Remote sensing monitoring of soil water buffering in Agricultural Terraced Landscapes: an application of OPTRAM methodology in Tuscany Region, Italy

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OBJECTIVES

The aim of this work is to test the **Optical Trapezoidal Method (OPTRAM)** developed by Sadeghi et al. (2017) for the remote sensing monitoring of soil moisture, at high resolution, in a terraced landscape. The objectives of the work are to:

- check the water retention potential of terraced landscapes at spatial level,
- assess the hypothesis of a universal parametrization of the OPTRAM methodology, and
- test the robustness of the methodology by an uncertainty analysis on the model parameters.

OPTRAM can predict the **moisture content in the first 5 cm of soil with an accuracy of 0.04-0.05 cm^3 cm^{-3}**

OPTICAL TRAPEZOIDAL METHOD (OPTRAM)

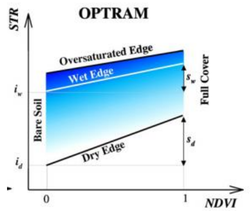
The OPTRAM methodology is based on the pixel distribution in a **scatter plot** of two variables, the Normalised Difference Vegetation Index (NDVI) and the SWIR Transformed Reflectance (STR), calculated as:

$$NDVI = \frac{\rho_{NIR} - \rho_{RED}}{\rho_{NIR} + \rho_{RED}}$$

$$STR = \frac{(1-\rho_{SWIR})^2}{\rho_{SWIR}}$$

With ρ_{RED}, ρ_{NIR} and ρ_{SWIR} calculated as the reflectance in red, near infrared and short-wave infrared wavelengths.

The NDVI-STR scatterplot assumes a trapezoidal shape. Pixel that correspond to saturated soil are located on the top edge of the trapezoid (Wet Edge), while pixel correspondent to dry soil are located on the bottom edge (Dry Edge).



Graphical sketch illustrating NDVI-STR space for OPTRAM method. Source: Sadeghi et al., (2017)

Slope and intercepts for the Dry Edge (s_d and i_d) and for the Wet Edge (s_w and i_w) can be calculated. Soil moisture (W) for each pixel can be thus calculated as:

$$W = \frac{i_d + s_d NDVI - STR}{(i_d - i_w) + (s_d - s_w)NDVI}$$

The optimal way to detect dry and wet edges is represented by visual inspection. This is not representing a major drawback of the methodology, since **the shape of the pixel distribution on the NDVI-STR space is identical for a given location**, at any time, regardless of the environmental factors.

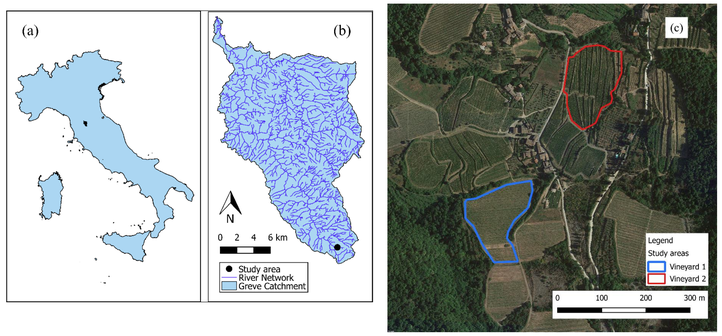
SATELLITE IMAGERY

USGS Earth Explorer database has been used to retrieve **Sentinel-2 images** for the study area. A selection of 5 Sentinel-2 Images has been chosen, according to the following criteria: totally cloud-free images for the Greve watershed; and 2A processing level (Main-Knorn et al., 2015), corrected for Bottom Of Atmosphere (BOA) reflectance values. Images were selected for: 04/07/2015, 03/08/2015, 13/08/2015, 18/07/2016, 26/09/2016. Band 4, band 8 and band 12 have been used for the analysis, and band 12 was resampled on a 10-m grid.

AREA OF STUDY

The study investigates the soil water content of 2 vineyards within **Lamole** area: Vineyard 1 (V1), characterized by no terracing and grapes line oriented towards the maximum slope gradient; and Vineyard 2 (V2), with stone bench terraces implemented. V1 and V2 presents similar soil characteristics (loamy sand), and identical land cover.

The study area is located in Tuscany Region (Italy) and it is situated in the municipality of Greve in Chianti (43°32'34.73"N, 11°21'29.14"E), in the headwaters of the river Greve catchment, tributary of the river Arno. For the OPTRAM parametrization, the study area of Greve catchment has been considered, according to the first test of the methodology by Sadeghi et al. (2017) on two river catchments in the US.

