Food and Agriculture Organization of the United Nations

International Network of Salt-Affected Soils

"Sustainable Soil Management in Salt-Affected Lands: Reducing Toxicity & Boosting Crop Production"

Prof. Dr. Jorge Batlle-Sales

INSAS Chair

Chair IUSS Commission on SAS

GLOBAL SOIL PARTNERSHIP

Food and Agriculture Organization of the United Nations

International Network of Salt-Affected Soils

Event's objectives

1. To introduce the problem of toxicity in salt-affected soils with indications on how to assess and monitor it.
2. To present management practices for enhancing crop productivity in salt-affected soils facing toxicity issues.
3. To support countries in managing salt-affected soils for increased crop productivity.

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ambio climático • El cambio climático se
fiere a los cambios a largo plazo de las...
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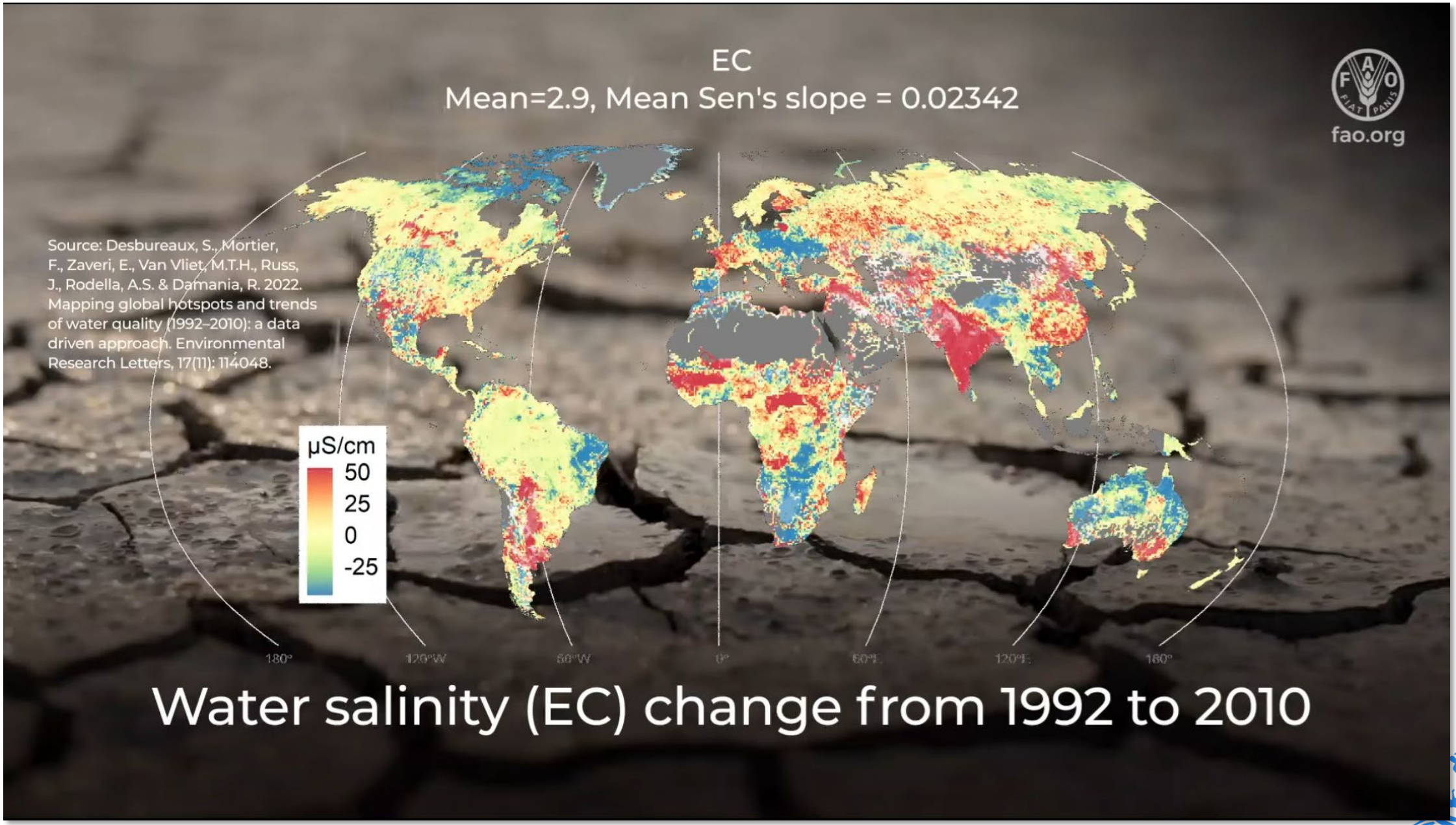
North America
78 Mha
(4% of the region)
Europe and Eurasia
238 Mha
(9% of the region)
Asia
154 Mha
(7% of the region)
Near East and North Africa
230 Mha
(18% of the region)
sub-Saharan Africa
88 Mha
(4% of the region)
Latin America and the Caribbean
235 Mha
(12% of the region)
Australia and the Pacific
357 Mha
(42% of the region)
Approximately 1.4 billion hectares of land, or 10.7 percent of the world's land area are affected by salinization.



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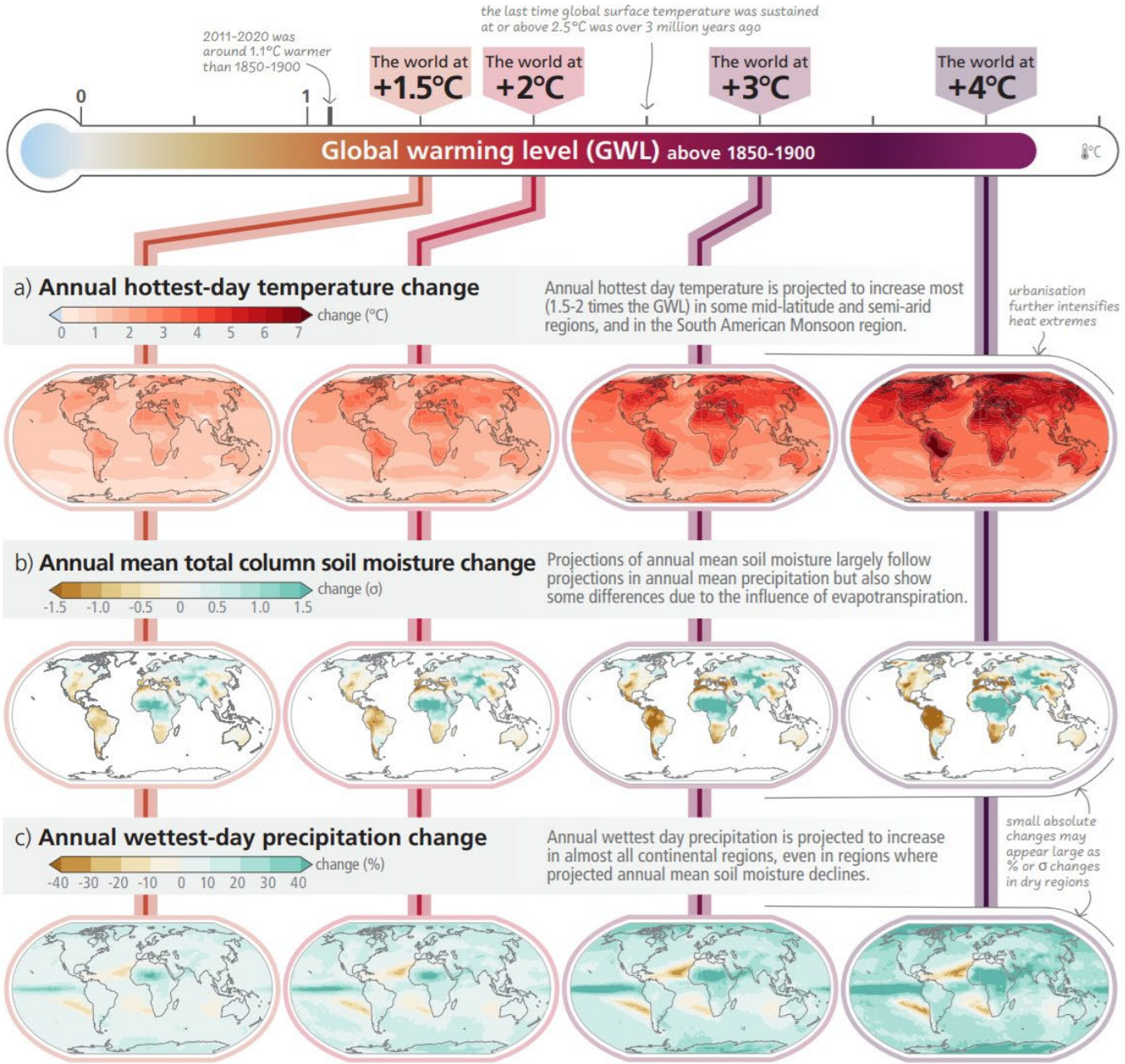
INTERGOVERNMENTAL PANEL ON climate change

WMO UNEP

The IPCC provides regular assessments of the scientific basis of climate change, its impacts and future risks, and options for adaptation and mitigation.

Section 3

With every increment of global warming, regional changes in mean climate and extremes become more widespread and pronounced



The Anna Karenina principle and the "health" of SAS

The name of the principle derives from Leo Tolstoy´s 1877 novel "Anna Karenina", which begins:

"All happy families are alike; each unhappy family is unhappy in its own way".

Primary salinity appears as a result of geochemical processes along the landscape or at the coastline.

