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Predicting and mapping of soil salinity using machine learning algorithms in central arid regions of Iran

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1. Introduction

Soil salinity, generally measured via electrical conductivity (EC), is a key soil property strongly related to land-use planning, land management decisions and land degradation and is also known as an important indicator of soil quality. There are mainly two kinds of soil salinity: primary and secondary salinity. Independently, high soil salinity results in low crop productivity and accelerates agricultural land degradation and desertification around the world. This issue of ample importance in arid and semi-arid countries such as Iran. Here, low potential agricultural productivity is to a large extend attributed to high soil salinity, especially in arid and semi-arid regions of Iran like the central plateau.

The spatial distribution of soil salinization in Iran is only roughly know from old and traditionally mapped soil maps, with spatial resolutions of about 1:1,000,000. This map is suitable for land use planning on a national scale but have only very limited resolution and information at regional and local scale. However, for a sustainable agricultural production and the prevention of any further salinization, land use management and practices and effective reclamation programs have to be developed and implemented. To do so, a detailed knowledge about the spatial extend and magnitude of soil salinity is essential. Traditional mapping of soil salinity is accompanied with intensive fieldwork, soil sampling and laboratory analyses. Such measures are costly, time-consuming and laborious and, subsequently, difficult to apply for large areas. Digital soil mapping (DSM) offers more efficiently and economically rapid tools in order to model the extent and magnitude of soil salinity for large areas and in data-poor regions.

Though different machine learning models have been used in DSM, to best of our knowledge, there is no study to conduct soil salinity mapping using hybrid methods. Therefore, in this study, we tried to predict and map the spatial distribution of soil salinity at high resolution in central Iran using hybrid machine learning algorithms and a large number of environmental covariates. We focused on the implementation of advanced machine learning algorithms such as support vector regression (SVR) and the hybrid of wavelet support vector regression (W-SVR) for predicting and mapping soil salinity. Moreover, we explored the relative importance of covariates in the study area of central Iran using the Boruta algorithm for the prediction of soil salinity.

2. Method

This work is conducted in a number of stages:

i.Preparing the soil databases in the study area covering ~100.000 km^2 (**Fig. 1**).

ii.Preparing a set of covariates at a regular grid spacing, including remote sensing data, terrain attributes and climatic data (**Fig. 2**).

iii.Implementing the feature selection Boruta algorithm (**Fig. 3**).

iv.Calibrating and validating of machine learning models such as support vector regression (SVR) and the hybrid of wavelet support vector regression (W-SVR) (**Fig. 4**).

v.Preparing the soil salinity maps in six soil depth intervals (**Fig. 5**).

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3. Results

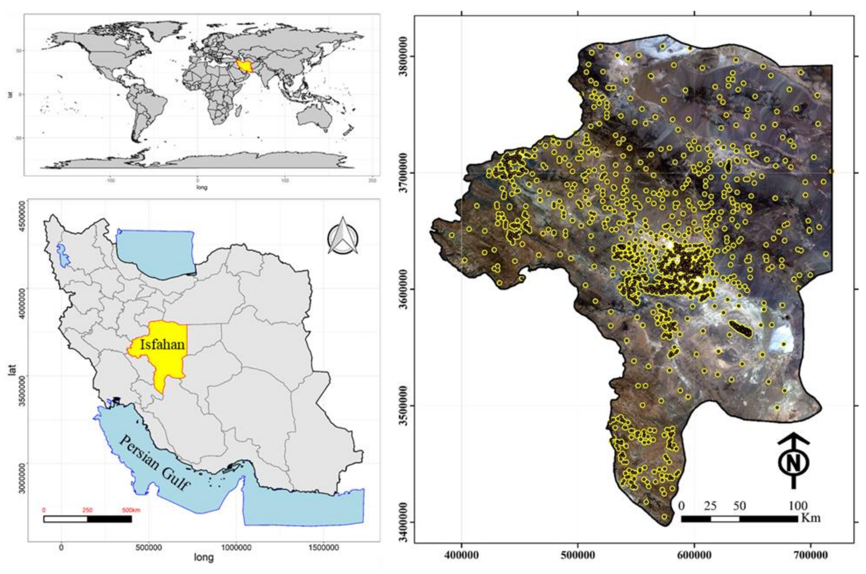

Fig. 1: Map of the study area in Iran.

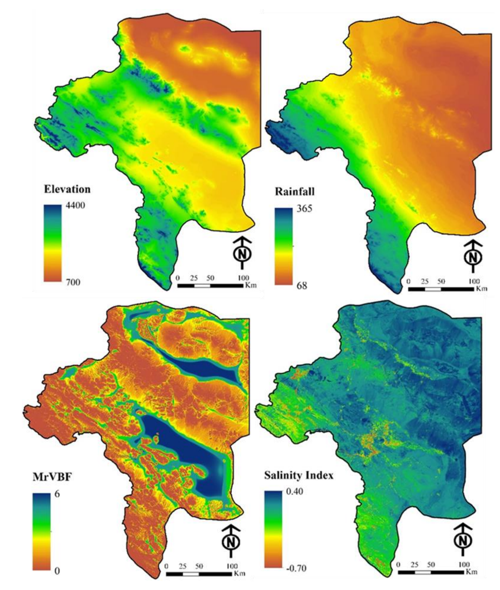

Fig. 2: Four examples of covariates.