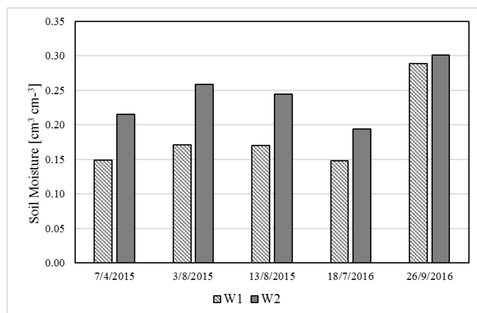


Study area: (a) location of Greve catchment, (b) location of Lamole within the Greve catchment; (c) overview of the Vineyards 1 and 2.

Vineyard	Orientation	Area [ha]	Slope [m/m]			Elevation [m a.s.l.]		
			mean	min	max	mean	min	max
V1	W	1.62	21.0	13.9	39.3	529	513	541
V2	W	1.76	26.8	21.0	36.6	559	545	577

Physical characteristics of the studied vineyards.

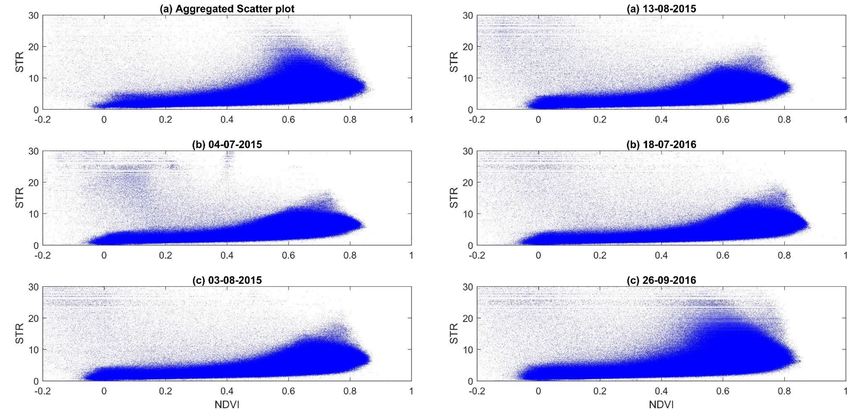
RESULTS: SOIL MOISTURE ANALYSIS



Analysis of soil moisture W in V1 (W1) and V2 (W2)

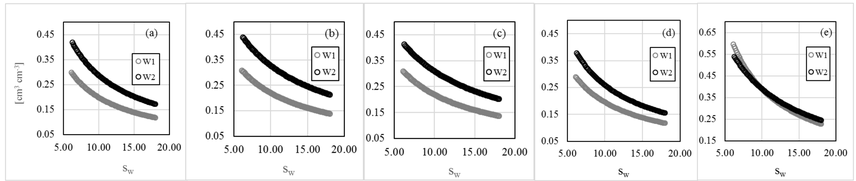
Results show that, for all the images considered for the analysis, terraced V2 vineyard is more humid than V1 vineyard. Only for the image of 26/09/2016, the difference in below 0.01 cm^3 cm^{-3}, and so below the OPTRAM method accuracy (Sadeghi et al., 2017); however, this effect can be related to a general elevated soil moisture content in the catchment, caused by autumn rains.

RESULTS: OPTRAM PARAMETRIZATION



Results show an identical shape for all pixel distribution, confirming the hypothesis of identical parametrization for the location.

RESULTS: SENSITIVITY ANALYSIS



Uncertainty analysis for the images selected: (a) image of 04/07/2015; (b) image of 03/08/2015; (c) image of 13/08/2015;(d) image of 18/07/2016; (e) image of 26/09/2016

An uncertainty analysis, that has been realised by varying s_w coefficient between 6 and 18, with 100 successive steps, showing V2 more humid than V1 for all the dry season (July and August) regardless of s_w value. Only for the image of 26/09/2016 values are almost equal given the high level of soil moisture in Greve catchment.

CONCLUDING REMARKS

The test of OPTRAM methodology confirmed the robustness of the method. The basic hypothesis of an uniformal parametrization for any given location, e.g. a river catchment, was confirmed. In addition to this, a sensitivity analysis showed how the direction of the differences in soil moisture, and the magnitude of the difference itself is not heavily affected by the uncertainity in parametrization.

The methodology has been tested for Lamole terraced landscape in Italy, where a terraced vineyard was found to be more humid than a non-terraced one, with a ground resolution of 10 m. Preliminary results suggest that agricultural terraces can retain soil moisture in summer even in temperate Mediterranean climate. However, further analysis is needed to avoid biases given by non-uniform groundwater dynamics between the sites.

References

Main-Knorn, M., Pflug, B., Debaecker, V. & Louis, J. Calibration and validation plan for the L2A processor and products of the Sentinel-2 mission, in: International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences - ISPRS Archives. pp. 1249–1255. 2015.

Sadeghi, M., Babaeian, E., Tuller, M. & Jones, S.B. The optical trapezoid model: A novel approach to remote sensing of soil moisture applied to Sentinel-2 and Landsat-8 observations. Remote Sensing of the Environment, 2017, 198, 52–68.