The effect of the 2019 eruption on the island of Stromboli (Aeolian Islands UNESCO Site, Italy)
TEST SITE & METHODOLOGY
Test site: Stromboli Island

Hazards
- Volcanic risk
- Landslide risk
- Tsunami risk
- Wildfires risk
- Seismic risk

Total area
12.6 km² (circa)

Main elements at risk
- Inhabitants: n. 500
- Buildings: n. 2,315
- Artifical areas: 0.7 km²
- Agricultural areas: 3.1 km²
- Semi-natural vegetated areas: 4.6 km²
DATASET:
• Sentinel-2 MSI satellite imagery

Normalized Burn Ratio (NBR) Index EVALUATION

Goals:
1) Identify wildfires impacted areas.
2) Produce preliminary LC and LU maps.
3) Evaluate wildfire severity.

Revitalized Burn Ratio (RBR) Index EVALUATION

DATASET:
• Sentinel-2 MSI satellite imagery

Multi-temporal Land Cover (LC) & Land Use (LU) EVALUATION

Goals:
1) Identify landscape patterns.
2) Produce detailed LC and LU maps.

DATASET:
• PLÉIADES-1 satellite imagery
• CORINE Land Cover

Semi-structured interviews

Goals:
1) Validate LC and LU analyses.
2) Obtain more information about eruption-induced damages.
3) Analyze transformation of land use management.

Wildfires impacts

Vegetation loss
Damages to agricultural heritage
Transformation to landscape patterns

Wildfires impact analyses
Volcanic & Tsunami Hazard Map

Figure 2 – Volcanic & Tsunami hazard map (Nave et al., 2010)
Figure 3 – Hot rock avalanches hazard map (Salvatici et al., 2016)
Figure 4 – Wildfire damages, caused by 2019 eruptions. (Turchi et al., 2020)
Volcanic & Tsunami Hazard Map

Figure 2 – Volcanic & Tsunami hazard map
(Nave et al., 2010)

Figure 5 – Tsunami hazard map
(Salvatici et al., 2016)

Figure 6 – Tsunami damages, caused by 2002 Sciara del Fuoco landslide.
(Tinti et al., 2005)
Figure 7 – Seismic hazard map.
(http://esse1-gis.mi.ingv.it/)
Remote sensing: data set

**Optical imagery, PLÉIADES-1 satellite**
- Very high spatial resolution
  (0.5m x 0.5m Pancromatic, 2m x 2m Multispectral data).
- Multispectral (RGB) and panchromatic.
- On-demand

**Optical imagery, SENTINEL-2 satellite**
- Moderate spatial resolution
  (10m x 10m or 60m x 60m, depending on the bands).
- Multispectral
  (13 visible and infrared bands, between 0.433μm and 2.19μm).
- 5 days
  (10 days on the whole island).
Remote sensing: data set

Figure 8 – (a) Geographic location of the Island of Stromboli (Google Earth image); PLÉIADES-1 images collected on (b) 1st September 2018; (c) 13th June 2019; (d) 13th August 2019; (e) 8th October 2019. (Turchi et al., 2020)
Figure 9 – Sentinel-2 image (false color) collected on: (a) 7th June 2019 (pre-eruption), (b) 7th July 2019, (c) 11th August 2019, (d) 5th September 2019.
(Turchi et al., 2020)
LAND COVER & LAND USE ANALYSES
Figure 10 – Flowchart summarizes the image processing procedure for the wildfire impact and severity mapping. (Turchi et al., 2020)
Wildfire impact & Severity recognition

NBR index

Used to easily identify wildfire affected areas and fire severity. Calculated on two Sentinel-2 imagery (bands 8 and 12), acquired on different dates before and after wildfires.

\[ NBR = \frac{NIR(B8) - SWIR(B12)}{NIR(B8) + SWIR(B12)} \]

NIR: Near InfraRed region reflectance value
SWIR: ShortWave InfraRed region reflectance value

Recently burned areas have relatively low near infrared reflectance and high reflectance in the short wave infrared band. A high NBR value generally indicates healthy vegetation, while a low NBR value indicates that the soil has no plant cover (bare soil) and that the areas have recently been burnt.

Figure 11 – Sentinel-2 images-derived Relativized Burn Ratio (RBR) on: (a) 7th June 2019 – 7th July 2019, (b) 7th June 2019 – 11th August 2019, (c) 7th June 2019 – 5th September 2019.
(Turchi et al., 2020)
Wildfire impact & Severity recognition

**RBR index**

Used to easily identify wildfire affected areas and fire severity. Obtained as the difference between the NBR index of the images acquired before and after the paroxysmal explosion.

\[
RBR = \frac{dNIR}{NIR_{pre} + 1,001}
\]

\[
dRBR = NBR_{pre} - NBR_{post}
\]

*NBR*<sub>pre</sub>: NBR calculated on the image before the wildfire

*NBR*<sub>post</sub>: NBR calculated on the image post the wildfire

Figure 11 – Sentinel-2 images-derived Relativized Burn Ratio (RBR) on: (a) 7th June 2019 – 7th July 2019, (b) 7th June 2019 – 11th August 2019, (c) 7th June 2019 – 5th September 2019.

