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Development of a tool for automatic bare soil detection from multitemporal satellite optical imagery for digital soil mapping applications

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Abstract. Understanding the variability of soil attributes allows to improve the farm production efficiency, accompanied by a reduction in environmental impacts and effective usage of resources. Several studies confirmed the potential of optical remote sensing data for quantifying soil attributes, such as clay content, soil organic carbon and texture classes A challenging issue in spatial-temporal soil surveying by remote sensing data is the limited availability of cloud-free images or affected by cloud/shadow. Further, imagery with high temporal resolution is extremely important for observing terrestrial surfaces. This study investigates the use of multispectral (Sentinel-2 MSI) satellite imagery at the regional/local scale, for the automated detection of agricultural bare soil occurrence, exploiting bands covering the spectral range from visible to shortwave infrared. The study objective is to provide bare soil time series that could be subsequently exploited in digital soil mapping (DSM) approaches based on multispectral or, also in view of the next future missions, hyperspectral remote sensing data.

1. Introduction

Although many studies are using remote sensing data for monitoring vegetation, crops, and land cover use and change, its use for extracting exposed soil information is limited. Soil information is required as input for modelling studies, such as climate change or estimation of carbon storage in soils [1]. High spatial and temporal resolution soil information is crucial for agriculture in order to maintain or increase agricultural productivity, to assess and avoid soil degradation and ultimately to achieve sustainable food security [2,3].

A promising approach that can be integrated into existing soil mapping approaches to increase temporal and spatial resolution of soil information is the use of remote sensing information [2]. Today more advanced remote sensing data, such as airborne hyperspectral data, can directly provide topsoil properties like texture, soil organic carbon and content of some minerals have now been successfully identified [2, 1].

Satellites equipped with hyperspectral imagers in the optical domain have or will be launched in the near future, such as PRISMA of the Italian Space Agency launched in March 2019, EnMAP of the German Aerospace Center, HISUI of the Japan aerospace exploration agency, the U.S. NASA

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Hyperspectral Infrared Imager HyspIRI, and the Israeli Hyperspectral imager SHALOM. These satellites will provide increased spectral information related to soils. Having such data sources provides a unique opportunity to have a large number of images available spatially and temporally that would allow for building an "archive" of exposed soil. Nevertheless, high quality multispectral sensors such as Sentinel-2 (S2) have been launched which capacity to quantify exposed soils may match the one of upcoming hyperspectral spaceborne sensors.

The objective of this research is to estimate the seasonal occurrence of bare soil conditions, in Italian arable land areas.

2. Methodology

All available Sentinel-2 images were collected for the period between 1 January 2016 and 31 August 2019 (n = 604). The large amounts of data that attend these Sentinel time series are handled using a recent development in image analysis, the Google Earth Engine (GEE) platform.

The study area of this research is focused on Central Italy 'Lazio region' (301,338 km²; latitude 42° N and longitude 12° E). The delineation of the country was done with the Large-Scale International Boundary (LSIB, 2013) dataset. In order to separate the exposed soils from other land covers, we divided the study area in two parts: (I) the agricultural arable land area and (II) the non-arable land area. The outline of the arable area was defined using the CORINE land cover ((CLC) 2012, Version 20) inventory map and includes only the classes non-irrigated arable land and permanently irrigated arable land. The other bands of the Corine map were excluded.

In order to select the bare soil pixels in the Sentinel time series, we used a bare soil index (BSI) introduced by Rikimaru et al. [4]. A combination between NDVI and BSI is a good alternative. We defined a threshold for the BSI in order to make a distinction between bare soil and dry vegetation or mixed pixels (values above 0.08 were considered bare soil). Within this area, we selected all pixels with a BSI value above the selected threshold, combined with minimum NDVI values (lower than 0.2). The result was the barest soil pixel areas. In order to validate the bare soil classification accuracy, we calculated the error matrix and computed the producer's accuracies and user's accuracies for 100 random pixels.

The frequency of bare soil estimation was calculated as the number of times a pixel is classified as bare soil, divided by the temporal coverage in this period.

3. Results

The seasonal occurrence, for all time periods, indicated an increase of bare soil area while approaching to summer time (especially in July and August), which is after the harvest periods for winter cereals in the region.

The producer's and user's accuracies indicate that the classification threshold for bare and non-bare soil pixels performed well. The producer's accuracies values for bare pixels and non-bare pixels is equal to 81% and 100%, respectively. The user's accuracies values for bare pixels and non-bare pixels is equal to 100% and 91%, respectively. The overall accuracy value is 94%. This illustrates that the prediction of the bare soil frequencies is straightforward at large spatial scales.

The research will investigate the feasibility of developing an open source tool able to generate bare soil time series suitable to apply DSM techniques to retrieve topsoil spectral characteristics, e.g. for variable-rate nutrient applications.

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