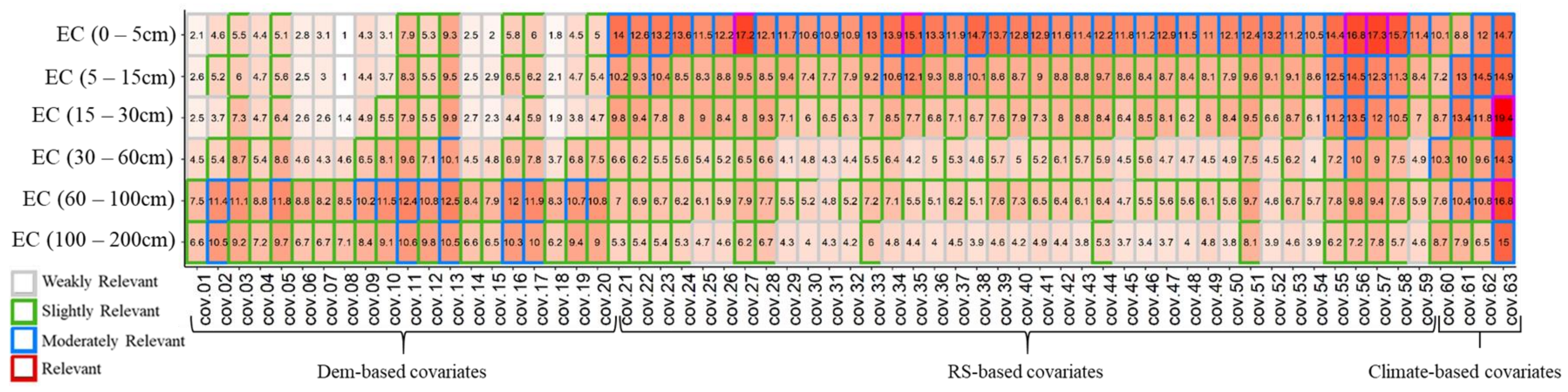

Fig. 3: Relative importance of covariates to predict soil salinity in six soil depth intervals.