(Turchi et al., 2020)
Multi-temporal LC & LU evaluation

Figure 12 – Examples of land uses at Stromboli Island: (a) urbanized areas at Stromboli village, (b) vegetable gardens at Ginostra village, (c) ancient olive groves mixed with shruberies and Mediterranean bushes at Vallonazzo (Piscità, Stromboli village), (d) costal dunes between Punta Lena ad Porto (Stromboli village).

Figure 13 – Land cover (LC) and land use (LU) classes. (Turchi et al., 2020)
Multi-temporal LC & LU evaluation

Land Use is referred to the type of management/use of soil resources, in relation to the peculiarities of the local socio-economic system.

Figure 14 – Land cover map (LC) pre-eruption (2018) and post-eruption (2019). (Turchi et al., 2020)
Multi-temporal LC & LU evaluation

Figure 15 – Land use map (LU) pre-eruption (2018) and post-eruption (2019). (Turchi et al., 2020)
### Multi-temporal LC & LU evaluation

#### Legend class

<table>
<thead>
<tr>
<th>LAND COVER</th>
<th>LAND USE</th>
<th>Pre-eruption 2019</th>
<th>Post-eruption 2019</th>
<th>Percentage variation (%)</th>
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<td>shruberies and Mediterranean bushes</td>
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#### Figure 16 – Percentage variation of land cover/land use classes pre-eruption, sin- and post.
(Turchi et al., 2020)
Multi-temporal LC & LU evaluation

LAND USE MAP: percentage variation

- Wildfire areas: +...%
- Abandoned olive groves: -34.2%
- Shrubbery and bushes: -81.1%
Land cover damages: 3\textsuperscript{rd} July 2019

Figure 17 – Damages to the adjacent area of the photovoltaic power station (a), damages to the ancient terraced olive groves (b), tephra accumulation on the roofs (c) and damages to the canopies (d) at Ginostra, following the 3\textsuperscript{rd} July 2019 explosion. (Turchi et al., 2020)
SOCIAL ANALYSIS
Eyewitnesses account

FRAMEWORK

**Eyewitnesses**: n. 20
**Age**: 24-76 years old
**Location**: Stromboli & Ginostra villages
**Time**: 10-10 min.

SEMI-STRUCTURED INTERVIEWS

**List of questions** to guide the interviewer.
**Open and flexible questions** to investigate as much as possible.

Social research

Social research was crucial to:
1) **validate** LC and LU analysis results;
2) **reconstruct** of the 2019 paroxysms;
3) **define people perception** of two paroxysms, from Stromboli and Ginostra villages;
4) **evaluate damages** to the urbanized and non-urbanized areas (agricultural and semi-natural lands), following each explosion;
5) **analyze transformations** of the land use management;
6) **analyze transformation** of the landscape patterns.
Eyewitnesses account

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<th>Eyewitnesses</th>
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<th>Location</th>
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<th>Damages description</th>
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<tr>
<td>1</td>
<td>26</td>
<td>--</td>
<td>--</td>
<td>1 casualty</td>
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| 2            | 46   | Stromboli    | 1) Violent explosion, ash column upwards.  
             |      | (San Vincenzo)| 2) Ash/lapilli fall at Ginostra. | Wildfires on vegetated areas at Ginostra; Ash/lapilli accumulation on the roofs (obstruction of rainwater harvest cisterns and dirty water) at Ginostra. |
| 3            | 49   | Stromboli    | 1) Explosion, ash column upwards;  
             |      | (San Vincenzo)| 2) Pyroclastic flow towards Sciara del Fuoco. | 1 casualty |
| 4            | 75   | n.d.         |                   |                   | 1 casualty |
| 5            | 68   | Stromboli    |                   | Ash/lapilli accumulation on the roofs (obstruction of rainwater harvest cisterns and dirty water) at Ginostra. |
| 6            | 51   | Stromboli    | 1) Violent explosion, ash column upwards;  
             |      | (Pizzillo)   | 2) Lava flows;  
             |      |              | 3) Ash/lapilli fall at Ginostra. | Ash/lapilli accumulation on the roofs (obstruction of rainwater harvest cisterns and dirty water) at Ginostra. |

Figure 18 – An extract from the summary of semi-structured interviews to the inhabitants of Stromboli island, after the 3rd July 2019 explosion. (Turchi et al., 2020)
Conclusions

The 3rd July 2019 explosion demonstrate that a moderate intensity explosion has impacted severely on the island (1 casualty, wide-spread wildfire).

The causes of the vastness of fires are due to natural factors and anthropogenic factors like agricultural land abandonment. The most affected areas by wildfires, located near Ginostra village (the south-western part of the island), have been those ones characterized by wild terraced olive groves and Mediterranean shrubberies and bushes, with an overproduction of highly flammable fuel indeed.

Multi-temporal LC and LU analyses and Semi-structured interviews have allowed to estimate not only damages (loss of Aeolian endemic vegetation and agricultural heritage), but also transformations of landscape patterns related to the land management changes.

From the 1930, the abandonment process has caused:
• physical impoverishment of terraces;
• reduction of hydraulic land management, in terms of outflow water drainage;
• increase of hydrogeological risk factors;
• reduction of crop diversity;
• reduction of landscape variety;
• loss of cultural heritage, in terms of material and immaterial settlings;
• loss of agricultural knowledges, techniques and practices.

Therefore LC and LU analyses are crucial to define the best strategies and policies that could be adopted to encourage a sustainable site-specific land management, taking into account the probability of occurrences of wildfires at Stromboli island.
References

