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Soil salinity assessment through satellite thermography for different irrigated and rainfed crops

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ABSTRACT

The use of canopy thermography is an innovative approach for salinity stress detection in plants. But its applicability for landscape scale studies using satellite sensors is still not well investigated. The aim of this research is to test the satellite thermography soil salinity assessment approach on a study area with different crops, grown both in irrigated and rainfed conditions, to evaluate whether the approach has general applicability. Four study areas in four different states of Australia were selected to give broad representation of different crops cultivated under irrigated and rainfed conditions. The soil salinity map was prepared by the staff of Geoscience Australia and CSIRO Land and Water and it is based on thorough soil sampling together with environmental modelling. Remote sensing data was captured by the Landsat 5 TM satellite. In the analysis we used vegetation indices and brightness temperature as an indicator for canopy temperature. Applying analysis of variance and time series we have investigated the applicability of satellite remote sensing of canopy temperature as an approach of soil salinity assessment for different crops grown under irrigated and rainfed conditions. We concluded that in all cases average canopy temperatures were significantly correlated with soil salinity of the area. This relation is valid for all investigated crops, grown both irrigated and rainfed. Nevertheless, crop type does influence the strength of the relations. In our case cotton shows only minor temperature difference compared to other vegetation classes. The strongest relations between canopy temperature and soil salinity were observed at the moment of a maximum green biomass of the crops which is thus considered to be the best time for application of the approach.

1. Introduction

Soil salinity is one of the severe land degradation problems that affects 1 billion hectares in more than 100 countries (Squires and Glenn, 2004). Moreover, it will increase at a rate of 2 million hectares per year (Abbas et al., 2013) because of the continuing global warming, resulting in desertification and sea water intrusion (Dasgupta et al., 2014). The causes of soil salinity differ from place to place and can be both natural and anthropogenic. There are areas where soils naturally has an increased content of soluble salts because of the weathering process and areas where the main cause is secondary salinisation of irrigated areas because of inefficient irrigation schemes and absence or malfunction of a drainage system (Ghassemi et al., 1995). The effect of soil salinity on agricultural crops are extremely negative as it leads to leaf necrosis, altered phenology and ultimately plant death (Volkmar et al., 1998).

Most often soil salinity is measured by the use of geophysical instruments that measures soil or soil water extract electrical conductivity. That is done either in the field or in the lab, if soil saturated paste extract should be prepared. With a proper calibration this is considered a standard measurement procedure in most of the countries that produce regular soil salinity surveys. The more classical chemical analysis of samples are still used sometimes, but less and less because of the high costs associated and the amount of time required. There is a rich body of literature on the topic of soil salinity assessment by field and laboratory analysis and main points are well summarised in FAO Irrigation and Drainage Paper #57 by Rhoades et al. (1999).

Nevertheless, even improved methods of assessment, like the use of

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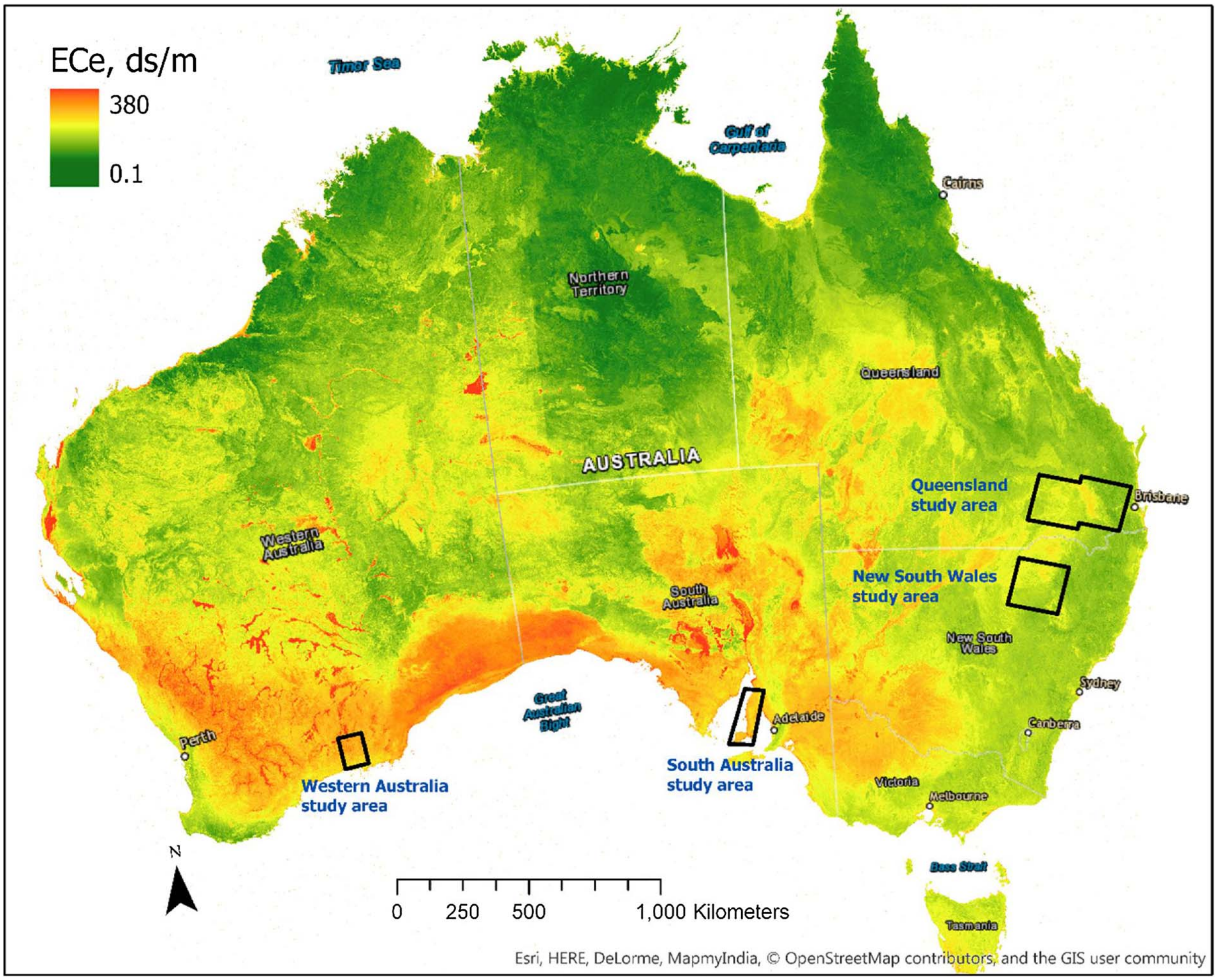

