Sentinel-2 images for effective mapping of soil salinity in agricultural fields

Khalid A. Al-Gaadi[1,2], ElKamil Tola[1,2], Rangaswamy Madugundu[1,]* and Ronnel B. Fulleros[2]

[1]Precision Agriculture Research Chair, Deanship of Scientific Research, King Saud University, Riyadh 11451, Saudi Arabia
[2]Department of Agricultural Engineering, College of Food and Agriculture Sciences, King Saud University, Riyadh 11451, Saudi Arabia

Salinity is a critical feature for the management of agricultural soil, particularly in arid and semi-arid areas. The present study was conducted to develop an effective soil salinity prediction model using Sentinel-2A (S2) satellite data. Initially, the collected soil samples were analysed for soil salinity (EC_e). Subsequently, multiple linear regression analysis was carried out between the obtained EC_e values and S2 data, for the prediction of soil salinity models. The relationship between EC_e and S2 data, including individual bands, band ratios and spectral indices showed moderate to highly significant correlations (R^2 = 0.43–0.83). A combination of SWIR-1 band and the simplified brightness index was found to be the most appropriate (R^2 = 0.65; P < 0.001) for prediction of soil salinity. The results of this study demonstrate the ability to obtain reliable estimates of EC using S2 data.

Keywords: Agricultural lands, multiple linear regression, satellite data simplified brightness index, soil salinity.

SOIL salinity is considered as one of the major soil characteristics affecting the interaction between plants and soil in addition to its significant impact on the availability of soil nutrients and thus affecting crop production[1,2]. Salinity is also an important factor with respect to sustainable agriculture and soil management, especially in arid and semi-arid regions. However, some agricultural practices contribute significantly to the salinization of agricultural lands such as irregular irrigation, use of salt-water and application of agrichemicals[3]. Corwin and Lesch[4] reported that about 50% (250 million hectares; m ha) of the irrigated soil around the world is adversely affected by soil salinity; of which, about 20 m ha is severely affected.

Electrical conductivity (EC) is closely related to the composition and concentration of dissolved salts in soil solution, and therefore EC of the soil saturation extract (EC_e) is used as a standard measure of soil salinity (expressed in mS/cm or dS/m)[5,6]. The commonly accepted range of soil salinity indicates that a soil with EC_e greater than 4 dS/m at 25°C is defined as saline soil and that with EC_e greater than 15 dS/m as strongly saline soil[7]. Although soil salinity mapping by conventional methods, such as field surveys and laboratory analysis is accurate, such methods are time-consuming, costly and labour-intensive, especially for large-scale measurements. However, advanced technologies such as proximal sensing (EM38 survey, Geonics Limited, Canada) and remote sensing (satellite images) methods, support EC mapping and provide accurate information regarding salt-affected areas. In this context, the potential satellite datasets and image analysis techniques have contributed to the accurate and economic mapping of soil salinity[8,9] and multi-spectral satellite images such as MODIS[10], Landsat TM[11], Landsat ETM$^+$ (refs 12, 13), Landsat-8 (refs 14, 15), IKONOS[16,17], WorldView[18], and Sentinel-2 (ref. 19) have been widely used for mapping soil salinity.

Various salinity indicators have been derived from satellite imagery and used to identify salt-affected agricultural areas[20–22]. The basis of these indicators is the spectral behaviour of saline soils captured by multispectral images[23]. As direct salinity indicators, indices such as brightness index (BI), normalized difference salinity index (NDSI) and salinity index (SI) have been developed and commonly used to identify salt-affected areas[24]. As indirect salinity indicators, however, vegetation indices (VIs) such as the normalized difference vegetation index (NDVI), enhanced vegetation index (EVI), soil adjusted vegetation index (SAVI) and green difference vegetation index (GDVI) have been widely used for soil salinity assessment and mapping[21,25,26]. A wide range of regression models such as linear and exponential regression[2], ordinary least square and spatial regression[27], and partial least square regression[28] have been used as tools to retrieve soil salinity.

Given the negative impact of saline soils on agricultural practices and ultimately on crop production, it is necessary to maintain soil quality and reclaim saline soils, particularly in arid regions such as Saudi Arabia[16]. In this regard, continuous monitoring of soil salinity in agricultural fields is important. Therefore, the main objective of the present study was to develop satellite-based models for monitoring soil salinity in agricultural fields under arid climatic conditions of Saudi Arabia, using remotely sensed Sentinel-2A (S2) multispectral data.

*For correspondence. (e-mail: rmadugundu@ksu.edu.sa)