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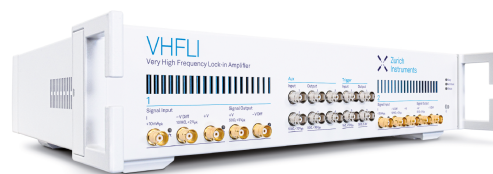
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# Remote Sensing Approach for Monitoring of Macrofactors Clime, Soil and Vegetation (Me.D.A.L.Us. Protocol) in the Desertification Process in Sicily

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**Abstract.** Remote sensing technology by analysis of multispectral images represents allows you to monitor climate, soil, and vegetation dynamics of a territory. By means spectral indices NDVI (Normalized Difference Vegetation Index), MSAVI (Modified Soil-Adjusted Vegetation Index), NDMI (Normalized Difference Moisture Index), NBR (Normalized Burn Ratio), Spectral Albedo values (BRDF) of Liang, BSI (Bare Soil Index) LST (Earth's surface temperature) and the GIS technology, is possible accelerating the acquisition of spatial-environmental data. The authors started out a research about the use of the aforementioned spectral data, considering as study area Mussomeli Municipality (Caltanissetta Province, Sicily), to evaluate the sensitivity of the area to desertification, in a short period (year, season). In this study, the satellite data are considered in MEDALUS (Mediterranean Desertification and land use) protocol, which adopts data attributable to four Macrofactors: protection, soil, climate, and land management.

## INTRODUCTION

"Desertification" means the process that leads to an irreversible reduction of the soil capacity to provide resources and services" (FAO-UNE-UNESCO, 1979), that is, to support the production of biomass due to climate changes, and human activity which compromises ecosystems resilience. The ecosystems decline determines the change of phytocoenosis composition of over time [1-4], of environmental quality in general [5-6], and a decrease in the ecosystem services provided by the plant-soil system. Sicily is a region with a high-risk grade of desertification, as documented by studies and cartographies [7-11]. MEDALUS - Desertification and land use in the Mediterranean [12] is the most used protocol in the Mediterranean area that allows the identification of areas sensitive to desertification, through the application of biophysical and socio-economic indicators. According to the MEDALUS protocol, the most recent cartographic representation of the desertification risk in Sicily (Piccione et al., 2020 in print) highlights area is in an advanced stage of desertification since most of its surface area 95.8% is sensitive to the desertification process. Satellite monitoring by analysis of multispectral images represents a powerful tool for diagnosing and monitoring the state of vegetation dynamics and land use, and is largely used to correlate vegetation, soil degradation and desertification, GIS and MEDALUS approach [13-24]. The authors presented the first results on the use of some spectral indices in an area of Sicily. IRSSAT Institute for research, development, and experimentation on the environment and the territory, carried out 12 ebooks with the multitemporal characterization of the sensitivity to desertification risk for the 390 Sicilian municipal territories (IRSSAT, 2020). This activity

intends to provide the Region of an annual scan of trend desertification risk, by means the continuous and capillary monitoring, useful for the management intervention actions of the territories.

## MATERIALS AND METHODS

### Study case

As a study case (Fig. 1), the municipal area of Mussomeli (164 sq km), located in an internal hilly area at 765 meters a.s.l., in the province of Caltanissetta (Central Sicily), was analyzed. The area was selected for the high (78%) and widespread (99%) risk of desertification (IRSSAT 2020). The area is affected by an arid season that lasts about 4 months (from mid-May to mid-September). The outcropping lithotypes are made up to a greater extent of very cemented sandstones and calcarenites, with sandy and clay-silty intercalations, and of Gypsums and associated lithotypes. The widely prevalent habitat is represented by vast crops and complex agricultural systems, which cover more than 82% of the territory. In the time, the human impact and the transformations have been heavy and vegetation consists mainly of secondary phytocoenoses of shrub communities and grasslands dominated by caespitose perennial graminaceous plants, linked to the series of vegetation belonging to various wood communities of the class *Quercetea ilicis*.

### Remote sensing indices

The spectral indices that characterize the bio-physical properties of the soil can be used as geo-environmental parameters. Following the MEDALUS protocol, the indices considered were referred to the macro-categories: vegetation, soil, and climate. In the study, a temporal scan ranging from 4 to 6 years has chosen (the studied period in the 2000-2020 range, includes, specifically, 2000, 2004, 2008, 2014, and 2019 years). The attention has been on the month of August, as it is representative of the maximum intensity of aridity and drought in Sicily. The spectral indices NDVI (Normalized Difference Vegetation Index) [25], MSAVI (Modified Soil-Adjusted Vegetation Index) [26], NDMI (Normalized Difference Moisture Index) [27], NBR (Normalized Burn Ratio) [28], Spectral Albedo values (BRDF) of Liang [22], BSI (Bare Soil Index) [29], LST (Earth's surface temperature) [30 - 35].

The spectral indices were calculated and managed in a GIS environment allowing a rapid extrapolation of synthetic territorial information.

## RESULTS AND DISCUSSION

In August, the trend of the NDVI has always attested the shifting of the peak towards the lower values with the increase of the frequency, as shown in figg. 3 and 4 relating to the year 2019, in another study case tested for Enna territory (Central Sicily), as example.

As regard Caltanissetta territory, two matrices of the differences have been calculated considering the range period of 2000- 2019, selected for the NDVI and albedo parameters (Figg. 4-5-6).

Two difference matrices were calculated considering the 2000-2019 interval period, selected for the NDVI and albedo parameters. As a function of the range of values can observe the overall evolution of the land cover (Figg. 7-8).

Based on data by Piccione [7] and IRSSAT 2020 the Mussomeli territory presents, in the comparison amongst two periods of thirty years and for the most risk class (sensu MEDALUS), the following values:

<i>30-year periods</i>	<b>Critical 1</b>	<b>Critical 2</b>	<b>Critical 3</b>
1961-1990	3,2	23,7	64,1
1991-2015	3,1	12,1	77,6

The 1991-2015 (IRSSAT, 2020) shows a shift from critical 2 to critical 3 of 11.6 percentage points of the territory with the consequence that more of the territory of the municipality displays the maximum criticality of the desertification risk.

Through ESPI Environmentally Sensitive Patch Index [11], the index that provides on a 0-100 range the overall sensitivity to desertification of a territorial area, the following Espi values have been obtained for the territory of the Mussomeli Municipality.

<i>Years</i>	<b>2000</b>	<b>2004</b>	<b>2008</b>	<b>2014</b>	<b>2019</b>
ESPI	67	83	85	84	86

By calculating the arithmetic difference of the values associated with each raster, the percentage of areas that have undergone an increase or decrease in a parameter or index under examination can be defined, especially when comparing the NDVI and Albedo parameters. Using the frequency histograms of the difference matrices, it is also possible to view the overall evolution of the land cover as a function of the range of values subtended by the curve. A promising correlation emerges in comparison with the ESPI data for the 5 years examined. More study cases are actually in progress on how to accurately analyze the correlation between remote sensing indices and the environmental features and parameters, the issue needs further discussion and development.

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