A study of the hyperspectral stress response of vegetation to drought situation. Case of study Como lake, summer 2022.

Abbes Madeleine

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Abstract

In the summer of 2022, the subalpine Italian forests suffered from high drought conditions. The scope of the analysis is to compare hyperspectral response of vegetation data between 2022 and 2021 (this former as model year) using multi-spectral indexes. NDVI will be computed and compared between the 2 years. Surprising results will allow the validation and invalidation of some scientific work.

1 Introduction

The summer 2022 was characterised by hot and dry conditions over much of western Europe [1]. In particular, the neighborhood of Como lake, in the north of Italy, was marked by a particular phenomenon : trees and grass showed signs of autumn earlier than usual. Only in the middle of August, the trees started to go brownish, and lose leaves. This is explained by B. Cerabolini, professor at the University of Varese, to be a way for plants to save water in case of high drought : "Leaves are the part of the plant losing the more water. In case of important drought, the tree can save water reducing its foliage density. " [2]. This behaviour can be of high impact on the rest of the plants, and also the animals of the ecosystems. Not only this could modify biodiversity : leafs are one of the main components in the soil of our forests. If this reduces, the organic matter content of the terrain may reduce, increasing the production of CO_2 and reducing the capacity of the soil to retain humidity.

Summer 2022 drought is only one of the issues induced the current climate deregulation our planet is facing. Research work on the field show that these kind of events will become stronger and more frequent in our future, if nothing is done to change the situation. Studying these phenomena is hence becoming the most important topic for research, as this could help finding solutions to lower there impact on people's lives and activities. Geospatial science are in this field very important, as they present very powerful tools to monitor and quantify climatic events and ecosystems state.

One of the most used multispectral index for monitoring vegetation health is Normalised Difference Vegetation Index (NDVI). This index is directly correlated with chlorophyll content of the plants canopy [3]. Recent work has evidenced that severe drought might result into a stress response of the plants increasing its chlorophyll content of hte tissues [4].

Using multispectral imagery Sentinel 2 data, and taking into account the scientific work on the field, this paper will aim at analysing what are the impacts of drought on vegetation's response to multispectral imagery, and hence try to determine how can a drought might be detected out of geospatial data.

2 Materials and methods

2.1 Study area

Northern Italy has a very rich flora and wildlife [5]. In particular, a big part of it's territory covered by lakes and rivers. Protected by the Alps from strong

winds, the region is known for it's very humid, rainy and foggy climate. With the climate change, these conditions are changing and this may affect strongly the wildlife of the area, and also the composition of soils impacting agriculture activities.
In particular, we center our study on the shores of Como lake, which is one of the biggest water basins of the north of the country.

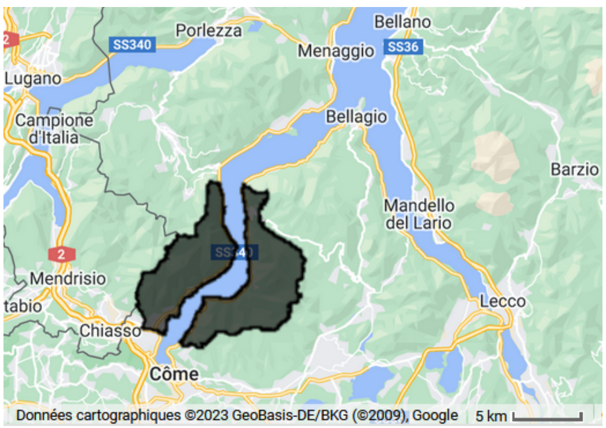


Figure 1: Area of interest : the southern shores of Como lake. Northern Italy

2.2 Data

Satellite imagery was used as data for this study. In particular, tiles from the Copernicus Sentinel 2 mission, composed of 2 identical satellites in the same orbit. This mission is characterised by a high-resolution multispectral imager with 13 spectral bands with a range of 0.443–2.19 μm in the electromagnetic spectrum and of different resolution, from $10m$ to $60m$. [6]

2.3 Frameworks used

Preliminary visual anlaysis, and data preprocessing were performed on the Google Earth Engine (EE) code editor, a computing platform that allows users to run geospatial analysis on Google's infrastructure. The Earth Engine Code Editor is a web-based IDE for the Earth Engine JavaScript API, designed to make geospatial workflows fast and easy. [7]
Processed data was then download from the Earth Engine, and quantitative analysis was performed locally using Python. Libraries *shapefile* and *seaborn* were used to perform the statistical analysis, and display the results.