Fig. 1. Study areas marked on soil salinity map of Australia (soil salinity data source: CSIRO Land and Water, Geoscience Australia).

geophysical instruments mentioned earlier, are labour and cost intensive and cannot be implemented several times per season or even yearly on a big scale. Given this situation, timely monitoring of the problem is crucial. Remote sensing is widely used for the monitoring of different environmental phenomena, including soil salinity (Metternicht and Zinck, 2009). Both the spectra of bare soils and vegetation have been used, the latter more widely. Assessment of bare soil salinity has been implemented mainly as a two-step process where firstly soil samples are spectrally analysed in laboratory conditions and a predictive model is built to relate the laboratory measurements to satellite spectral data which is subsequently applied for landscape scale assessments (Aldabaa et al., 2015; Bai et al., 2016; Nawar et al., 2014; Sidike et al., 2014). The vegetation canopy has been studied mainly by calculating different vegetation indices, from which normalised difference vegetation index (NDVI), enhanced vegetation index (EVI) and soil-adjusted vegetation index (SAVI) are the most popular ones (Elhag and Bahrawi, 2017; Hamzeh et al., 2016; Muller and van Niekerk, 2016; Rahmati and Hamzehpour, 2017; Scudiero et al., 2015). But current methods using vegetation indices and bare soil reflectance are site specific and do not demonstrate good performance on different study areas (Allbed et al., 2014).

The use of canopy thermography is an innovative approach for salinity stress detection in plants (Ishimwe et al., 2014; Urrestarazu, 2013). The mechanism of the temperature change is based on plant salt stress response. One of the first components of this response is stomatal closure, which leads to reduced transpiration of a plant and increase of its canopy temperature (Munns and Tester, 2008). The effectiveness of canopy thermography was proven in laboratory and small scale field trials for many plants, including wheat, cotton, barley, euonymus (Gómez-Bellot et al., 2015; Hackl et al., 2012; Howell et al., 1984; Peñuelas et al., 1997), but its applicability for landscape scale studies using satellite sensors is still not well investigated.

Ivushkin et al. (2017) demonstrated that there is a significant correlation between satellite-derived canopy temperature and soil salinity levels, using MODIS satellite thermal images together with NDVI and EVI vegetation indices and a soil salinity map. Using an NDVI threshold they selected only cropped areas and implemented an ANOVA analysis on series of images for the growing season of wheat and cotton (April-October) in Syrdarya province of Uzbekistan. That study showed that satellite thermography data is significantly correlated to soil salinity and has a potential application in soil salinity mapping. Moreover, the F-values were higher for the thermography data then for commonly used vegetation indices. Despite the positive outcome, the research had some limitations. It was conducted on a homogeneous irrigated area with mainly two crops grown in one climatic zone. As a result, questions about the method's applicability in different arid and semi-arid regions of the world and on different crops remained.

Therefore, the aim of this research is to test the satellite thermography soil salinity assessment approach (Ivushkin et al., 2017) on a different study area with different crops, grown both in irrigated and rainfed conditions, to evaluate whether the approach has general applicability. Three research questions are addressed. Does the satellite thermography soil salinity assessment approach apply to study areas different from the one on which it was developed? Is it applicable for different crops? Does it apply to both irrigated and rainfed agriculture?