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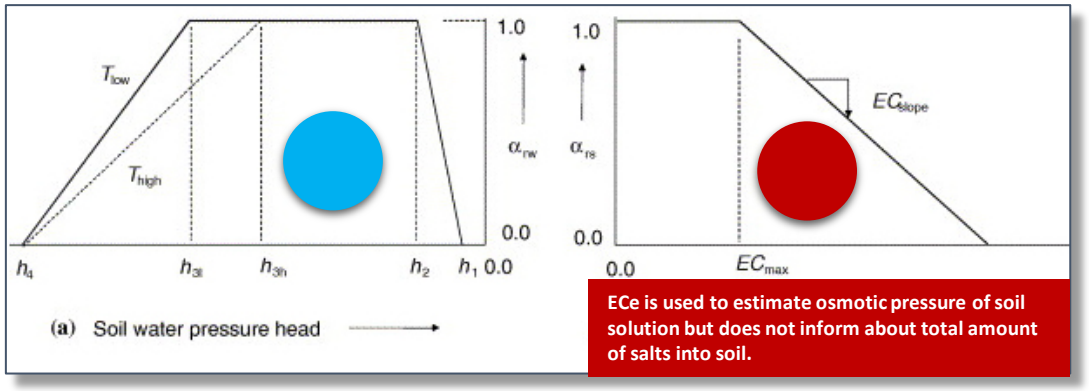
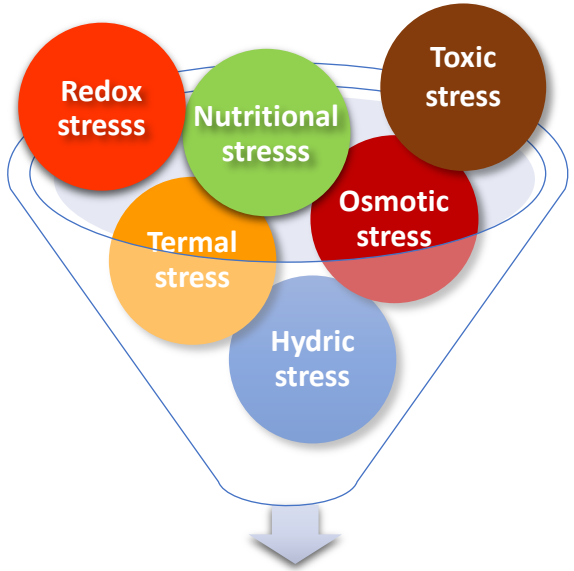
What affects plant growth in SAS?

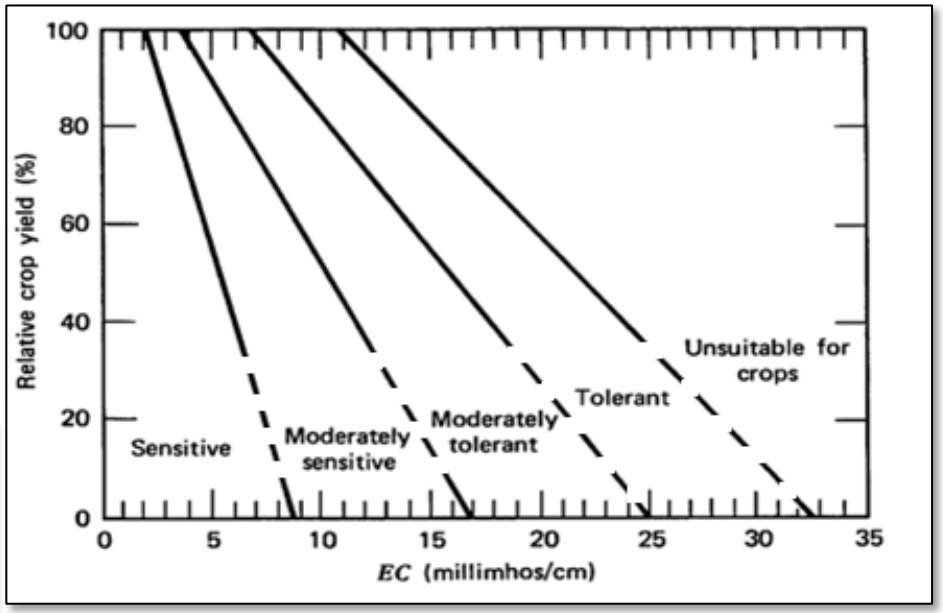


ECe is used to estimate osmotic pressure of soil solution but does not inform about total amount of salts into soil.



Total abiotic stress

+ biotic stress



Plants sensitivity to salinity differs along their development stage

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Comparison Table of Salt-Affected Soils

Soil Type	ECe (dS/m)	SAR	ESP (%)	pH	Effects
Saline	>4	<13	<15	<8.5	Osmotic stress, reduced growth
Sodic	<4	>13	>15	>8.5	Poor structure, low infiltration
Saline-Sodic	>4	>13	>15	>8.5	Toxicity, structural issues

$$ESR = \frac{[NaX]}{[CaX]+[MgX]} = K_G \cdot \frac{[Na^+]}{\sqrt{\frac{[Ca^{2+}]+[Mg^{2+}]}{2}}}$$

ESR = Exchangeable Sodium Ratio

$ESR = K_G \cdot SAR$

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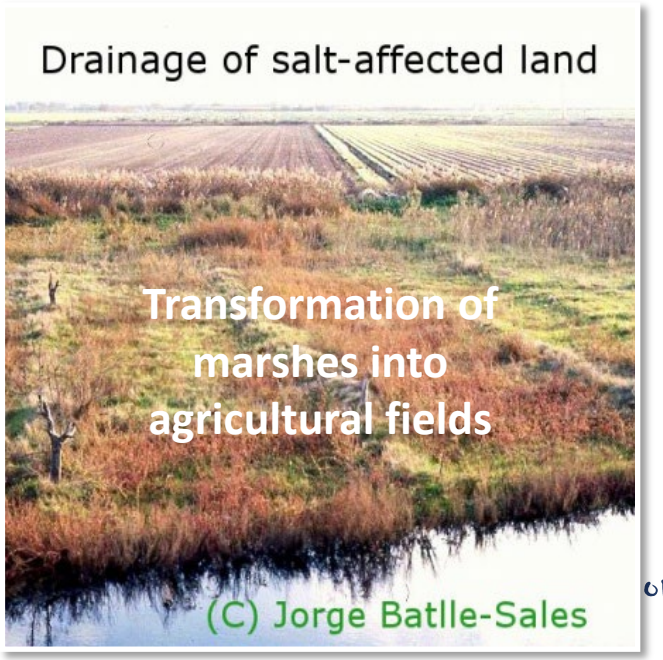
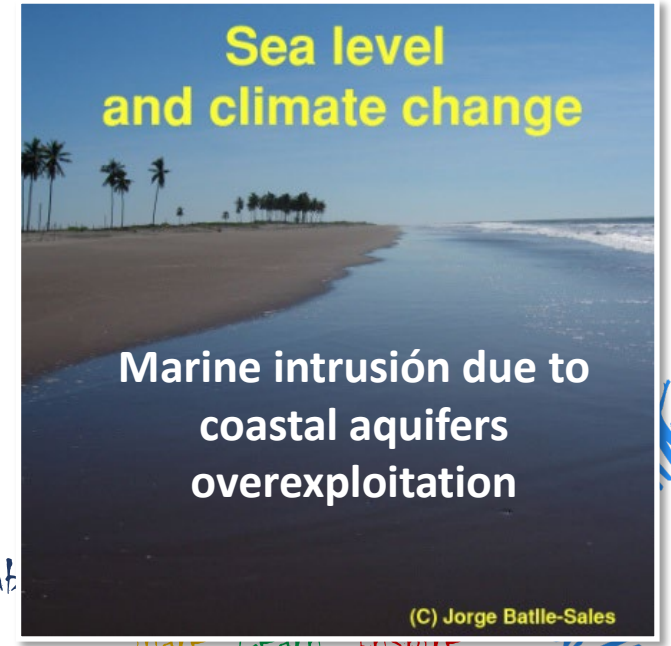
Salinized irrigated fields
in Central Spain
Irrigation with brackish
and saline waters
(C) Jorge Batlle-Sales


(C) Jorge Batlle-Sales
Remobilization of fossile
salts by irrigation


Salt tolerant crops
Improper irrigation
management and
defective drainage
(C)Jorge Batlle-Sales


Salinization of lands
induced by deforestation
Saline groundwater
raise after eliminating
“natural pumps” that
keep groundwater deep


Drainage of salt-affected land
Transformation of
marshes into
agricultural fields
(C) Jorge Batlle-Sales


Sea level
and climate change
Marine intrusión due to
coastal aquifers
overexploitation
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ATLANTIC OCEAN
MEDITERRANEAN SEA
GALICIA
ASTURIAS
CANTABRIA
CASTILLA Y LEON
CATALUNA
ARAGON
EXTREMADURA
LA MANCHA
VALENCIA
MURCIA
ANDALUCIA
ILES BALEARS
La Coruna
Gijon
Oviedo
Santander
Bilbao
Donostia-San Sebastian
Pau
Toulouse
Montpellier
Marseille
Perpignan
Santiago de Compostela
Pontevedra
Vigo
Orense
Leon
Vitoria-Gasteiz
Pamplona
NAVARRA
ANDORRA
Andorra la Vella
Burgos
Logrono
Palencia
Braga
Zaragoza
Lleida
Porto
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ECe10.64 dS/m
ECe 37.8 dS/m

Learning from halophytes


Argila
(Varietat
testimoni)

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Salt-tolerant plants

eHALOPH V5.63 (07-04-25)

a database of halophytes and other salt-tolerant plants

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Lobularia maritima (L.) Desv.

Submitted by **T J Flowers**
May 19th 2025, 5:39 am
Approved by **T J Flowers**
May 19th 2025, 5:39 am

Oxybasis glauca (L.) S.Fuentes, Uotila & Borsch

Submitted by **Mohammed J. Al-Azzawi**
May 18th 2025, 3:02 pm
Approved by **T J Flowers**
May 19th 2025, 5:35 am

Oryza coarctata Roxb.

