupts the capillary pores and the rising of salts. The incorporation of organic substance (mulching) with compost and manure further inhibits this tendency and provides a fertilizing effect.

FERTILIZATION

Special problems are encountered when trying to fertilize an arid climate with saline water and sandy textures.

Most Nitrogen fertilizers are produced as salts and, when applied, tend to aggravate the problem of salinity. An exception is noted for the use of Nitrogen in the form of Urea, which can in fact be recommended. Nonetheless, Nitrogen should also be applied in a pH neutral form (e.g. Calcium Ammonium Nitrate). Acid forms of Nitrogen tend to dissolve as carbonates and gypsum, which should be avoided (subsidence). On the other hand, Potassium is usually naturally contained in irrigation water, with the exception of desalinated water where it is added in water soluble form based on fertilization recommendations. Phosphates have limited solubility in water, except for various grades of Superphosphates, which can be mixed into irrigation water and applied as needed.

The retention of fertilizers in irrigated soils depends on the soil's texture and organic substance composition. In loamy soils, fertilizers cling to the exchange complex of organic substance and clay minerals. Therefore, they are not easily washed out and remain available for plant roots. However, in sandy soils, the dominant soil type in the Emirate of Abu Dhabi, fertilizers tend to wash out rapidly due to excessive permeability. In this case, it is recommended to apply fertilizers in low but frequent doses based on the actual needs of the plants. This will help reduce losses and avoid contamination of the aquifer. Organic manure and compost fertilizers also improve the retention of water soluble fertilizers.

CROP WATER REQUIREMENTS

Water is a scarce commodity. Even when provided free of charge, pumping and application costs are still a real consideration. Furthermore, and while it is evident that the rational use of water is beneficial for the environment, such rationing also carries economic significance. Therefore, applying crop water requirements effectively means reaching the best compromise between a good plant yield, water conservation, serving the environment, and reducing irrigation costs. The table below highlights the clear advantage of using drip irrigation compared to sprinkler or flood irrigation when it comes to irrigation efficiency (reducing losses by infiltration and evaporation).

Furthermore, the application of saline water brings salts into the soil. The excess salt consequently needs to be washed out with leaching water.

FOR EXAMPLE, WITH AN IRRIGATION WATER QUALITY OF 15,000 µS/CM (9,600 MG/L) AND A USUAL IRRIGATION RATE OF 35,000 M³/HA PER YEAR (PALM TREES), A 33.6 KG/M² OF SALT IS DEPOSITED. THE AMOUNTS OF SALT DEPOSITED INTO THE SOIL SHOULD THEREFORE BE LIMITED BY REDUCING IRRIGATION TO THE CLIMATIC CROP WATER REQUIREMENT.

The calculation is based on Abu Dhabi climatological data recorded over the last ten years and made available by the National Centre for Meteorology and Seismology (2017), and on Crop Water Requirements (Dorenboos J. and Pruitt, W.O., 1996) Typical Crop Water Requirements (gross requirement that caters for typical losses for drip, sprinkler or flood irrigation) for the three regions in Abu Dhabi are detailed for main all-year crops

ALFALFA

LOCATION	IRRIGATION TYPE	NET WATER REQUIREMENT m3/ha/year	APPLICATION EFFICIENCY	CROP COEFFICIENT	GROSS WATER REQUIREMENT m3/ha/year
Al Ain	Drip	29,680	0.9	0.95	34,713
	Sprinkler	29,680	0.6	0.95	52,070
	Flood	29,680	0.35	0.95	89,263
Abu Dhabi	Drip	25,846	0.9	0.95	30,229
	Sprinkler	25,846	0.6	0.95	45,344
	Flood	25,846	0.35	0.95	77,733
Mezeira	Drip	26,040	0.9	0.95	30,456
	Sprinkler	26,040	0.6	0.95	45,684
	Flood	26,040	0.35	0.95	78,315

