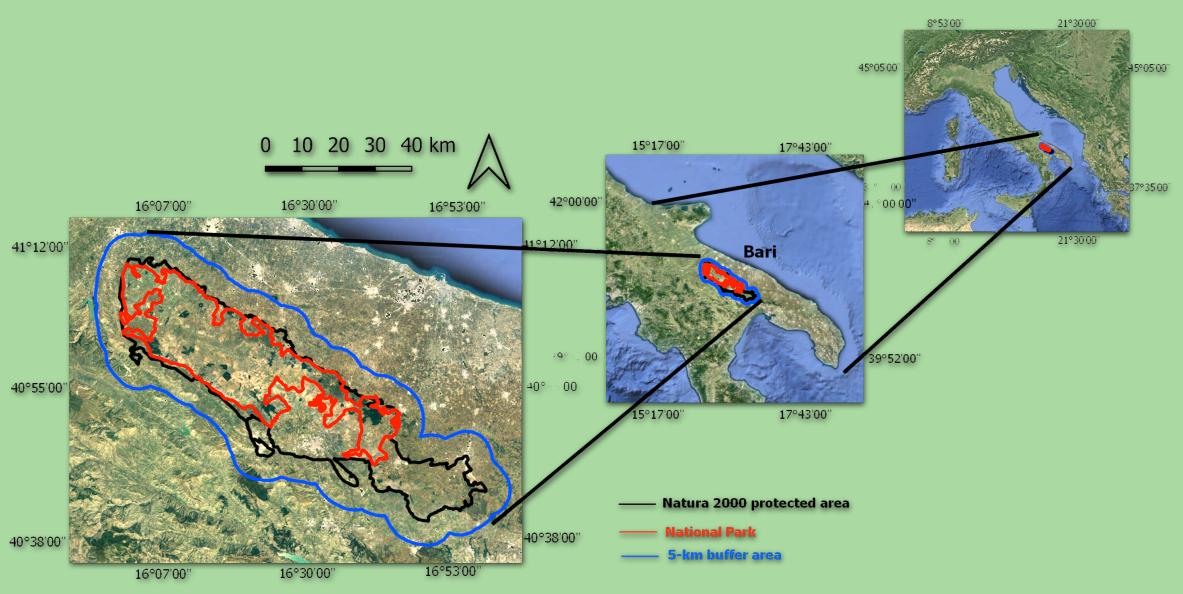# Forest Monitoring: Fires and Recovery in Alta Murgia, the MOIRA Project

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Introduction

The risk of forest fires has increased significantly in recent years, not only in Europe, but around the world. In Italy alone, hundreds of thousands of hectares burn every year, causing deaths, destruction of forests, loss of biodiversity, and damage to infrastructure and farms. One way to address this problem is through satellite remote sensing, which is a valuable tool for monitoring and managing fires, assessing risks, measuring and evaluating damage caused by fires, and preparing recovery actions.

The MOIRA project aims to develop automated satellite monitoring procedures using Landsat and Sentinel-2 imagery to assess the health of forest areas in the Alta Murgia National Park and to identify and characterize land degradation caused by negative events such as forest fires, illegal logging, conversion of forest land to agriculture, and inappropriate use of areas affected by fires.

This project also aims to track the process of vegetation recovery after a critical event through time series analysis of past events and real-time monitoring of actual vegetation recovery.

