Joint FAO/IAEA Centre
Nuclear Techniques in Food and Agriculture

CRP: D15027 - Developing Climate Smart Agricultural Management, Including Polyhalite to Alleviate Soil Salinisation and Sodification Impacts on Crop Production, Using Nuclear and Related Techniques

Background:

Scientific situation and problem(s) to be researched:

Soil salinisation is a worldwide problem with wide ranging socio-economic and environmental implications. 1381 million ha, or 10.7% of the total global land area1., with almost 60% of these exhibiting soils with excess sodium; Of this total, 62 million ha are irrigated2. The majority of irrigated salt-affected soils occur in smallholder farms. In the last 20 years, an area equivalent to an additional 2000 ha per day of irrigated land has become degraded by salinisation in arid and semi- arid regions, across 75 countries. This trend is likely to be exacerbated in many climate scenarios due to the expected aridity increase.

Table 1: Countries representing 70% of the total area of salt affected soil

(Source: FAO, 2024)

Country	Area of Salt Affected Land (million ha)
Australia	357
Argentina	153
Kazakhstan	94
Russian Federation	77
United States of America	73.4
Islamic Republic of Iran	55.6
Sudan	43.6
Uzbekistan	40.9
Afghanistan	38.2
China	36

To avoid food shortages and to meet the increasing demand for food of the growing human population, agricultural production must increase by 70% globally and by 100% in some developing countries by 2050 (FAO, 2024). Soil salinisation is a major threat to food security and the sustainability of natural resources worldwide. To meet the food demand for a rapidly increasing human population, protect productive soils against salinisation and sodification, and best utilise salt affected land, effective climate smart agricultural (CSA) solutions must be developed to meet changing climate scenarios.

Soil salinity remediation has been addressed through water management practices by implementing irrigation strategies for salt leaching, improving drainage or combining both approaches depending on

soil conditions. Additionally, when salinity is associated with excess sodium, the risk of dispersion is increased. The current solution is the application of soil amendments such as gypsum which enhances calcium availability although the accessibility and quality of this input varies amongst countries and regions within a country.

In this regard, the International Atomic Energy Agency (IAEA), through its Joint FAO/IAEA Centre of Nuclear Techniques in Food and Agriculture, and Anglo American Crop Nutrients, will closely collaborate to find sustainable practices to alleviate soil salinisation and sodification, build fertility of marginal land, and increase crop productivity. Collaboration with Anglo-American will provide access to the world's largest known deposit of polyhalite, which is a naturally occurring mineral that contains, as sulphates (SO42-), potassium (K), magnesium (Mg), and calcium (Ca), making it a suitable candidate as a natural fertiliser for use in salt affected soils. In production, polyhalite has the potential to be a scalable solution, with a low carbon and water footprint. Through the IAEA's Joint FAO/IAEA Centre of Nuclear Techniques in Food and Agriculture's extensive experience and expertise in the use of nuclear and related techniques to trace the dissolution and movement of Ca, Mg, S and K from polyhalite in salt-affected soils. Understanding elemental scale interactions will allow the building of a mechanistic approach of these interactions, providing the scientific base for the creation of guidelines to preserve and improve these vulnerable soils. Polyhalite has the potential to provide better crop nutrition and displace sodium from soil. Currently there is limited information available regarding the effectiveness of polyhalite in salt-affected soils; therefore, further research is required to gain fundamental insights to unlock the full potential of this complex mineral.

Relevant references:

- UNU-INWEH (2014) World Losing 2,000 Hectares of Farm Soil Daily to Salt-Induced Degradation. United Nations University, Hamilton.
- Global Status of Salt Affected Soils, (2024) FAO.
- Global Climate Projections AR4, (2007) IPCC.
- The State of Food Security and Nutrition in the World, (2024) FAO.

Nuclear Component/Relevant Nuclear Field(s):

