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Digital soil mapping of deltaic soils: A case of study from Hirmand (Helmand) river delta

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ABSTRACT

Digital soil mapping (DSM) can predict the spatial distribution of soil classes. In the present study, DSM was investigated to predicted soil classes in a flood plain. Taxonomic classes including soil great groups, subgroups, and families were modeled using Random forest (RF) technique and covariate sets for an area of ~60,000 ha in Sistan Region, eastern Iran. 108 soil profiles were excavated in the study area. Overall model accuracy and the Kappa statistic were used to evaluate the model using 10-fold cross-validation. Results showed fluvial activities are the main factors affected soil formation and development in the studied area. The channel networks, valley depth, convergence, NDSI, and catchment area were the most important covariates. The overall accuracy was 46, 44 and 46.4% for soil great groups, subgroups, and family levels, respectively. Predicted map at family level showed more details than legacy map but at the great group and subgroup levels were similar to legacy maps. Results showed channel networks were the most important covariate at all taxonomic levels in this deltaic area and RF showed high potential to map soil classes in the arid deltaic regions.

1. Introduction

Soil survey and mapping supply basic information for environmental modeling and land use planning. The spatial distribution of soil properties and classes has a key role in soil management decisions for sustainable development. Digital soil mapping (DSM) used quantitative models to link between soil observations and environmental covariates (McBratney et al., 2003; Brungard et al., 2015; Chen et al., 2016; Hengl et al., 2015; Pahlavan-Rad et al., 2014; Pahlavan-Rad et al., 2016). DSM can be an attractive approach for soil mapping at the large-scale in a data-poor region (Zeraatpisheh et al., 2017). Different techniques and methods have been used to link soil properties and environmental covariates such as artificial neural networks (Malone et al., 2009), regression trees (Adhikari et al., 2014; Somarathna et al., 2016; Wang et al., 2016), generalized additive models (de Brogniez et al., 2015) and random forests (Brungard et al., 2015; Pahlavan-Rad et al., 2014; Hengl et al., 2015).

Random forest (RF), a regression tree based technique, has high prediction performance, is robust to noise, and low bias, and variance; therefore it is suitable for modeling soil spatial variation. In other words, RF is a useful and precise method for predicting and mapping soil characteristics. Sreenivas et al. (2016) observed high performance in modeling soil organic carbon (SOC) density by using RF technique in India. Hengl et al. (2015) compared a linear regression and RF for predicting soil properties in Africa continent and found that RF performed better than linear regression model. Camera et al. (2017) used RF and multinomial logistic regression (MLR) to predict world reference base (WRB) soil groups, soil depth, and soil texture classes and found that RF had higher performance than MLR. Zeraatpisheh et al. (2017) believed RF has better performance at the great group and subgroup levels (lower taxonomic levels) comparing with MLR.

RF also shows the most important and affected factor on soil classes distribution which can exhibit impact of soil formation factors and soil genesis conditions. Barthold et al. (2013) used RF for predicting soil types in China and climate and land use were shown to be the most important factors on soil type distribution.

There are rare studies on using DSM for mapping soil classes in flood plains or deltas. Therefore RF could be used as a tool for understanding and predicting soil types in these regions. So, the objective of this study was the application of DSM by using random forest technique for predicting soil taxonomic classes in the part of Sistan region in east Iran which is a delta of the Hirmand river and its landscape is dominated by eolian erosional and depositional landforms.