DATE PALM, RHODES GRASS					
LOCATION	IRRIGATION TYPE	NET WATER REQUIREMENT m3/ha/year	APPLICATION EFFICIENCY	CROP COEFFICIENT	GROSS WATER REQUIREMENT m3/ha/year
Al Ain	Drip	29,680	0.9	0.9	36,642
	Sprinkler	29,680	0.6	0.9	54,963
	Flood	29,680	0.35	0.9	94,222
Abu Dhabi	Drip	25,846	0.9	0.9	31,909
	Sprinkler	25,846	0.6	0.9	47,863
	Flood	25,846	0.35	0.9	82,051
Mezeira	Drip	26,040	0.9	0.9	32,148
	Sprinkler	26,040	0.6	0.9	48,222
	Flood	26,040	0.35	0.9	82,666

TABLE 20: Net and Gross Crop Water Requirements for Alfalfa, Rhodes Grass and Date palm in Three Regions in Abu Dhabi; Irrigation Efficiencies with Drip, Sprinkler and Flood Irrigation Calculations Based on Abu Dhabi Climatological Data and Crop Water Requirements (Dorenboos J. and Pruitt, W.O., 1996).

REAL APPLICATION RATES IN THE EMIRATE OF ABU DHABI (35,000 UP TO 85,000 M³/HA), AS MEASURED IN THE FIELD, CLEARLY EXCEED CALCULATED GROSS WATER REQUIREMENTS, ESPECIALLY FOR FLOOD AND SPRINKLER IRRIGATION. THIS OUTCOME CONSEQUENTLY CALLS FOR THE ADEQUATE USE OF DRIP IRRIGATION. AN ADDITIONAL LEACHING REQUIREMENT OF 20 TO 30% IS NECESSARY ONLY WHEN WATER-SAVING DRIP IRRIGATION IS USED.

SOILS WITH DRAINAGE PROBLEMS, OVER-IRRIGATION

Another problem encountered at the root level, that also hinders free water drainage, is the presence of soils with an impermeable layer within their rooting depth such as rock, calcareous or gypsiferous hardpans. Free drainage is important, as is the lack of stagnant water in the root zone, and this to avoid ascending capillary salinization from the perched water level. Drainage can be improved by using hardpan breaking equipment, for example, by ripping drainage lines into the hardpan at horizontal distances from 3 to 5 m. Underground leakage in the irrigation pipes may also contribute to local drainage problems, and therefore to salinity.

GYPSUM FOR NON-SALINE SODIC SOILS

Soils with high SAR and high salinity are usually unaffected by infiltration problems. However, toxicity for Sodium susceptible plants (fruits, vegetables, beans) is a serious issue and may lead to the exclusion of such plants from the cropping pattern (see SAR above).

Under normal salt leaching procedures, the SAR is reduced to a harmless level. But when desalinated irrigation water is applied, this could lead to a SAR problem due to the residual enrichment of Sodium. In this case, additional sources of Calcium must be provided. High SAR values are indicated by a high pH value (>8.8). Based on the identified pH, the following melioration measures may be implemented:

pH	tons/ha for top 15 cm of soil (sandy)
8.8	0
9.0	1.5
9.2	3.0
9.4	4.5

TABLE 21: Gypsum Requirement for Sodic Soils (Abrol, Dargan and Bhumbla, 1973)

CROP ROTATION AND FALLOW FOR SOIL RECUPERATION

The conducted field survey revealed that farm surfaces that had been fallow for some years were noticeably less saline than irrigated areas. This result could be attributed to a natural and slow desalinization process that occurs in sandy soils catalyzed by natural precipitation and dew. In such cases, it is recommended to give the soil an opportunity to recover.

IRRIGATION SUITABILITY

Along with soil mapping and classification, the UAESIS survey provided an evaluation of soil suitability for the development of irrigated agriculture.

The adopted evaluation follows the land suitability classification concepts developed by the FAO in its Framework for Land Evaluation (FAO 1976). The FAO system is generally recognized as a benchmark for land evaluation and has been used as the basis for specific land evaluation applications such as irrigated agriculture (FAO 1985).