Submitted by **Mohammed J. Al-Azzawi**

Posts

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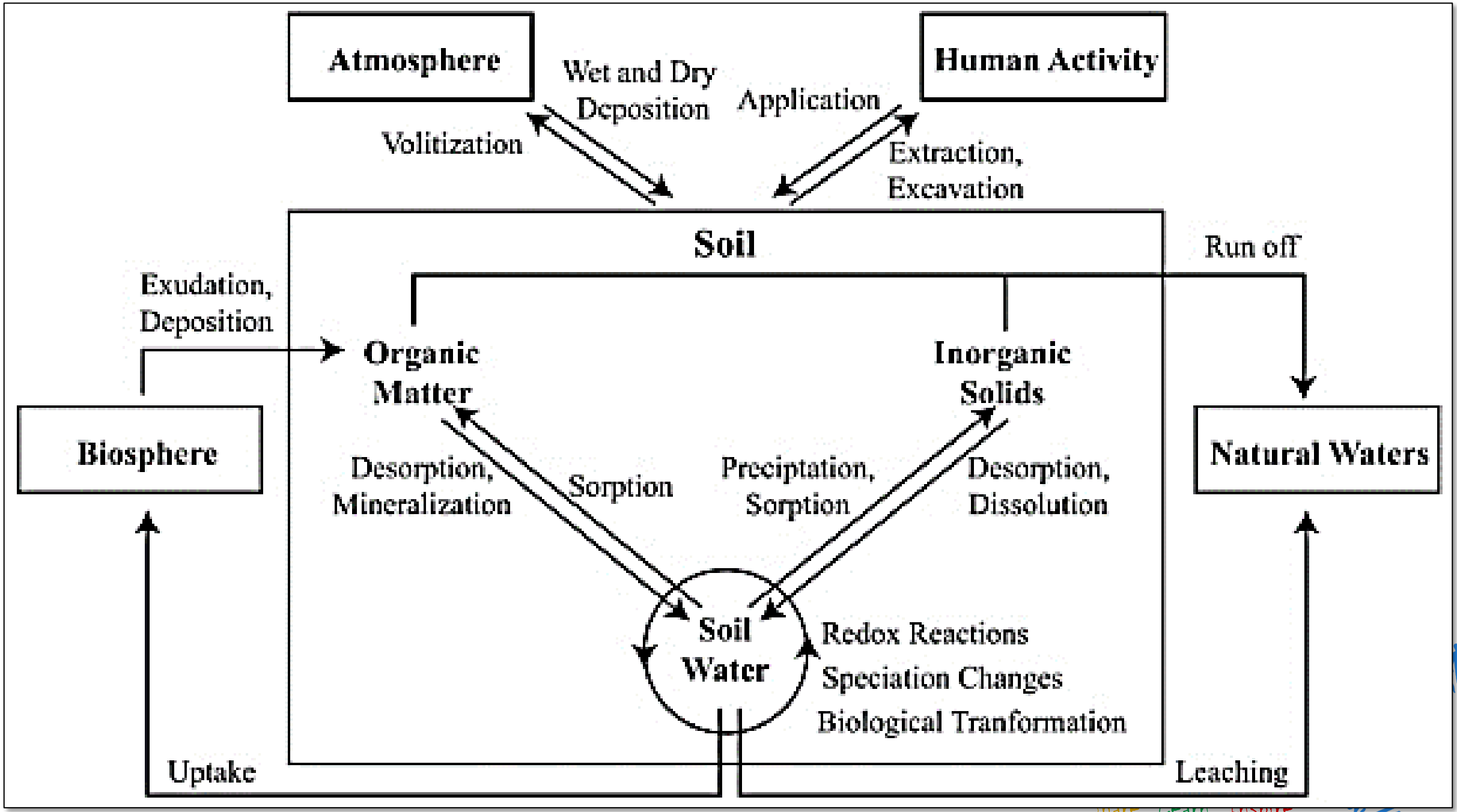
Toxicities of concern in SAS

- Chloride.
- Sodium.
- Boron.
- Aluminium.
- Cadmium.
- Arsenic.
- Biocides.
- Emerging pollutants.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Volitization
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Extraction, Excavation
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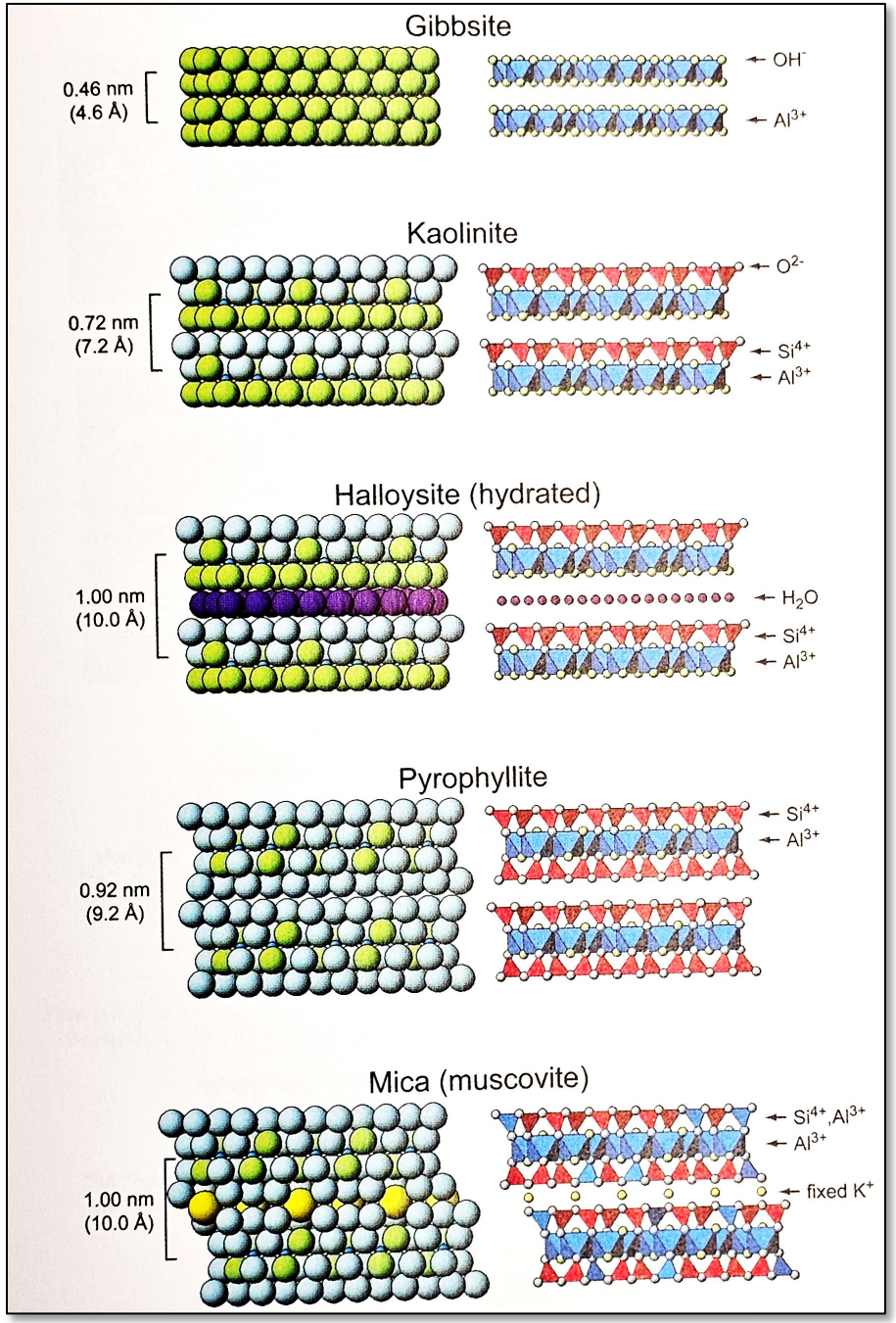
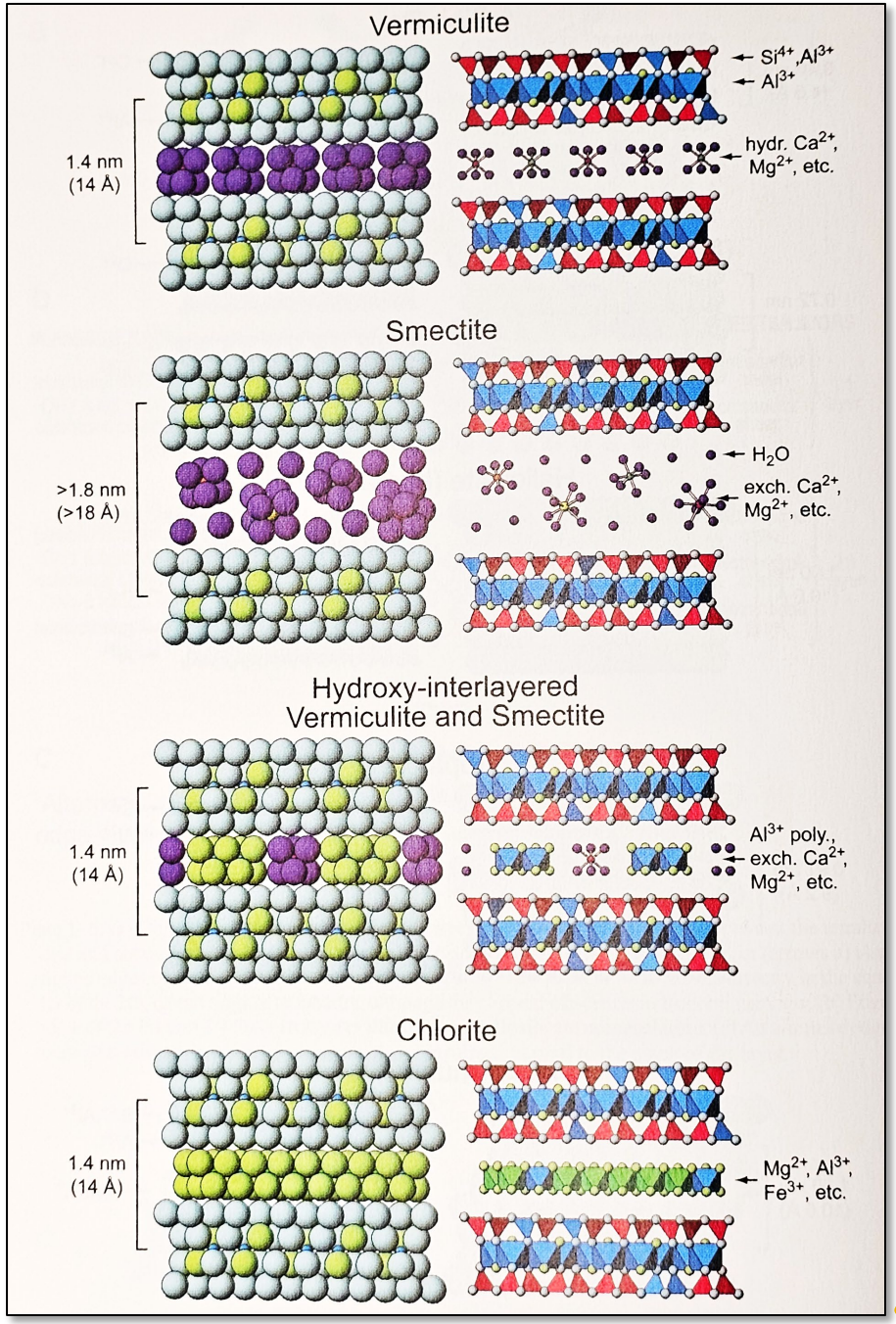
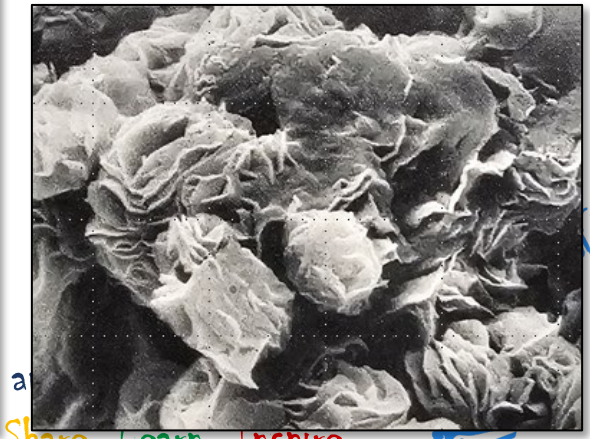
Inorganic Solids
Biosphere
Natural Waters
Desorption, Mineralization
Sorption
Precipitation, Sorption
Desorption, Dissolution
Soil Water
Redox Reactions
Speciation Changes
Biological Tranformation
Uptake
Leaching