Finally, the project aims to establish a pilot low-cost ground-based monitoring system to complement the existing video surveillance network. This system will focus on monitoring remote or less frequented areas of the park where the installation of high-end monitoring stations would not be cost effective. The proposed system is self-sufficient in terms of power and is capable of performing real-time image analysis over the study area.
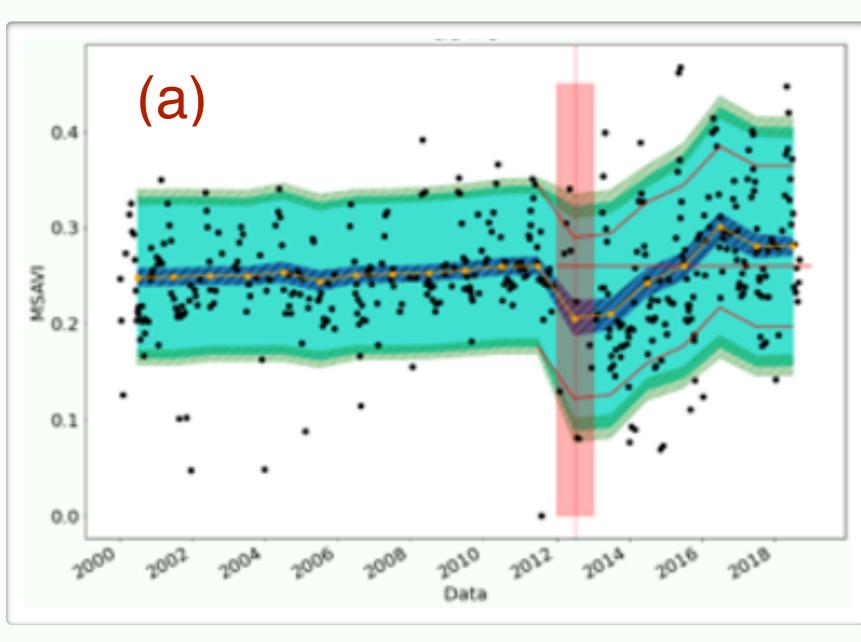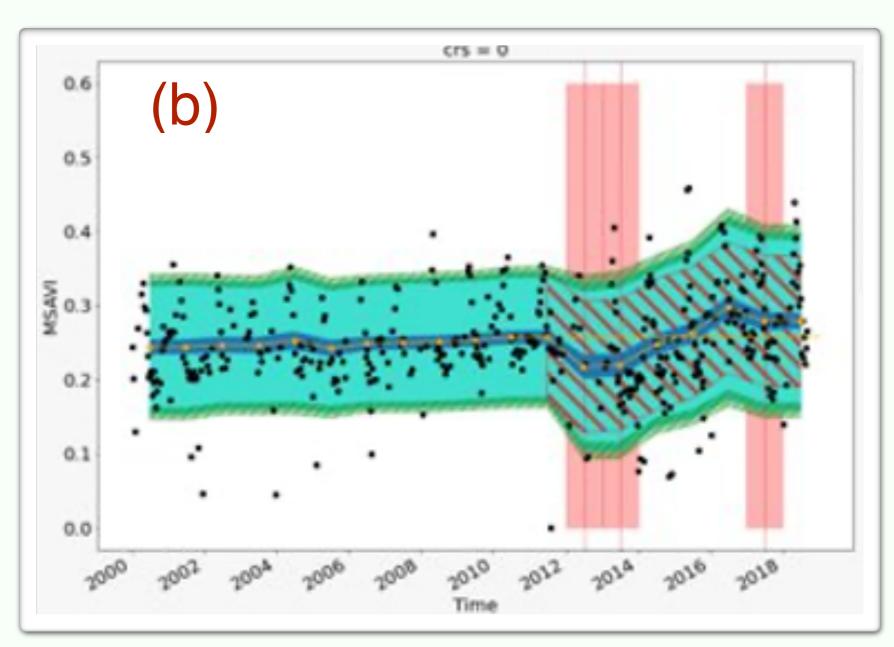
Satellite monitoring

The Alta Murgia National Park is located in Puglia, southern Italy, and covers an area of about 680 km2 within a larger Special Protection Area that extends nearly 126 km2. The altitude of the area ranges from 285 to 680 m above sea level and its climate is meso-Mediterranean, oceanic and subcontinental with a dry to sub-humid ombrotype.

The Park's landscape is typically Mediterranean agro-pastoral, mainly occupied by semi-natural rocky dry grasslands, while the forest vegetation consists only of residual patches of downy oak, woodland and Aleppo pine.