2.4 NDVI

The Normalised Difference Vegetation Index (NDVI) relies on the fact that spongy and healthy vegetation reflects a lot of light in the nearinfrared (NIR) spectrum, in stark contrast with most non-plant objects. On the contrary, the vegetation that is dehydrated and unhealthy reflects less light in the NIR, but the same amount in the visible range.

$$NDVI = \frac{NIR - VIS}{NIR + VIS}$$

NDVI can help to highlight vegetation from other land features, and even help differentiate healthy vegetation from unhealthy vegetation [6].

2.5 NDBI

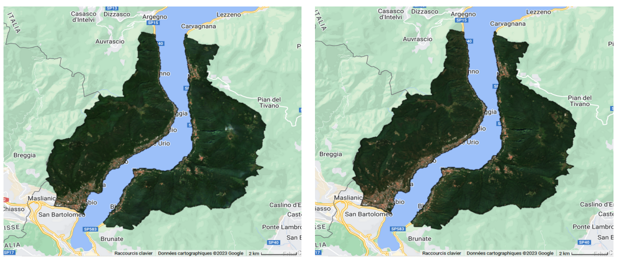
The Normalized Difference Built-up Index (NDBI) is useful in monitoring the distribution of urban areas. It can also be used paired to NDVI to study vegetated areas. The formula is given by the formula :

$$NDBI = \frac{SWIR - NIR}{SWIR + NIR}$$

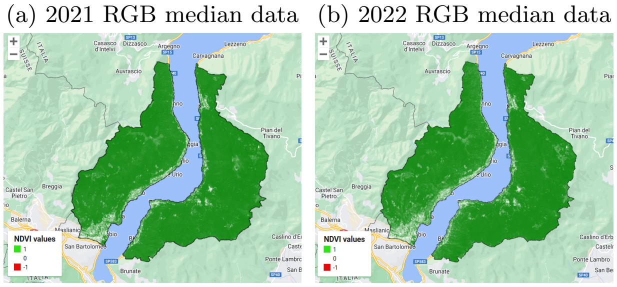
2.6 Preprocessing

Sentinel 2 multispectral satellite imagery was retrieved directly on the EE platform. We selected 2 different time periods : from July 1st to August 31st of 2021 and 2022. Images were first filtered per cloud cover, and we kept from 2 time periods only images with less than 10% cloud cover. This was to reduce the impact of clouds on the data.
After filtering per cloud cover, we applied a mask for removing the remaining clouds on the remaining images for both time period.
Then, as the mask can create void areas where the

cloud was in the image, we transformed the image collection into single image, by taking the median pixel of the collection for each period. This averaging is also allowing us to reduce the effect of the time period on imagery. In fact, selecting one single tile per time period for the analysis the date of the chosen image is strongly impacted by the cloud cover percentage of the tiles. Hence one could get one early-July image for 2021, and late-August 2022. comparing both images would not have much meaning, as through the 2 months of summer the vegetation can change a lot.



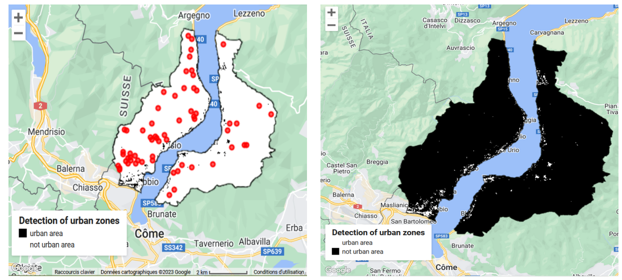
(a) 2021 RGB median data (b) 2022 RGB median data



(c) July-August 2021 median NDVI value (d) July-August 2022 median NDVI value

Figure 2: Median data for the 2 period. RGB visualisation after cloud filtering and NDVI values.