Cation exchange and colloidad activity

Family	Layer charge per formula unit	CEC meq/kg	Surface area m^2/g	C-spacing Angstrom	Expansible	pH-dependency of charge	Colloidal activity
Kaolinite	0	10-100	10-20	7.2	No	Extensive	Low
Smectite	0.25-0.6	800-1200	600-800	Variable	Yes	Minor	Extremely High
Vermiculite	0.6-0.9	1200-1500	600-800	10-15	Yes	Minor	Medium
Illite	0.6-0.10	150-400	70-200	10	No	Minor	Low
Mica	1	200-400	70-120	10	No	Medium	Low
Chlorite	1	200-400	70-150	14	No	Medium	Low
Allophane	-	200-1500	100-1000	-	No	Extensive	Medium
Organic matter	-	1000-3000	100-800	-	No	Extensive	Medium

Cation exchange

Salinization and cation exchange

$$Clay\text{-}Ca + 2Na^{+} + 2Cl^{-} \rightleftharpoons Clay\text{-}Na_2 + Ca^{2+} + 2Cl^{-}$$

$$Clay\text{-}Ca + 2Na^{+} + CO_3^{2-} \longrightarrow Clay\text{-}Na_2 + CaCO_3 \downarrow$$

Desalinization and alkalinization (soil dispersion)

$$Clay\text{-}Na_2 + 2H^{+} + 2OH^{-} \rightleftharpoons Clay\text{-}H_2 + 2Na^{+} + 2OH^{-}$$

Correction of alkalinization (gypsum application)

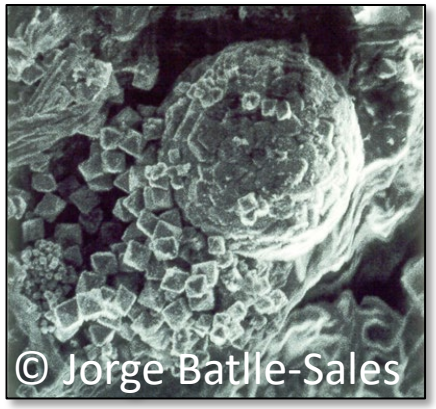
$$Clay\text{-}Na_2 + Ca^{2+} + SO_4^{2-} \rightleftharpoons Clay\text{-}Ca + 2Na^{+} + SO_4^{2-}$$

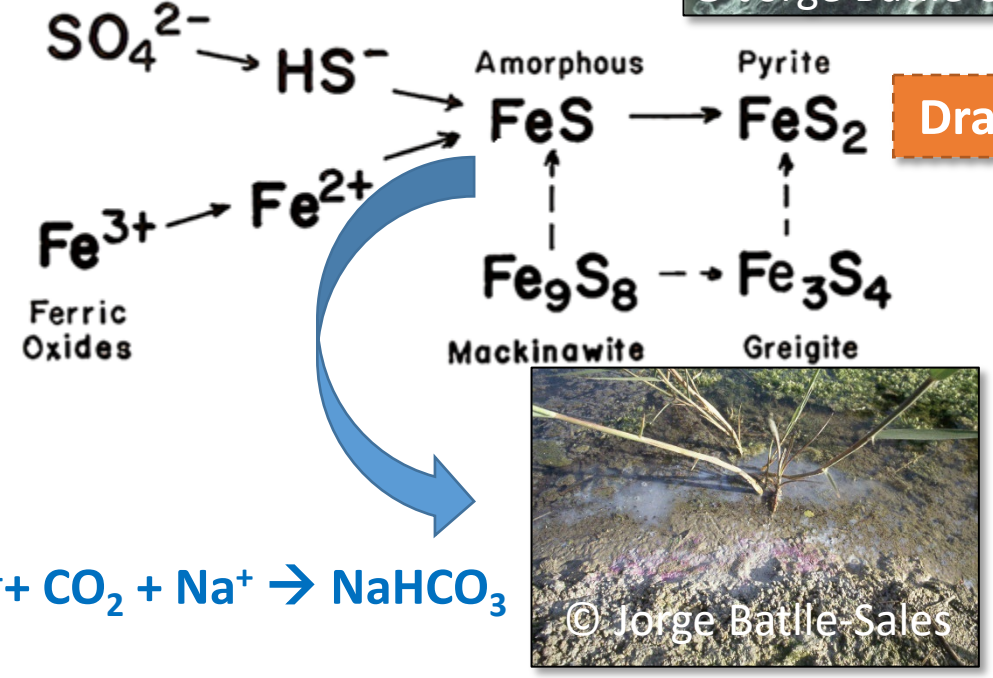
Seawater: Cl^- + Na^+ + SO_4^{2-} + Mg^{2+} + B + …

Marine intrusion on submerged soil

Reduction conditions promoted by *Desulfovibro* in presence of organic matter.

$Ox + ne^- + mH^+ \leftrightarrow Red + m/n\ H_2O$



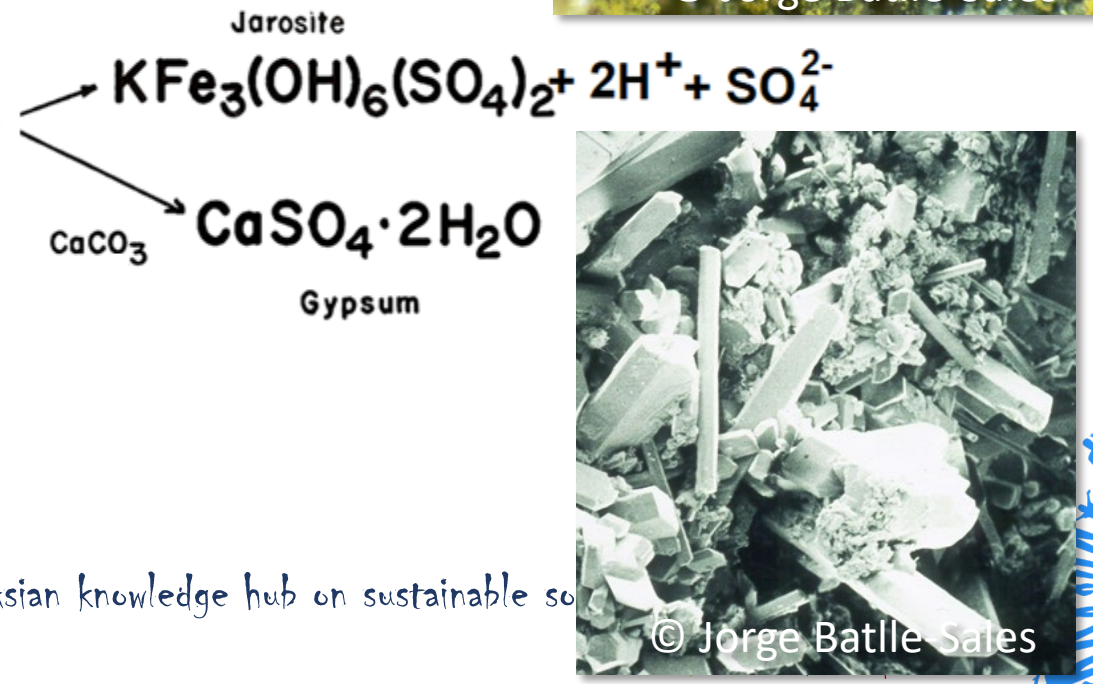


$OH^- + CO_2 + Na^+ \rightarrow NaHCO_3$

Reaireated drained soil

Oxidation conditions promoted by *Thiobacillus ferrooxidans*

Drainage



Characterization of soil properties and salinity status

Characterization of the soil profile.
Field tests.
Soil sampling (pit and/or augering).
Laboratory determinations:

- **Analysis of physical and chemical properties, and mineralogy of each horizon.**
- **Analysis of the saturation paste extract of every horizon.**

Assessment of salinity spatial and temporal variation.

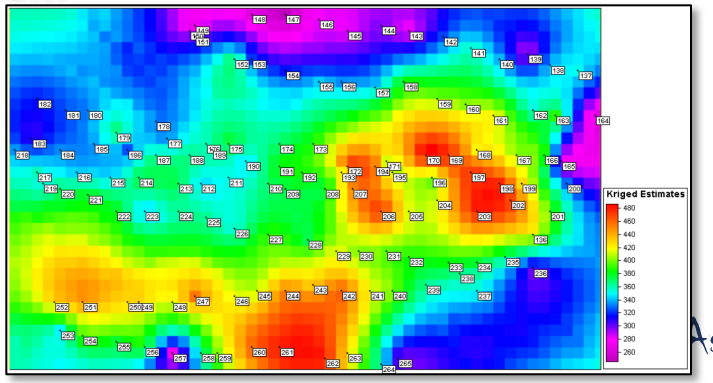
Selected technological developments used in quick mapping and multitemporal characterization of SAS

Proximal soil sensing technologies (non intrusive).