This area is considered to be of crucial importance for the conservation of wildlife, in particular because the semi-natural grassland ecosystem hosts numerous regionally endemic and rare plant species, as well as many plants with a trans-Adriatic distribution.

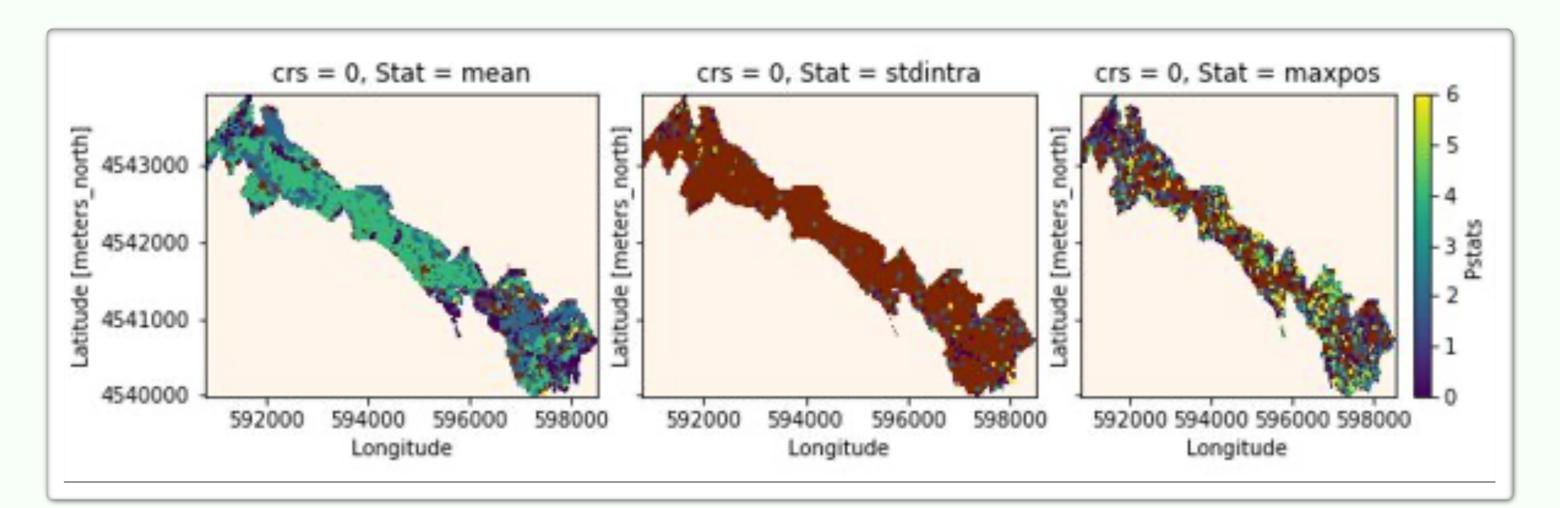During the last 30-40 years, grassland ecosystems have been exposed to severe impacts and accelerated processes of habitat degradation and fragmentation within and adjacent to their borders, caused not only by natural events, such as the reduction of precipitation due to climate change or the spread of invasive species, but mainly by anthropogenic changes, such as the conversion of grassland pastures into cereal crops, the dumping of illegal waste and toxic sludge causing heavy metal contamination of soils and aquifers, legal and illegal mining activities, and frequent fire events.

The analysis of the time series of the land cover maps shows an accentuated loss of the dominant ecosystem represented by natural grasslands in the decade 1990-2001, amounting to ~25% of the monitored area, a loss that continued until 2004, when the Alta Murgia National Park was established. The creation of the National Park has stopped the loss of natural grasslands and, in recent years, the subsequent regrowth of natural grasslands in several areas previously burned by fire. A similar analysis is being carried out for the areas covered by forest vegetation, which are often severely affected by natural or arson fires.

Grassland cover maps from 1990 to 2018 (Landsat data).