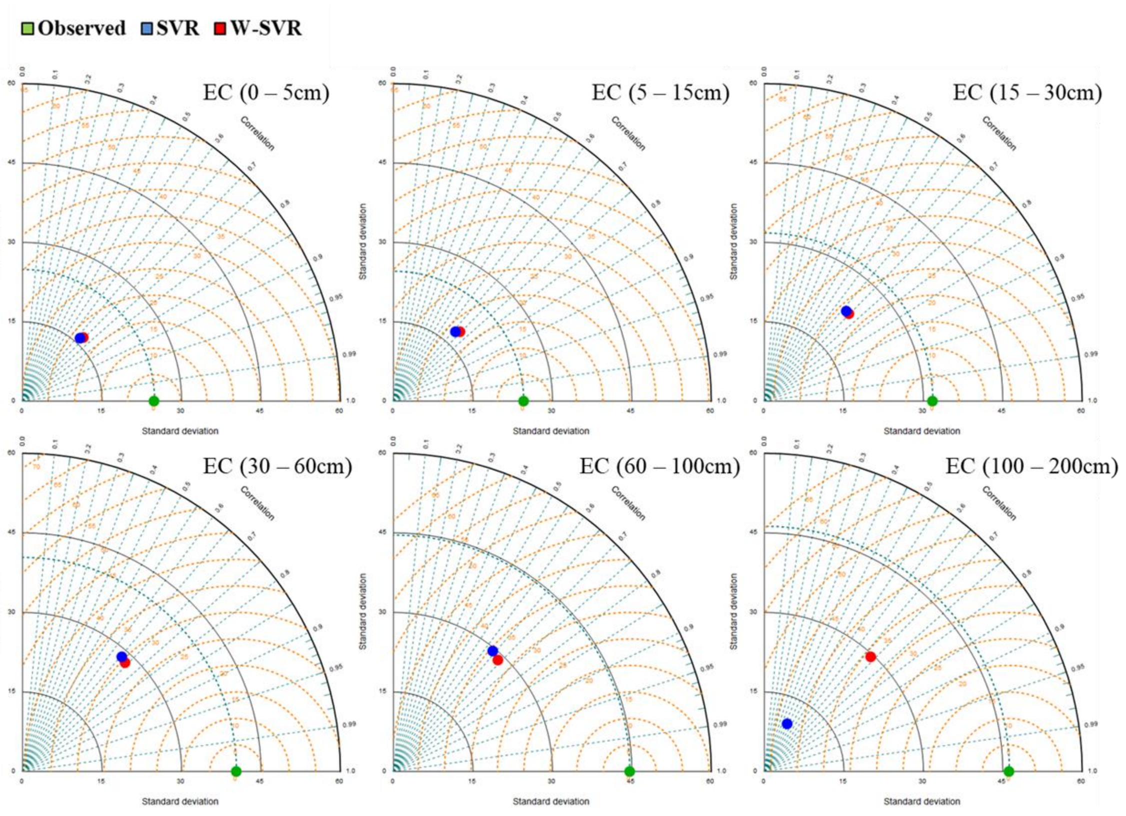

Fig. 4: Taylor diagrams of estimated values of soil salinity using SVR and W-SVR models in six soil depth.

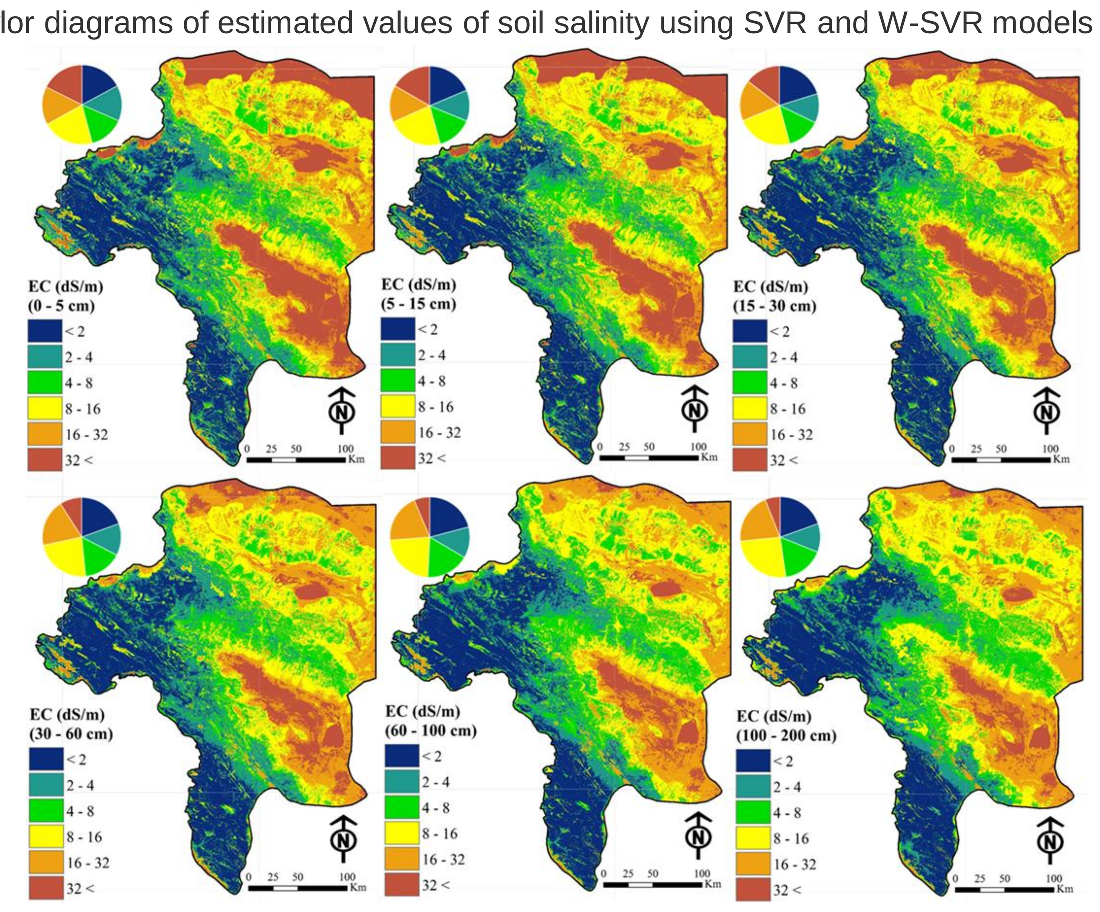

Fig. 5: Spatial distribution of soil salinity in six soil depth intervals.

4. Conclusion

We implemented a hybrid ML algorithm (wavelet support vector regression) through digital soil mapping framework to map and predict soil salinity from up to down of soil profiles in Iran. Here, using soil data base and the full suite of covariates— including remote sensing data, terrain attributes and climatic data—SVR and W-SVR models were built for each of the standard soil depth intervals (i.e. for 0–15, 15–30, 30–60, 60–100 and 100–200 cm). Our results indicated the higher performance of W-SVR to predict soil salinity in comparison to SVR. This is particularly true at the lowest soil depth, when W-SVR indicated ~1.5 time higher accuracy compare to the SVR. In addition, our finding based on Boruta algorithm revealed that RS- and terrain-based covariates were useful predictors to model soil salinity.

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Further reading

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