- **Electromagnetic Induction (EMI).**
- **Geo-electrical resistivity profiling (ERP).**
- **Time Domain Reflectometry (TDR).**
- **In-the-field soil spectroscopy in Vis–NIR.**
- **Ground-penetrating radar (GPR).**

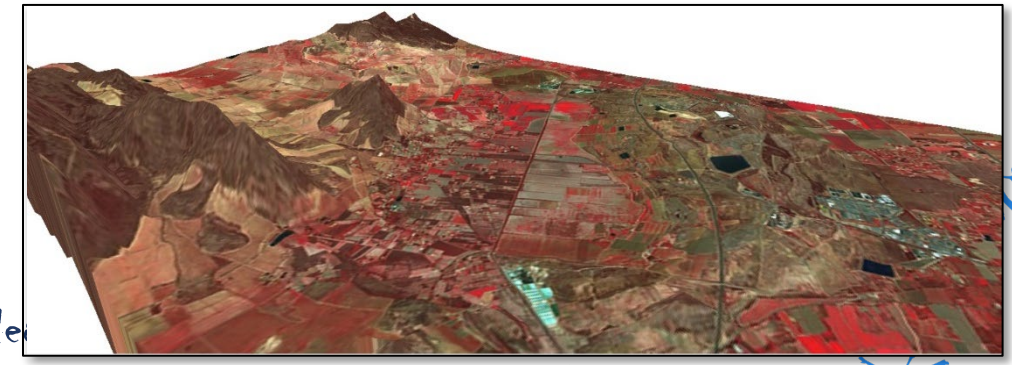
Mathematics and computing.

- **Geostatistics.**
- **Conditional simulation.**
- **Machine learning.**



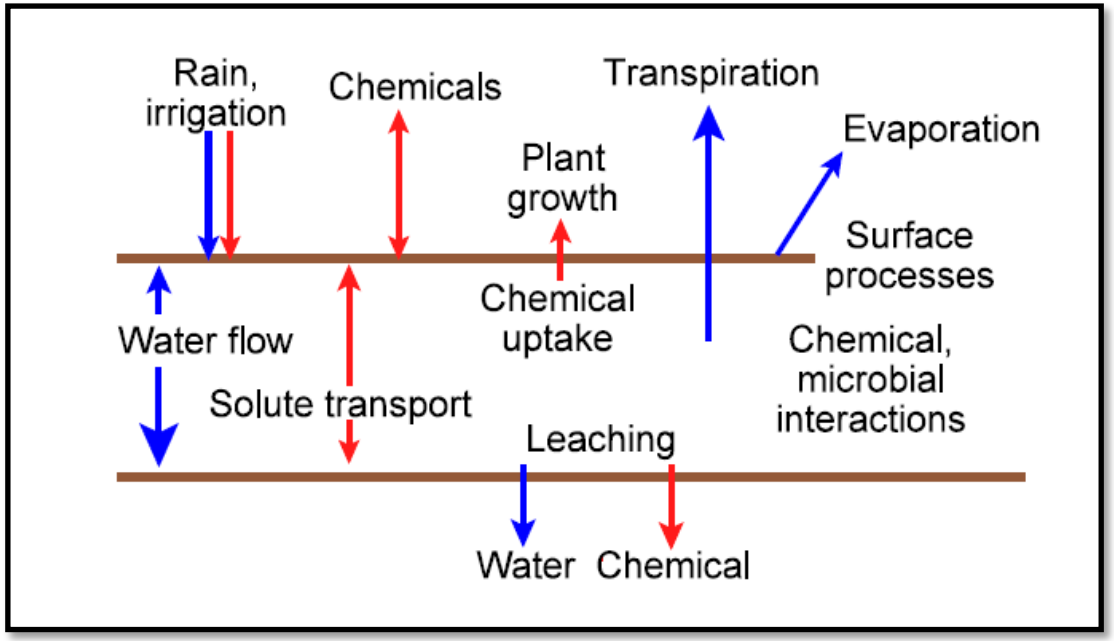
Remote sensing.

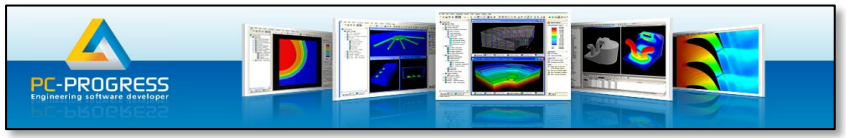
- **Multi sensor/multitemporal satellite datasets.**
- **Multiespectral sensors airborne and in UAV.**
- **Airborne electromagnetic induction (EMI).**

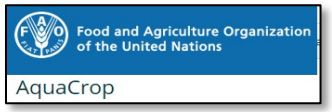


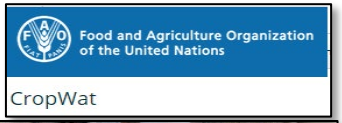
Irrigated crops under risk of salinization

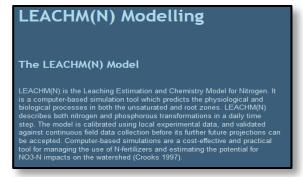
The development of simulation models applicated to SAS

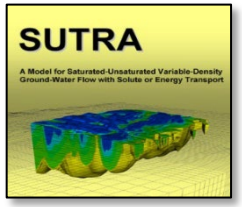


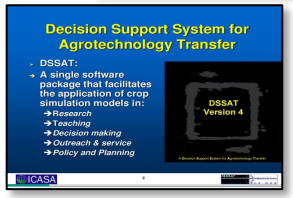


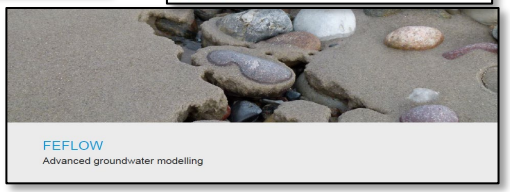












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Optimization of crop irrigation under risk of salinization

ENTRY DATA

SOIL PROPERTIES
- * Physical
- • Hydraulic
- • Chemical
- • Mineralogy
- • Geometry

DESCRIPTION INITIAL STATUS

CLIMATE (projected)
- * Precipitation
- * Evapotranspiration

CROP
- * Phenology
- * Water requirements

MANAGEMENT
- * Fertilizers
- * Biocides

IRRIGATION
- * Modality
- * Water quality
- * Volume applyed
- * Irrigation schedule

MODELS

Computing reactive transport through soil depth.
Transport of mass and energy.

- Mass and energy fluxes through nodes during the simulation period (gains and losses).
- Isochronous profiles or equipotential surfaces for chemical concentrations and hydraulic potentials.

Contrast of the scenario conditions with the desired conditions (crop tolerance and % yield, risk of soil structure degradation, accumulation of salinity in the soil).

Acceptable?

No (change in management, irrigation or cultivation)

Yes

OPTIMIZATION
- Irrigation design (ψ_{min})
- Drainage fraction

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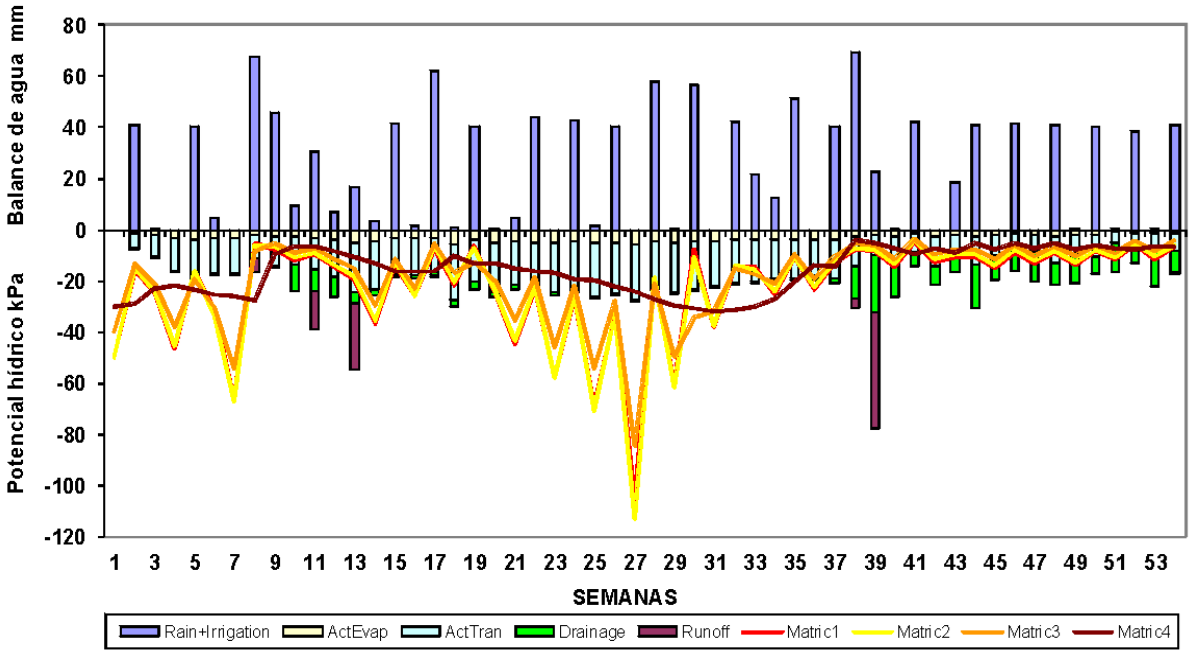
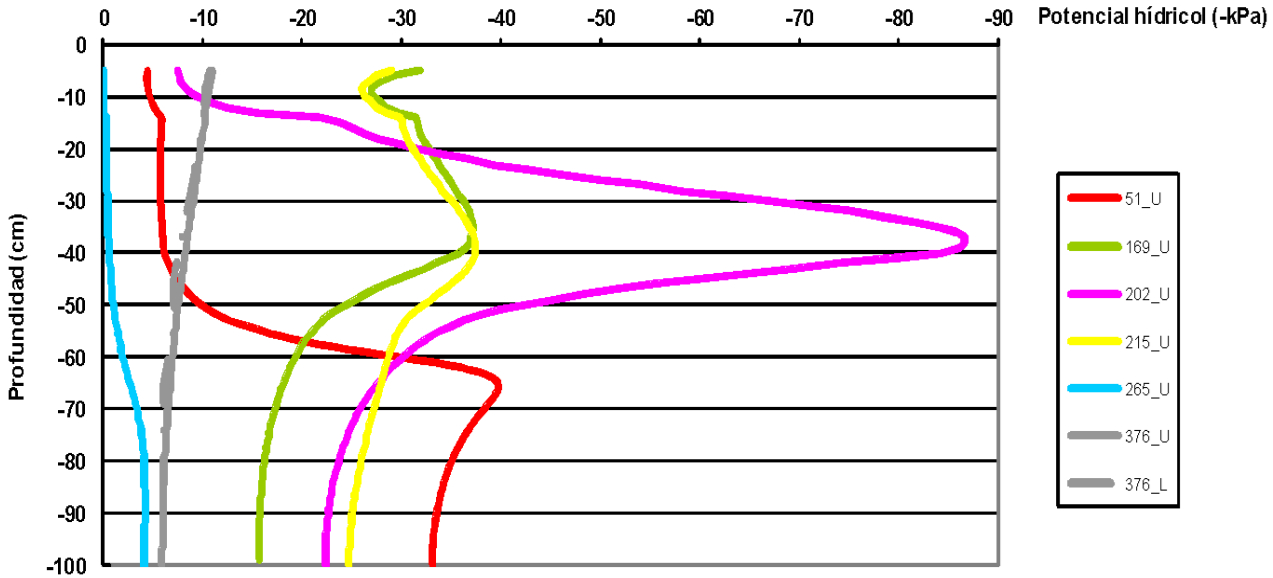
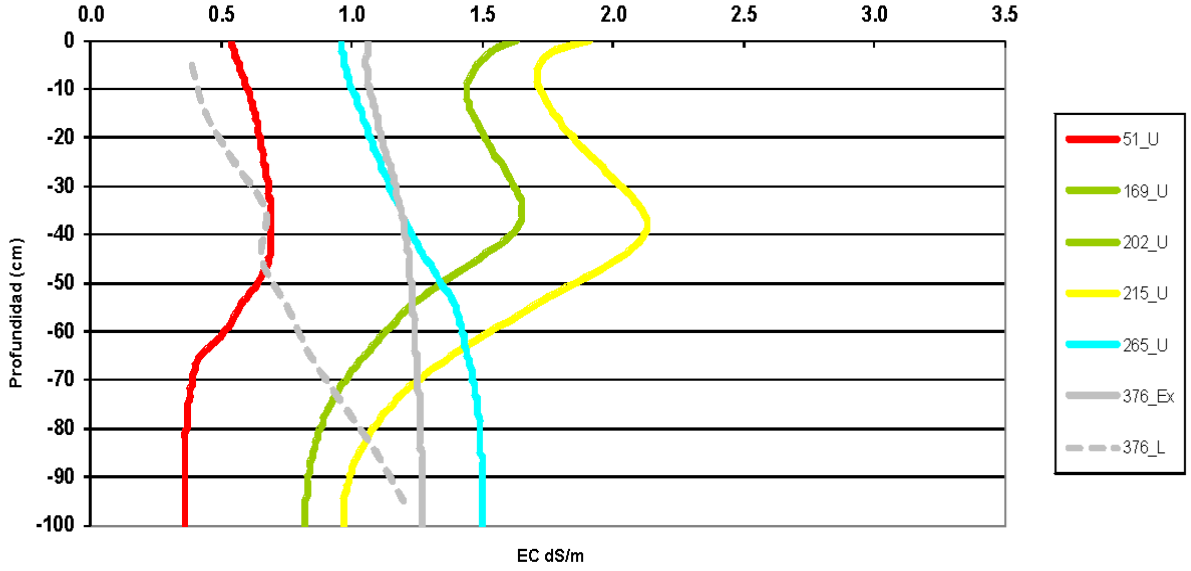