In a second time, NDVI values were computed for both images 2c, 2d. NDVI will be used in analysis for measuring the health and chlorophyll content of the trees.
It is important to consider that some parts of the area has buildings, so this can false the NDVI analysis. For this purpose, we computed the NDBI of the images, to mask urban area before point sampling, as the urban area NDVI values could add bias to our analysis. Pixels considered as "built-up" where those with NDBI value > 0 [8] and where not considered in further analysis.



(a) Sampling points (red) (b) Urban area (white)

Figure 3: 3a. Sampled point were chosen outside of the built area. 3b. Pixels with values of $NDBI > 0$ are considered as built up.

For the next step, we selected manually sampling points on the images. The criteria for the selection was visual : points where the 2022 RGB value looks more brownish than the 2021 RGB value were selected. The scope is to sample the NDVI rasters on this cloud of point, to see if the early falls phenomena has an impact on multispectral data. Attention was paid to not select pixels with buildings, as we are interested only in vegetation. The final cloud of point for sampling is covering most of the area 3a

Eventually, both NDVI images **??** were sampled according to the cloud of point 3a. Sampled NDVI values were exported to local drive for analysis in Python.

3 Results and discussion

When building the histogram of point samples from both years, we can visually interpret that the distribution of NDVI for 2022 is slightly shifted to the right with respect to the 2021 distribution 4. This would mean that brownish points have higher NDVI value than green points. In fact, we can observe that the basic statistical analysis can confirm this intuition.

Year	2021	2022
Mean	0.22183	0.24205
std	0.035049	0.045836

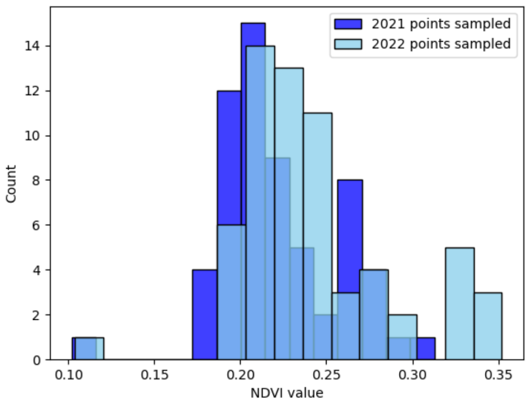


Figure 4: Distribution of the NDVI value of points sampled from both years.

A Student's 2-samples t-test allow us to validate our hypothesis :

	t test results
t-statistic	-2.7373
pvalue	0.0071209
df	122.0

As the p value is lower thant our threshold $\alpha = 0.05$, we can invalidate the null hypothesis : the difference between both means is significant, and not due to error.
This means NDVI is on average significantly higher of 2% in the 2022 sampled dataset than in the 2021 sampled dataset.
This is a surprising result, as high NDVI values are usually associated with healthier vegetation, and low values linked with dry or burnt area [9]. So our study is going in the same direction than Rustioni's work on plants response to drought stress. Indeed, due to the very high correlation coefficient (0.8) between NDVI and chlorophyll canopy content [3], we can deduce that in our study case drought increased the chlorophyll content of plants in summer 2022 as NDVI increased.

4 Conclusion

We have demonstrated in this paper that the NDVI can be used efficiently for drought monitoring and detection. We found that NDVI of an area is higher in case of drought, such as the Summer 2022 drought. We have shown that severe drought results into a stress response of the plants, that is an increase of the chlorophyll canopy content of the vegetation in the area touched by drought. We have unvalidated the hypothesis saying that NDVI is linked directly to the health and humidity condition of the vegetation [6], as by definition stressed vegetation is not healthy vegetation [4].

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