Below is an overview of the soil characteristics associated with the various ratings:

S1 **Land that is highly suitable for irrigated agriculture.**
The soil in this category is able to sustainably produce high yields for a wide variety of climatically adapted crops. The soils are nearly level and well drained; and are deep, with a fine sandy texture or a finer, single grained texture. This allows for easy root penetration and for the retention of abundant air and water in the root zone. The soils have low soluble salts, sodicity, gypsum content, and calcium carbonate content and a neutral pH. Soils that form part of this category in Abu Dhabi have a lighter texture and contain more gravel and carbonate than other locations considered to be highly suitable. However these criteria are appropriate for a range of soils available in the Emirate.

S2 **Land of moderate suitability for irrigated agriculture.**
The soil in this category has an inherently lower productive capacity compared with S1 soils. The quality of soils and lands in this category may restrict irrigation but such restrictions can be corrected or compensated for relatively easily. S2 soils in Abu Dhabi have a sandy texture and are single grain or massive. They are deep and somewhat excessively or well drained. These soils are typically very slightly saline, non-sodic, have low gypsum content, and can have a hummocky microrelief. Appropriate management strategies can help overcome these moderate restrictions.

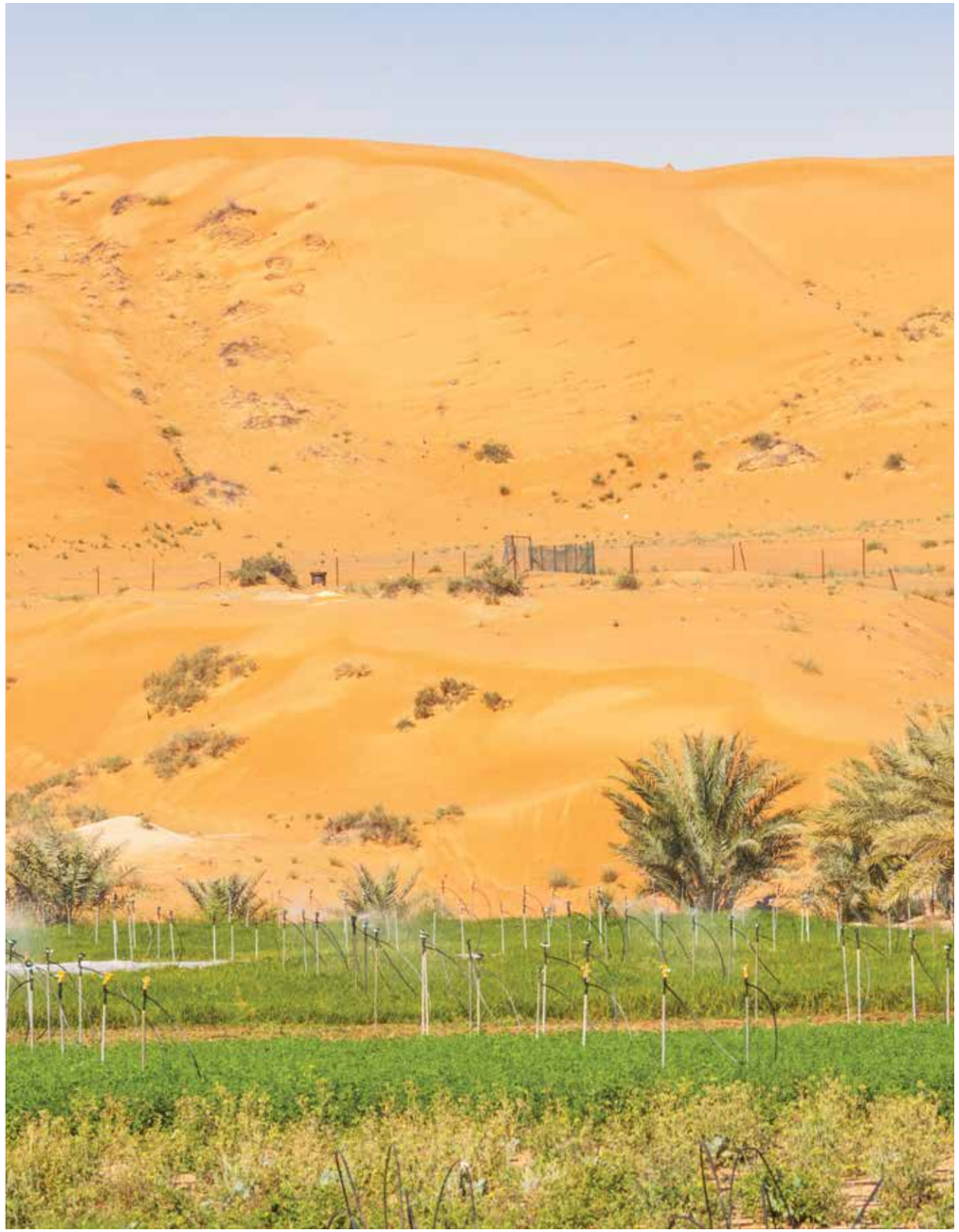
S3 **Land of marginal suitability for irrigated agriculture.**
The soil in this category has a lower productive capacity compared with S1 and S2 soils. It presents severe limitations that could be corrected with the implementation of appropriate management strategies. Soils that fall under this category in Abu Dhabi are moderately deep with a hardpan or water table occurring within 100-150 cm from the soil surface. They have a sand to a sandy loam texture and are single-grained or massive. They are typically slightly saline to saline and have moderate gypsum contents. These soils may have a moderately steep gradient (up to 32%) with a moderately high relief (up to 9 meters).