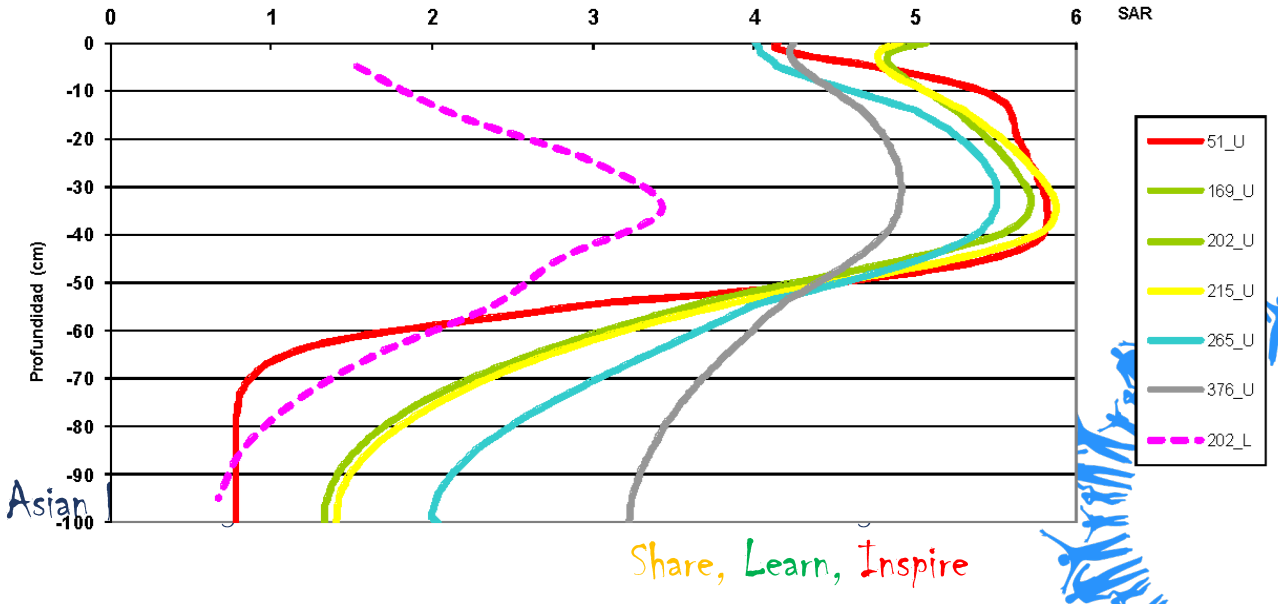
Seis isocronas para potencial hídrico



Seis isocronas para conductividad eléctrica



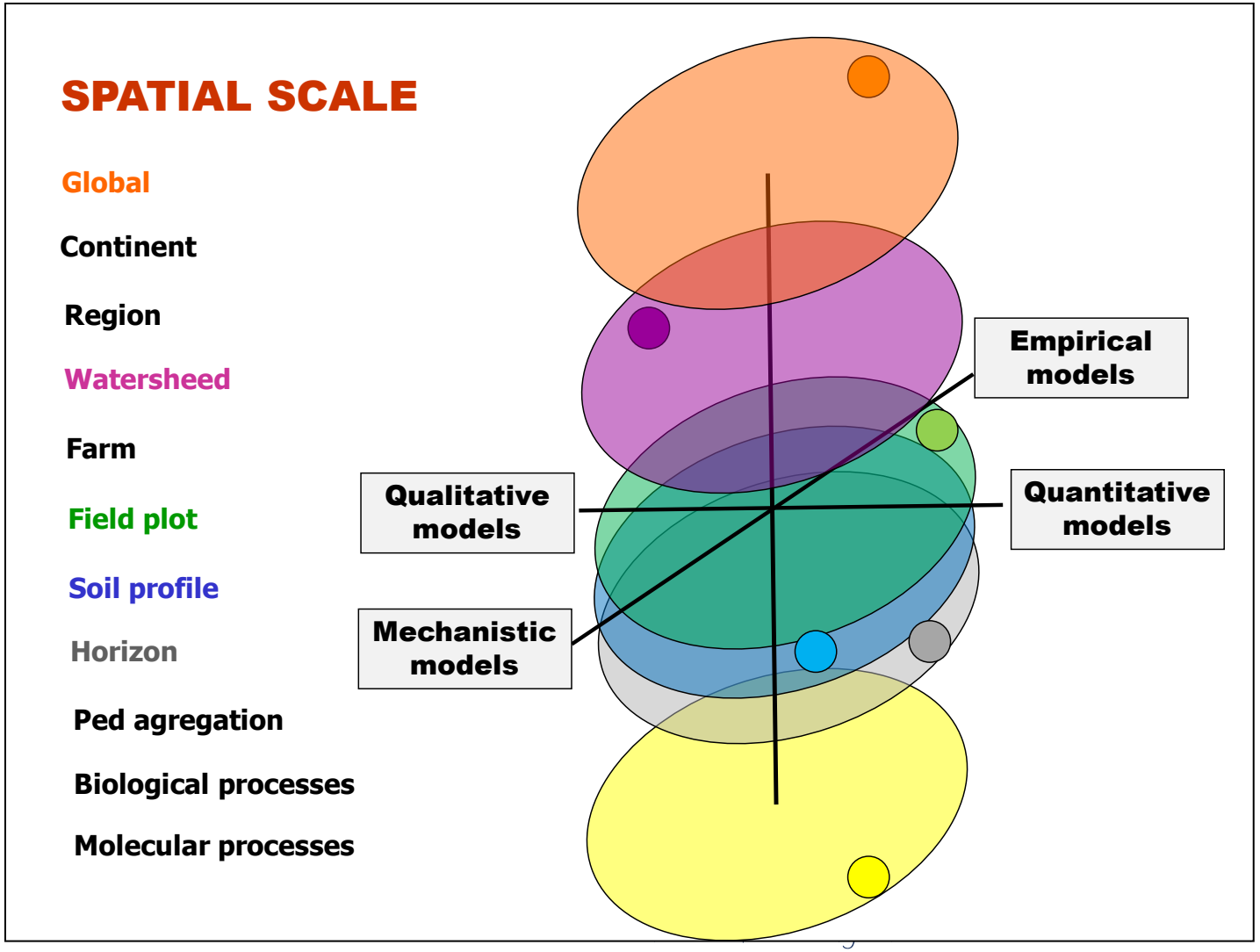
Seis isocronas para el SAR



What can we do with the models?

- Forecast of the physicochemical evolution of the modelled system.
- Management optimization.
- Irrigation optimization.
- Determination of leaching requirements.
- Quantification of amendments needed.
- Crop adaptation to field conditions.
- Scenarios analysis What if...? Useful as well for:
    - Environmental Impact Analysis.
    - Basis for decision makers.
    - Environmental policy.
    - Agricultural policy.

Management of uncertainties. Upscaling/downscaling.