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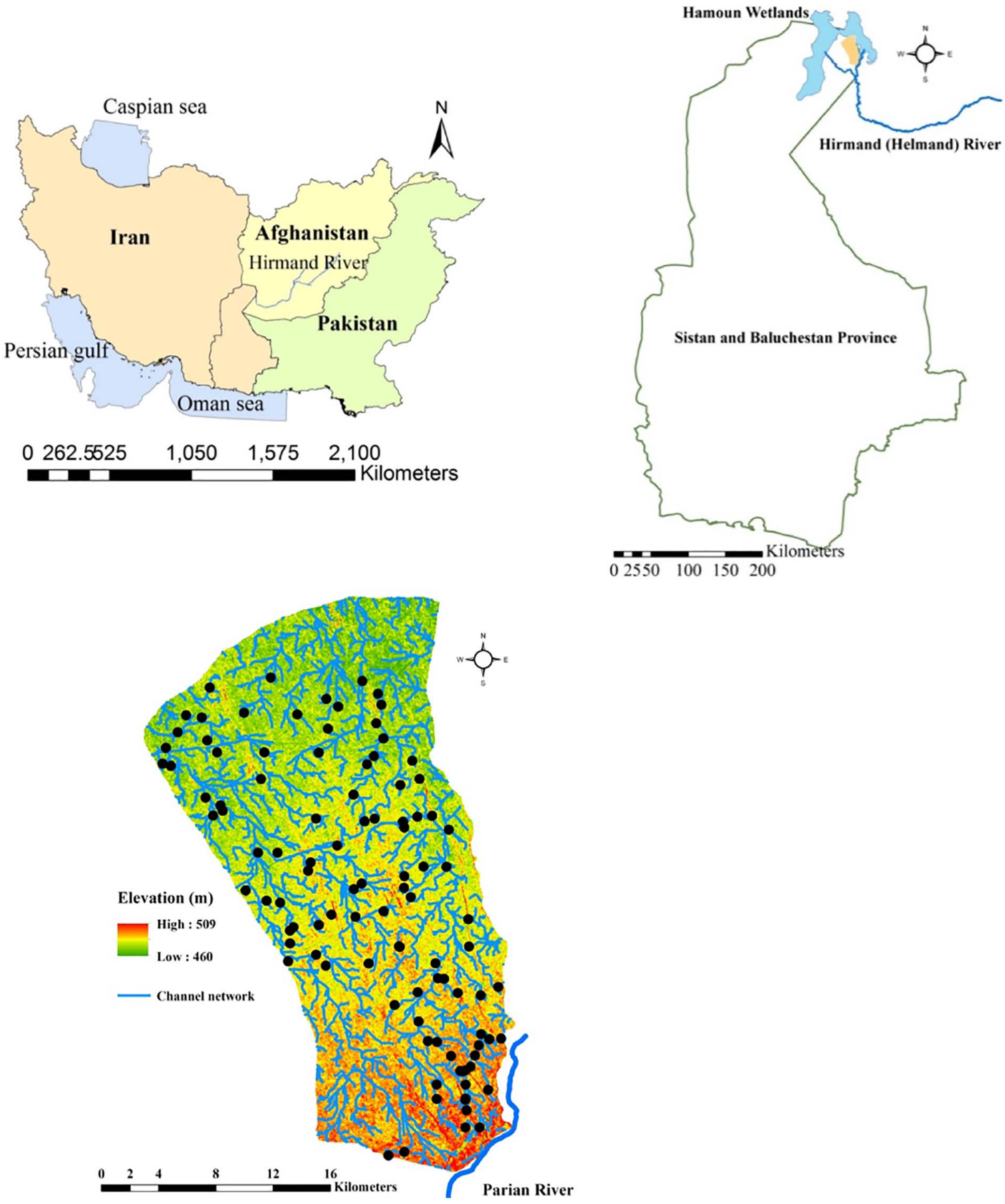

Fig. 1. The position of study area, rivers, channel networks and the locations of sampling points on digital elevation model.

2. Materials and methods

2.1. Study area

The study area is located in Sistan region (Hirmand county) close to the Iranian border with Afghanistan in the eastern part of Iran with an area approximately 60,000 ha (Fig. 1). The study area is part of Hirmand river (also known as the Helmand River) delta. Hirmand River is the lifeblood of eastern Iran and southern Afghanistan and has supported desert civilizations in the Hirmand basin for over 6000 years. The river has a length of 1100 km and as it approaches the southwestern part of the basin, its direction curves sharply to the north as it enters the Sistan depression and terminates in several of the semi-connected wetlands (Hamoun wetlands including Hamoun Puzak, Hamoun Saburi, and Hamoun Hirmand) that straddle the Afghan-Iran border (Whitney, 2006) (Fig. 1).

The region has an arid climate with 55 mm annual average precipitation which is occurring mainly in winter (December to February) while evaporation exceeds 4000 mm/yr as a result of high temperatures (Moghaddamnia et al., 2009). The soil temperature regime is Hyper thermic and the soil moisture regime is Aridic. Wind also is a notable climatic phenomena in this region which has a significant effect on the