Fire detection system

As part of the MOIRA project, we are developing a low-cost pilot monitoring system to detect the onset of new fire events in areas of the park that are more difficult to access or less frequently visited, where it would not be economically feasible to install the high-capacity monitoring stations that make up the current fire remote sensing system.

Each node in the pilot system is capable of automatically determining if there is a fire in the immediate area by analyzing the images captured by the cameras and the atmospheric gas composition.

Each node is self-powered and can connect to the central server either through a direct connection or by hopping the wireless signal through surrounding nodes. This makes them easily relocatable to better adapt to the changing needs of monitoring local fire events.

Evaluation of post-fire recovery

Post-fire vegetation recovery was estimated using the MSAVI vegetation index, which allows for better differentiation of the vegetation signal from the ground. The images on the left show the MSAVI index between 2000 and 2018 for (a) the Acquatetta forest and (b) the Difesa Grande forest. The light red vertical bars mark the occurrence of fire events.

These data can be used to estimate the vegetation recovery time, i.e. the number of years it will take for the seasonal statistics to recover to pre-fire values with a 95% probability, as shown in the maps below: (left) annual mean, (center) annual standard deviation, and (right) day of annual maximum). The dark red pixels represent locations that will not recover to pre-fire values in the allotted 6-year time frame (image below).

Post-fire monitoring

To better understand the process of vegetation recovery after a fire, a burned forest area is closely monitored with an eddy covariance tower to measure greenhouse gas fluxes and primary productivity of the vegetation.

The area of the park burned by the last fire is shown in the top image on the right, while the bottom image shows a 360° photo taken at the most interesting candidate site within this area for the positioning of the eddy covariance tower, due to the low slope of the surrounding terrain and the apparent characteristics of the incoming wind. The final choice of the site will depend on a more detailed analysis of the characteristics of the winds circulating in the area, in particular the effect of the turbulence caused by the difference in altitude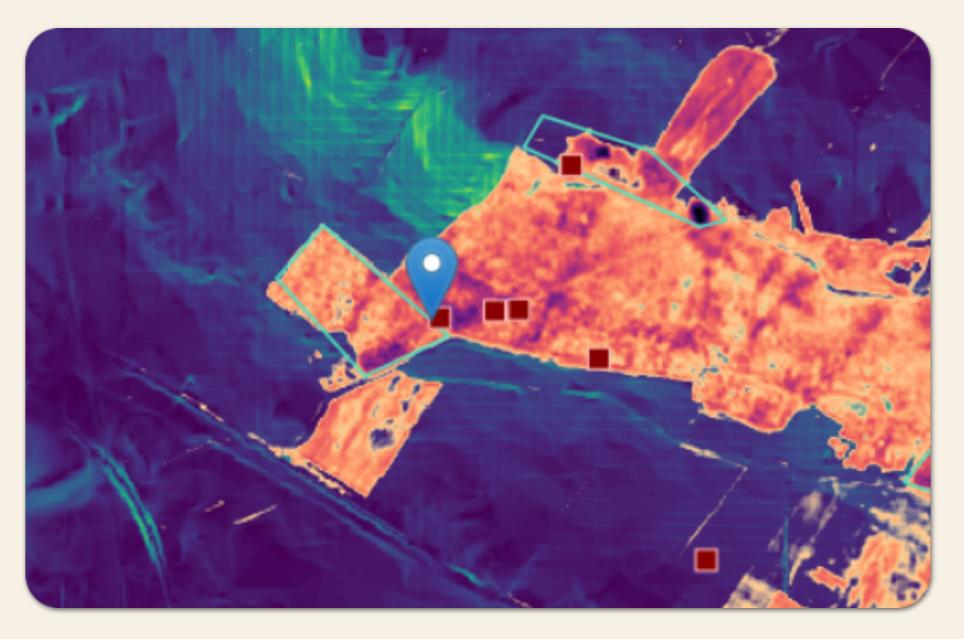 between the plain and the adjacent plateau.