Salinization thread and SAS management at different scales

Global scale.

- Reduction of gas emissions that contribute to global warming and climate change.
- Invest in gathering better knowledge on SAS status.

National and international scale.

- Development and adoption of policies that regulate the conservation of natural saline ecosystems as well as the sustainable management of land and water under risk of salinization.
- Promote technological innovation and research on crops more resistent to salinity and drough stress.

Watershed scale.

- Holistic approach to water resources management, considering hydrogeological connections and water quality change impact on soils and aquifers.

Farm scale.

- Rise awareness on the importance and impacts of salinization and abandon unsustainable practices that lead to it.
- Explore alternative quality management approaches for irrigation water.
- Adopt sustainable irrigation and drainage management practices that enhance salts leaching, soil permeability and drainage, organic matter content, biological activity and soil health.
- Selection of crops adapted to existing salinity/sodicity conditions.
- Adequate fertilization and amendments to counteract the negative effects of salinity.
- Assessment of posible specific toxicities and implement measures to neutralize them.

UN Year of Saline Agriculture - 2028

- ✓ 2021 (COP26, UNFCCC), Salinity and climate-smart agriculture: understand, connect and act now!
- ✓ 2022 (COP 27, UNFCCC), Scaling up the financing of sustainable saline agriculture
- ✓ 2023 (COP 28, UNFCCC), Promoting the declaration of 2028 as the “Year of Saline Agriculture”
- ✓ 2024 (COP 16, CBD), Nature-based solutions to enhance biodiversity and ecosystem restoration in salt-affected areas: nexus approach

Partners:

- ❑ Dutch Ministry of Agriculture, Nature and Food Quality
- ❑ Wageningen University and Research
- ❑ Vrije Universiteit Amsterdam
- ❑ Asian Development Bank
- ❑ International Center for Biosaline Agriculture

https://youtu.be/3P0CgXSexMA

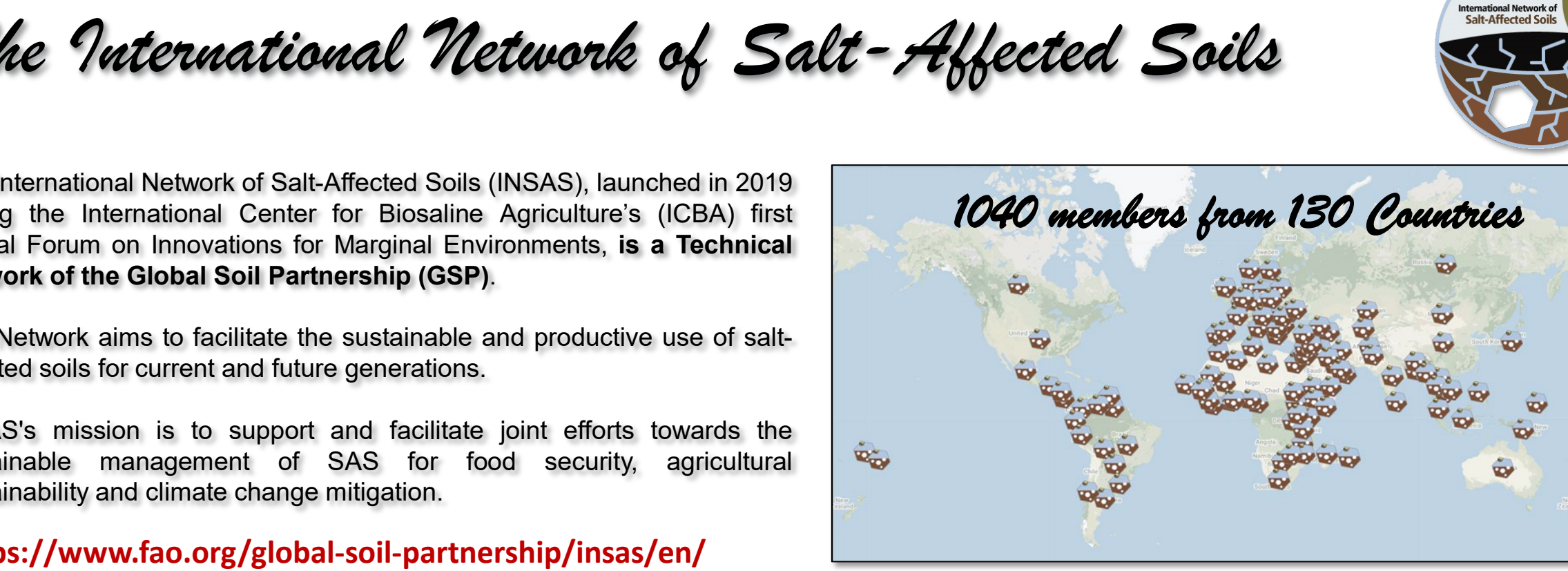
The International Network of Salt-Affected Soils

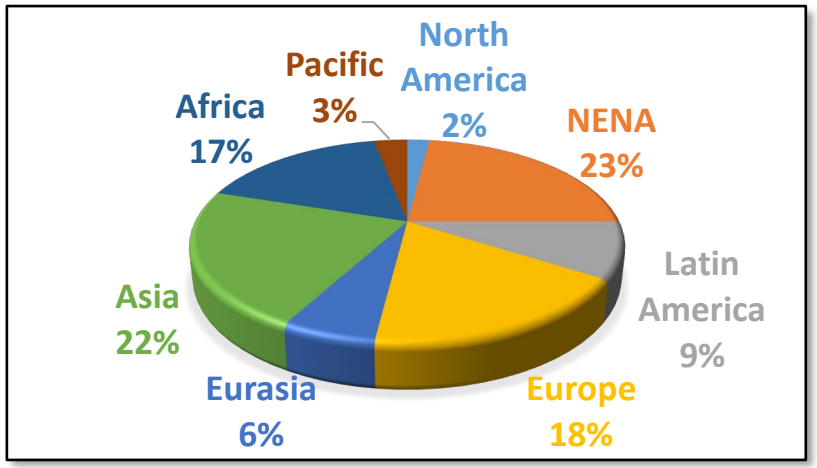
The International Network of Salt-Affected Soils (INSAS), launched in 2019 during the International Center for Biosaline Agriculture's (ICBA) first Global Forum on Innovations for Marginal Environments, **is a Technical Network of the Global Soil Partnership (GSP)**.

The Network aims to facilitate the sustainable and productive use of salt-affected soils for current and future generations.

INSAS's mission is to support and facilitate joint efforts towards the sustainable management of SAS for food security, agricultural sustainability and climate change mitigation.