The IAEA has developed a range of nuclear, isotopic and related techniques to find integrated solutions in sustainable use and management of soil, fertilisers and water resources. This could be achieved by enhancing nutrient and water use efficiency, increasing the capture of atmospheric nitrogen through biological N fixation and carbon through photosynthesis. This will also improve soil fertility, mitigate emission of GHGs and minimise land degradation. The proposed CRP will explore a range of nuclear and related techniques to assess the role of polyhalite in soil fertility improvement, and salinity and sodicity mitigation. This includes investigating the potential use of isotope natural abundance studies and isotope proxies to trace potassium (K), calcium (Ca), magnesium (Mg), and sulphur (S) from polyhalite to crops. The ^{15}N stable isotopic technique at enriched and natural abundance levels precisely quantifies fertiliser use efficiency, biological N fixation. Similarly, the ^{13}C tracing technique is used to assess crop tolerance to drought and salinisation/sodification and C-sequestration. The stable isotopes of ^{18}O and ^{2}H in water will guide scientists to differentiate between water losses through evaporation versus transpiration to improve water use efficiency and produce more food from each drop of water. Techniques such as Isotope Ratio Mass Spectrometry (IRMS) for $\delta^{34}S$ analysis, gamma spectroscopy for ^{40}K detection, and isotope dilution approaches using stable rubidium (^{87}Rb) for potassium and stable or gamma-emitting strontium (^{85}Sr, ^{86}Sr, ^{87}Sr) for calcium assessment will be evaluated for their applicability in this context. The CRP will also examine spectroscopic methods, including Mid- and Near-Infrared Spectroscopy (MIRS, NIRS), for their potential in rapidly estimating exchangeable K, Ca, and Mg and monitoring soil properties such as electrical conductivity, pH, and base saturation. Additional analytical techniques, such as Ultra High-Performance Liquid Chromatography coupled with Inductively Coupled Plasma Mass Spectrometry (UHPLC-ICP-MS) and Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OES), may be explored to enable high-sensitivity, multi-element analysis. The feasibility of using ICP-MS and Multi-Collector ICP-MS (MC-ICP-MS) for high-

precision isotope ratio analysis of Ca, Mg, Rb, and Sr will also be assessed. To support capacity building and facilitate the implementation of these techniques, the FAO/IAEA Soil and Water Management and Crop Nutrition Laboratory can provide targeted training, conduct specific analyses, and support controlled pot experiments. These activities will enhance the understanding of polyhalite's effects on soil fertility and salinity and sodicity stress reduction, contributing to the development of evidence-based recommendations for sustainable agricultural practices.

Overall Objective:

Evaluate the benefits and effectiveness of applying polyhalite to prevent salinisation effects and reclaim sodic soils productivity under different cropping systems.

1. Determine the dissolution mechanisms and movement of Ca, Mg, K & S provided by polyhalite in saline and sodic soil within the soil plant continuum
2. Determine the role of soil components that influence the thresholds of sodium concentration causing soil physical degradation
3. Investigate field scale interactions among different mineral nutrients including Ca, Mg, K and sulphate (SO_4^{2-}) released from polyhalite within the soil-plant continuum of salt-affected soils
4. Develop novel scalable nutrient-management tools and guidelines to mitigate salinisation and sodification for improving crop production and farmer livelihoods
5. Quantify the wider ecosystem goods and services by using polyhalite inputs, through a cost-benefit and lifecycle analysis

Expected Outputs:

- New knowledge and insights established for the reactive transport of ions released from polyhalite to improve soil health
- Enhanced understanding of the impact of CSA practices and crop nutrition on the distribution of saline/sodic soil systems and specific threats related to food security
- CSA solutions developed to elucidate soil salinisation and sodification impacts on crop production to enhance food security and disseminated to end users.
- Improved and validated model on reactive transport of Na and Ca ions in saline, saline-sodic and sodic soils
- Identification of degradation mechanisms and soil attributes affecting crop production in salt-affected areas
- Provision of user-friendly scalable tools to guide decision making on land use (e.g. decision trees, cost-benefit analysis, time series analysis, etc.) in salt-affected areas
- Regional ESP (Exchangeable Sodium Percentage) recommendations
- Creation of a FAIR (Findable Accessible Inter-operable and Reusable) and centralised database for all project data
- Development and validation of predictive models to determine the limitations of application of CSA interventions

- Monitoring salinisation and sodification under different nutrient management regimes assessing field practices and protocols for crop production and soil health amelioration
- Collection of farmer livelihood data to drive creation of end user tools
- Creation of product life cycle assessment to assist decision making
- Evaluation of change in ecosystem services using the existing framework of Soil Health Indicators (FAO-GSP)
- Creation of a dataset for policymakers and decision makers

Requirements for the CRP:

Applicants must have:

- Staff with adequate laboratory capacity to implement the project activities.
- Proven research experience in soil, nutrient and water management, including enhancing nutrient and water use efficiency of marginal land and mitigating salinity using nuclear and related techniques.
- Extensive experience in establishing strategic partnerships with regional key stakeholders (i.e., decision-makers, end-users, members of the civil society and extension workers) for implementation and roll out of project activities, as well as with international counterparts for knowledge sharing and analytical support.
- Access to additional funding for assessment of salt affected land.

Proposal submission forms

Research institutions in Member States interested in participating in this CRP are invited to submit proposals directly to the Research Contracts Administration Section (NACA) of the International Atomic Energy Agency. The forms can be downloaded from the CRA website. For more information about research contracts and research agreements, please visit our web-site.

Deadline for submission of proposal

Proposals must be received no later than 10 June 2025. The CRP will be for 5 years.