NI **Land that is currently unsuitable for irrigated agriculture.**
Soils that fall under this category in Abu Dhabi typically have shallow rooting depths with hardpans within 50 – 100 cm of the soil surface. They also have a high gypsum content close to the surface, are saline or have a high relief (up to 30 m) and a steep gradient (up to 56%).

N2 **Land considered permanently unsuitable for irrigated agriculture.**
The soil in this category has an inherently lower productive capacity compared with S1 soils. The quality of soils and lands in this category may restrict irrigation but such restrictions can be corrected or compensated for relatively easily. S2 soils in Abu Dhabi have a sandy texture and are single grain or massive. They are deep and somewhat excessively or well drained. These soils are typically very slightly saline, non-sodic, have low gypsum content, and can have a hummocky microrelief. Appropriate management strategies can help overcome these moderate restrictions.

SOIL CHARACTERISTIC	LIMITATION CODE	RATING CATEGORIES S1	S2	S3	N1	N2	RESTRICTIVE FEATURE	DEFINITION
Hardpan or rock depth, c	m	>200	200 - >150	150 - >100	100 - > 50	0 - 50	Restrictive layer	Impervious soil or rock layers inhibit the movement of water or roots in soil
Water table depth, cm	w	>200	200 - >150	150 - >100	100 - > 50	0 - 50	Wetness	Soil is wet in the desired time of use
Salinity (EC 1:1 weight/volume), avg. 50-0 cm	z	1.3 - 0	>1.3 - 2.7	>2.7 - 5.3	>5.3 - 13.3	>13.3	Excess salt	Excess water-soluble salts in the soil restrict the growth of most plants and cause yield depression
(EC 1:1 weight/volume) avg. 100- 50cm	z	1.3 - 0	>1.3 - 2.7	>2.7 - 5.3	>5.3 - 13.3	>13.3	Excess salt	Excess water-soluble salts in the soil restrict the growth of most plants and cause yield depression
Gypsum- depth to upper boundary of gypsic diagnostic horizon	y	>200	200 - >100	100 - >50	50 - > 20	0 - 20	Excess gypsum	Excess gypsum can result in soil subsid-ence after irrigation
Texture for 25-0cm layer	t	lS, lfS, lvfS, fS	S				Too sandy	The soil is soft and loose, low water holding capacity and low fertility
Texture for 25-0cm layer	t	scL	S				Too clayey	The soil is not permeable enough, slow to dry and induces secondary salinity
Slope gradient%	s	1 - 0	>3 - 1	>3 - 32	>32 - 56	>56	Too steep	The slope limits machinery use, and causes erosion risk
Relief, height above surrounding area, m	r	1 - 0	>3 - 1	>3 - 9	>9 - 30	>30	Too high	The height restricts the ability to re-contour the area

TABLE 22: Soil Rating Criteria Based on the FAO System (1976, 1985).