https://www.fao.org/global-soil-partnership/insas/en/





2019 → 2021 → 2021 → 2025

INSAS established

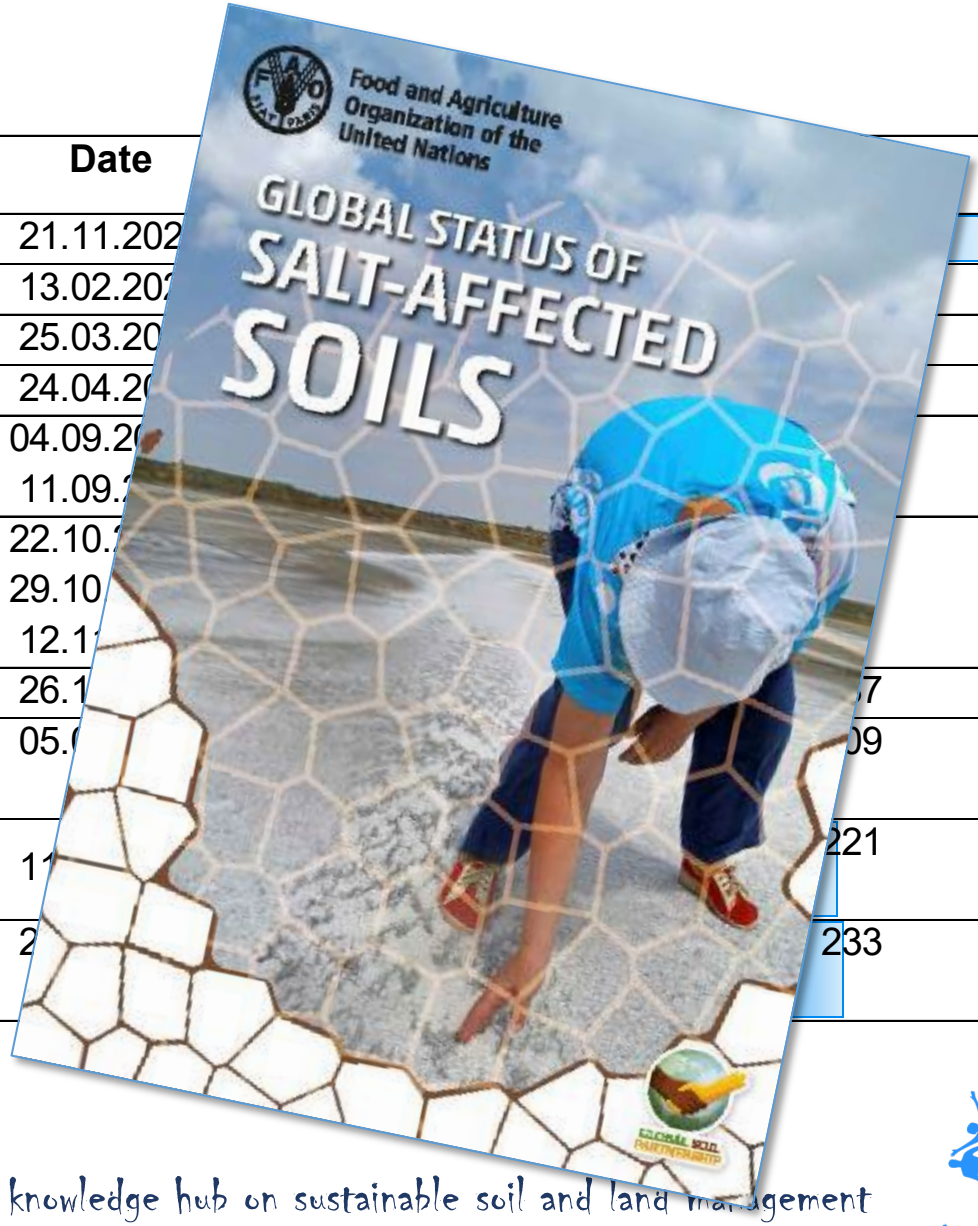
1st meeting

Global Symposium on Salt-affected soils

1040 members from **130 countries**

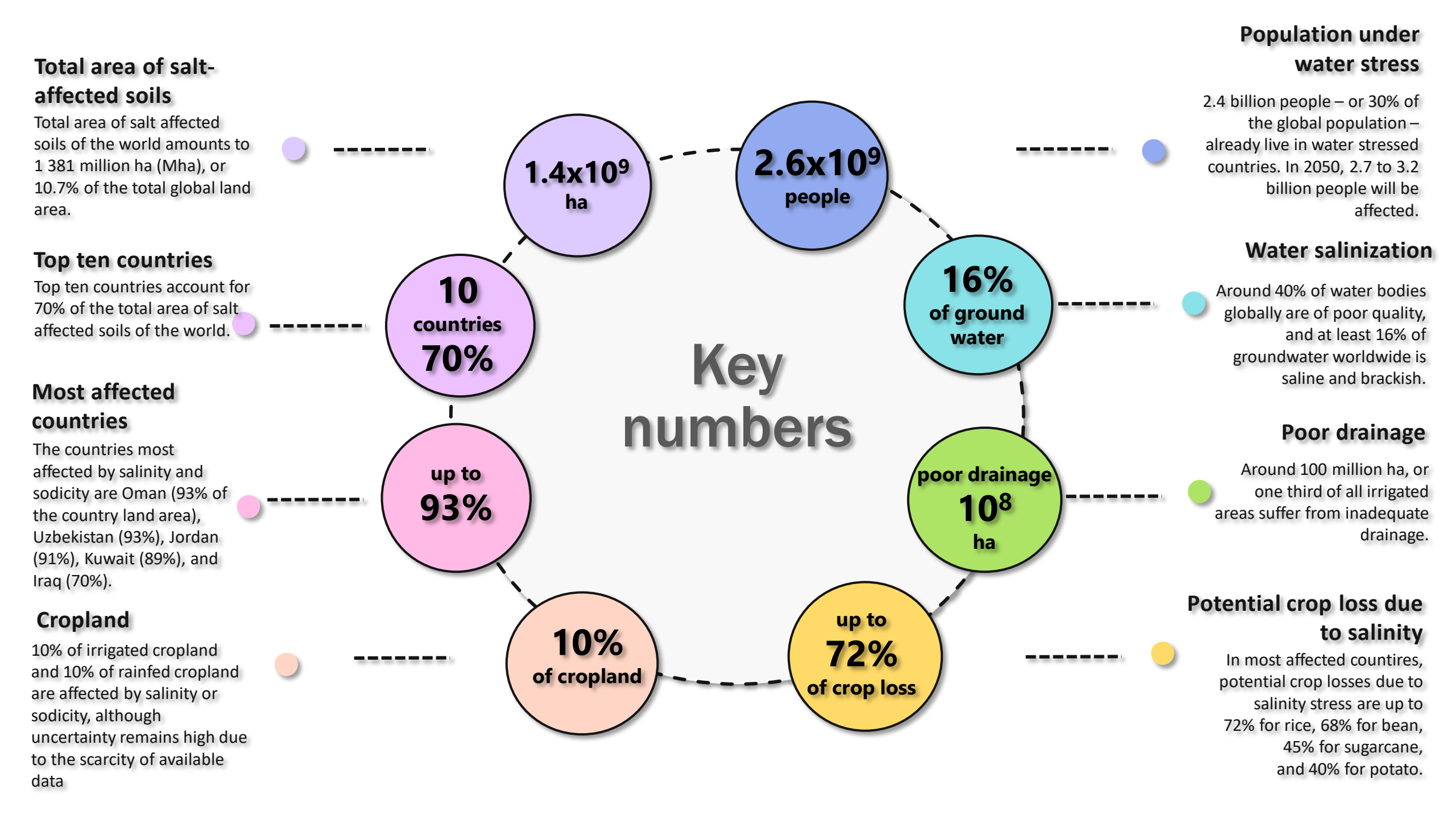
MSAS Webinars

No	Title	Date	Coverage
1	Health of salt-affected soil	21.11.202	global
2	eHALOPH and the economic uses of salt-tolerant plants	13.02.20	global
3	Salinity in Sub-Saharan Africa: impacts and initiatives	25.03.20	regional
4	Crop nutrition in salt-affected soils	24.04.2	global
5-6	Assessing soil salinity and sodicity using remote and proximal sensing data (theory+practice)	04.09.2 11.09.	global
7-9	Optimization of crop irrigation under the risk of salinization using agrohydrological tools (practice, theory, interactive session)	22.10. 29.10 12.1	global
10	Modelling plant growth with AquaCrop	26.1	7 global
11	Soil salinity in the Mediterranean region: implications and recommendations for policy actions	05.	09 regional
12	The SALTMED model as an integrated management tool for water, crops, soil, salinity and N-fertilizers	11	221 global
13	Modelling crop growth in salt-affected soils with the Decision Support System for Agrotechnology Transfer (DSSAT)	2	233 global



Asian knowledge hub on sustainable soil and land management

Share, Learn, Inspire



Total area of salt-affected soils

Total area of salt affected soils of the world amounts to 1 381 million ha (Mha), or 10.7% of the total global land area.

Top ten countries

Top ten countries account for 70% of the total area of salt affected soils of the world.

Most affected countries

The countries most affected by salinity and sodicity are Oman (93% of the country land area), Uzbekistan (93%), Jordan (91%), Kuwait (89%), and Iraq (70%).

Cropland

10% of irrigated cropland and 10% of rainfed cropland are affected by salinity or sodicity, although uncertainty remains high due to the scarcity of available data

Population under water stress

2.4 billion people – or 30% of the global population – already live in water stressed countries. In 2050, 2.7 to 3.2 billion people will be affected.

Water salinization

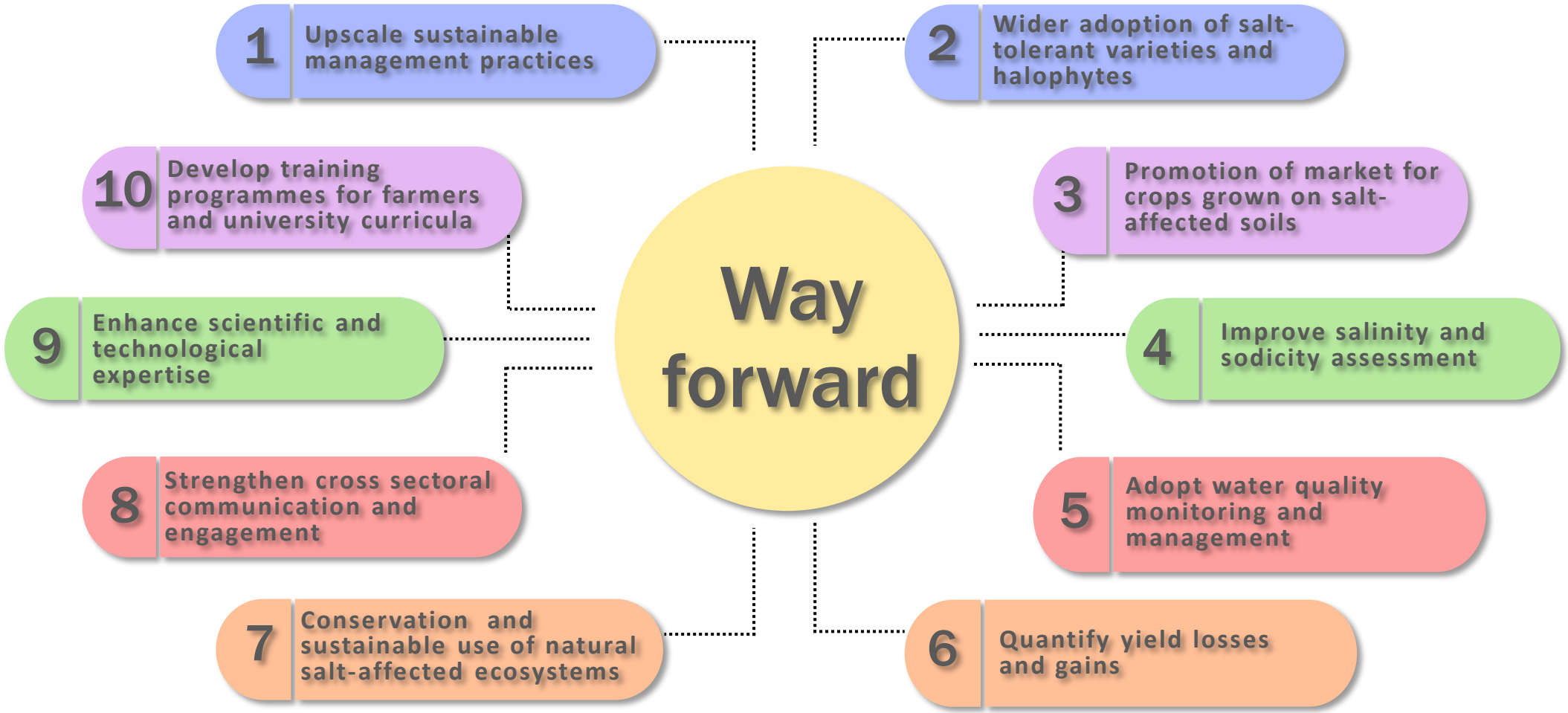
Around 40% of water bodies globally are of poor quality, and at least 16% of groundwater worldwide is saline and brackish.

Poor drainage

Around 100 million ha, or one third of all irrigated areas suffer from inadequate drainage.

Potential crop loss due to salinity

In most affected countires, potential crop losses due to salinity stress are up to 72% for rice, 68% for bean, 45% for sugarcane, and 40% for potato.


Way forward
1 Upscale sustainable management practices
2 Wider adoption of salt-tolerant varieties and halophytes
3 Promotion of market for crops grown on salt-affected soils
4 Improve salinity and sodicity assessment
5 Adopt water quality monitoring and management
6 Quantify yield losses and gains
7 Conservation and sustainable use of natural salt-affected ecosystems
8 Strengthen cross sectoral communication and engagement
9 Enhance scientific and technological expertise
10 Develop training programmes for farmers and university curricula

Thank you for your attention!

Asian knowledge hub on sustainable soil and land management

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