Food and Agriculture Organization of the United Nations

GLOBAL SOIL PARTNERSHIP

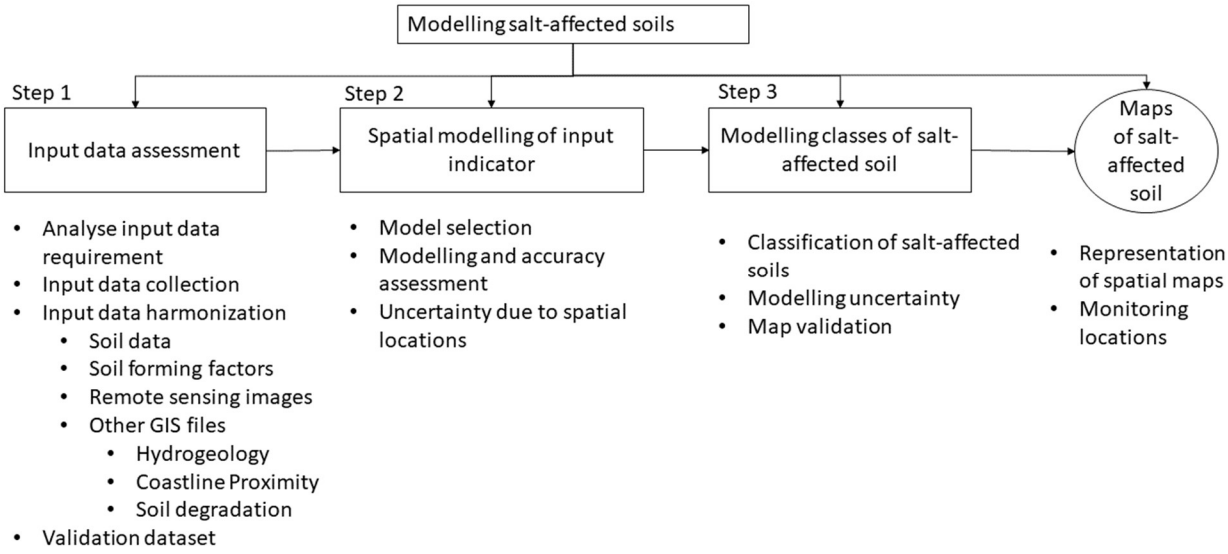
Overview: Spatial modelling of salt-affected soils

1. Introduction

Salt-affected soils are soils with high amounts of salts and sodium ions. They occupy a significant proportion of the land area worldwide. The last global information of these soils was made in the early 1980s. Recent literature continue to cite the old global statistics because of lack of updates. Inadequate harmonized guidelines is partly blamed for the frozen update activities, which in turn negatively affects efforts for global mobilization towards new global information of salt-affected soils. FAO GSP has developed a technical manual focusing on a harmonized protocol to guide countries in assessing, reporting and monitoring national information of salt-affected soils. The manual outlines practical steps for mapping salt-affected soils using measured soil properties (EC, pH and ESP) and their spatial predictors. It has given prominence to the input data requirements, harmonization of data and procedures, and freely downloadable software and implementation steps. A generic schedule for implementing tailor-made capacity building program is also included.

2. Approach for mapping salt-affected soils

The approach is a three-step that begins with input data harmonization where input data is standardized to facilitate uniformity of assessment down the soil profile and across the landscape. The harmonized input data feeds into the spatial modelling step where maps of soil indicators are developed. Here, digital soil mapping (DSM) techniques are combined with machine learning and uncertainty assessment to analyse and develop spatial distribution of the soil indicators of salt problems. At least EC, pH, and ESP maps are produced for the desired soil depths. Uncertainty maps for each soil indicators are also produced for all analysed soil depths. These maps are finally used to classify types and severity of salt-affected soils for the chosen soil depths.



3. Input data requirements

Summary minimum data requirements for mapping salinity

Data type	Variables	Units	Main data source	Other sources	
				Name	Format
Georeferenced soil data (between 0-100 cm)	EC_{SE} (or equivalent)	dS/m	National data	WOSIS[1]	vector point data
	PH	-			
	ESP	%			
	*Soluble ions**	*cmol/kg*			
	*TSS**	*g/l*			
Climate (Mean annual)	Rainfall	mm	National data	Worldclim[2]	vector point data
	Min Temperature	°C			
	Max Temperature	°C			
Land use/cover	cover/use types	-	National data	ESA[3]	raster image (300 m)
	Irrigation areas*		National data		
soil map	soil types	-		WOSIS	vector polygon
DEM	Elevation	m	National contour map	USGS[4]	raster image (15, 30, 90 m, etc.)
Remote sensing land surface reflectance	Visible (RGB) reflectance	-	National data	USGS	MODIS Landsat OLI Sentinel, ASTER images
	IR reflectance	-			
	SWIR reflectance	-			
Geology	Lithology types	-	National data		
Hydrogeology*	Groundwater level	m	National data		
Soil degradation*	Degradation drivers and classes		National data		