OUTLOOK AND RECOMMENDATIONS

OUTLOOK AND RECOMMENDATIONS

Water resources in the Emirate of Abu Dhabi face severe risks of depletion and quality deterioration. Meanwhile, farms are experiencing a lack of good irrigation water and are consequently facing the salinization of their soil resources. This has led to the widespread temporary fallow (40%) of farmlands. More than 80% of agricultural soils in the Emirate are affected by soil salinity.

As for factors influencing soil salinity, they mainly include precipitation, leaching processes, the capillary ascent of dissolved salts, irrigation management, heavy textures, and impermeable layers. Furthermore, the incorrect disposal of brine on farms from desalination units has become a growing concern as the number of desalination units on farms rises rapidly.

FARM IRRIGATION MANAGEMENT

It should be noted that, based on a comparison of irrigation water and soil salinity, most farms (75%) are well managed. However, most farms can still improve their irrigation management when it comes to crop patterns, groundwater use, and tillage. Accepted rules for good farm management include:

- Leaching out accumulated salts during the cooler and wetter seasons of the year, when evaporation levels are low.
- Breaking crusts on the soil surface and covering the surface with mulch to prevent capillary action that leads to evaporation and salt deposition at the surface.
- Avoiding over irrigation during the summer to avoid salt deposition.
- Selecting crops based on the available quality of irrigation water and soil.
- Using available good groundwater resources and desalinated seawater for high-value crops. Saline groundwater should be used for more salt tolerant crops while TSE should be used whenever possible. However, TSE use should be limited to cases where it does not come into contact with products designated for direct human consumption. It can be safely used for landscapes and fruit tree irrigation.

Further recommendations are provided below to help mitigate soil salinity and maintain the usefulness of soils for more sustainable agricultural practices:

- Controlling brine disposal at desalination plants to guarantee correct processes are followed.
- Implementing more efficient irrigation practices, e.g. drip irrigation.
- Avoiding irrigation beyond crop water requirements during the summer to avoid salt deposition, perched water tables and the capillary rise of salts.
- Leveraging the recognized positive effect of organic fertilizers to attenuate the effect of salinity and alkalinity.
- For non-saline sodic soils, applying gypsum amendments according to the identified pH.
- For annual crops, applying crop rotation within the farm, i.e. leave a proportion of the surface fallow for some years to give the soil a chance to revert to lower salinity levels.

LONG-TERM SOIL SALINITY MONITORING

Soil salinity monitoring was established during this project. It is recommended that such monitoring continues throughout the coming years on a biannual basis in order to assess seasonal changes in soil salinity and long-term changes in soil salinity, and to optimize farm irrigation management.

The observation of long-term changes in agricultural soils can lead to the establishment of key performance indicators. Such KPIs are necessary to develop a nationwide concept for the optimal use of available water and soil resources. Building on this scientific basis, decision makers can develop meaningful and valuable policies and regulations.

SOIL MANAGEMENT PLAN

The Soil Management Plan provides recommendations for every Irrigation District in the Emirate of Abu Dhabi. Together with the soil suitability map and groundwater quality data, the soil management plan can form the basis of discussions with ADAFSA and other stakeholders for any future development of agriculture in the Emirate. Further to the plan, recommended measures should be initiated and implemented in cooperation with stakeholders.

SOIL CLASSIFICATION

Together, the extensive soil survey, the intensive soil survey, and the current farmland soil survey provide a comprehensive database for the soils available in the Emirate of Abu Dhabi. The survey approach, classification scheme, and the UAESIS database can also serve as a standard reference for similar soil surveys to be conducted in the other Emirates.

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