*Optional, Soluble ions: Na^+, Ca^{2+}, Mg^{2+}, K^+, $C0_3^{2-}$, $S0_4^{2-}$, Cl^-, $HC0_3^-$, $N0_3^-$,

Minimum data requirements:

- Georeferenced soil data (EC, pH, and ESP or SAR). Check and note method of determination such as saturated soil paste extract or soil-water mix solution (and include mix ratio); soil depth is 0 – 100 cm
- GIS data: Soil map, climate (mean annual rainfall and temperature), land use/cover and DEM. Irrigation command area, geology, hydrogeology, and soil degradation should be included if available.
- Remote sensing images: at the national scale – MODIS (7 Bands of MOD9A1 V6) for the national scale mapping

[1] WOSIS: https://www.isric.org/explore/wosis
[2] WorldClim: https://www.worldclim.org/
[3] ESA: https://www.esa-landcover-cci.org/
[4] USGS: https://earthexplorer.usgs.gov/

4. Software requirements

The modelling process uses freely downloadable software and focusing on their potential in mapping salt-affected soil. The software are:

a) QGIS: QGIS is versatile and relatively fast with many GIS functionalities such as GIS database development and organization, GIS operations (layer trimming, projections, format conversion, views, etc.), remote sensing applications (such as image download, correction, pre-processing, classification, band analysis, etc.), map layouts, among others. The software is freely downloadable from https://qgis.org/en/site/forusers/download.html. The site also contains documentation of its functionalities and tutorials for beginners

b) ILWIS: ILWIS is a free GIS software that is downloadable from https://www.itc.nl/ilwis/download/ilwis33/ or https://52north.org/software/software-projects/. The software has special functionalities with neighbourhood functions, multivariate statistics, quality check especially for incompatible projections, and simple scripting for image adjustments. These characteristics are significant steps in input data harmonization for mapping salt-affected soils.

c) R: R is both language and computing environment for statistics and data handling. It is freely downloadable from https://www.r-project.org/. Owing to its flexible computing environment, R software encourages contributed packages with versatilities in statistical analyses, spatial and non-spatial data analyses, machine learning models, and GIS analyses. These advantages go beyond classical GIS software; hence making R suitable for complex models for mapping salt-affected soils. Prominent packages for mapping salt-affected soils are *soilassessment, raster*, *sp, rgdal, car, carData, dplyr, spacetime, gstat, automap, randomForest, fitdistrplus, e1071, caret, soiltexture, GSIF, aqp, plyr, Hmisc, corrplot, factoextra, spup, purrr, lattice, ncf, npsurv, lsei, qrnn, nnet, mda, RColorBrewer, vcd*

5. Capacity building program

Capacity building program in digital mapping of salt-affected soils is designed to help countries or GSP partners to gain technical knowledge and skills for developing maps of salt-affected soils and be able to periodically monitor salt problems in their areas of jurisdiction. In the spirit of country-driven approaches and global soil information system, the need for harmonized national capacities and products cannot be over-emphasized. It is envisaged that national capacity building and harmonized information on salt-affected soils will give uniform message for raising national, regional, and global awareness on the need for sustainable management and economic use of these soils.

This program is designed for 48 contact hours between participants and instructors. Participants are required to have own datasets during the training. The main components of the training outline are:

1. Lecture and discussions on the basics of salt-affected soils (3 hrs)
2. Lecture and discussions on input data requirements for mapping salt-affected soils (3hrs)
3. Practical hands-on session on input data preparation (8 hrs)
4. Practical session on introduction to software and basic operations (4 hrs)
5. Practical session on spatial modelling of indicators of salt-affected soils (20 hrs)
6. Practical session on spatial modelling of classes and types of salt-affected soils (6hrs)

7. Lecture and discussions on information sharing (4 hrs)

The following are expected deliverables at the end of the training program:

i. Enhanced capacity for developing and monitoring national status of salt-affected soils
ii. Updated and harmonized national database of salt-affected soils
iii. Spatial national information (map with documentation) on salt-affected soils
iv. National maps of salt indicators (EC_{SE}, pH, ESP) for 0-30 and 30-100 cm soil depths submitted to the GSP as contribution to global mapping of salt-affected soils
v. National maps of uncertainties for mapping salt-affected soils at 0 – 30 cm and 30 – 100 cm soil depths

6. Preparation and resources

The following notes are also available to support preparation for national mapping of salt-affected soils:

1. Outline of requirements: input data requirements, expertise, computer specifications
2. Input data preparation
3. Technical manual
4. Software installation guide