A night at the OPERA:

a conceptual framework for an integrated Distributed Sensor Network–based system to figure out safety protocols for animals under risk of fire

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Agenda

- ✓ Background and Issues
- ✓ CeRVEnE and the FRAC program
- ✓ Objectives
- ✓ Work Methodology
- ✓ Preliminary results
- ✓ Concluding remarks

Background and Issues

- The problem of early detection of fires in forest areas is widely recognized at both national and international level

  "[…] *Fires are harmful for a number of ecosystem services (whose loss is estimated at around 146–191 Bln dollars per year) including carbon storage, biodiversity support, protection of water sources, reduction of soil erosion, land degradation, and climate regulation*" (*UNISDR, 2013*).

- Availability of government regulations such as the 2006 PETS Act in the US or the Directive 2010/63/EU within the European Union, for animal rescue during wildland fires

ICT solutions available:

Distributed sensing systems as **wireless sensor networks (WSN)** can offer a suitable measurement resolution of the relevant parameters involved in fire risk and, hence, in its early detection

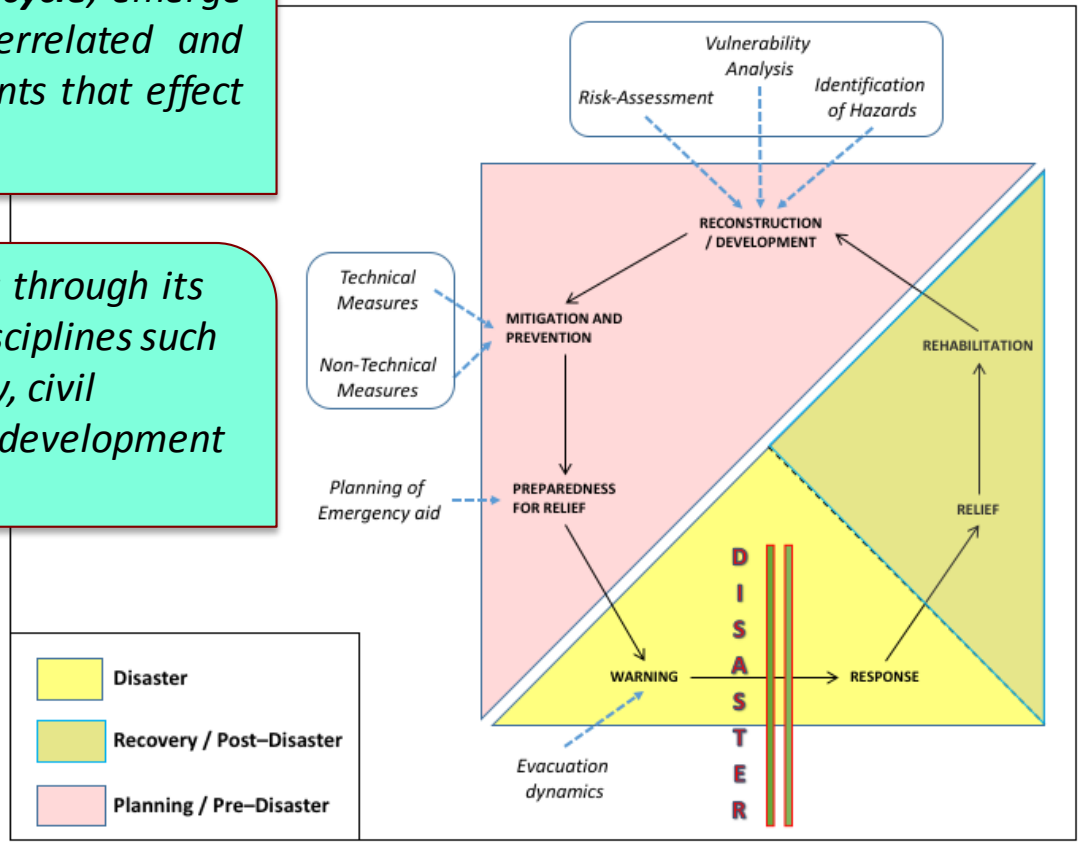
Attempts made to prepare a forest fire risk zone map by integrating a satellite image, topographical and other ancillary data from a **geographic information system (GIS)**

Background and Issues

- **Disaster epidemiology** (i.e., applied epidemiology in disaster settings) as source of reliable and actionable information for decision-makers and stakeholders in the disaster management cycle

*Disaster management and management tools, such as the **disaster management cycle**, emerge out of a complex system of interrelated and interdependent conditions and events that effect its development.*

The disaster management cycle has through its history been influenced by many disciplines such as sociology, geography, psychology, civil defence, public administration and development studies

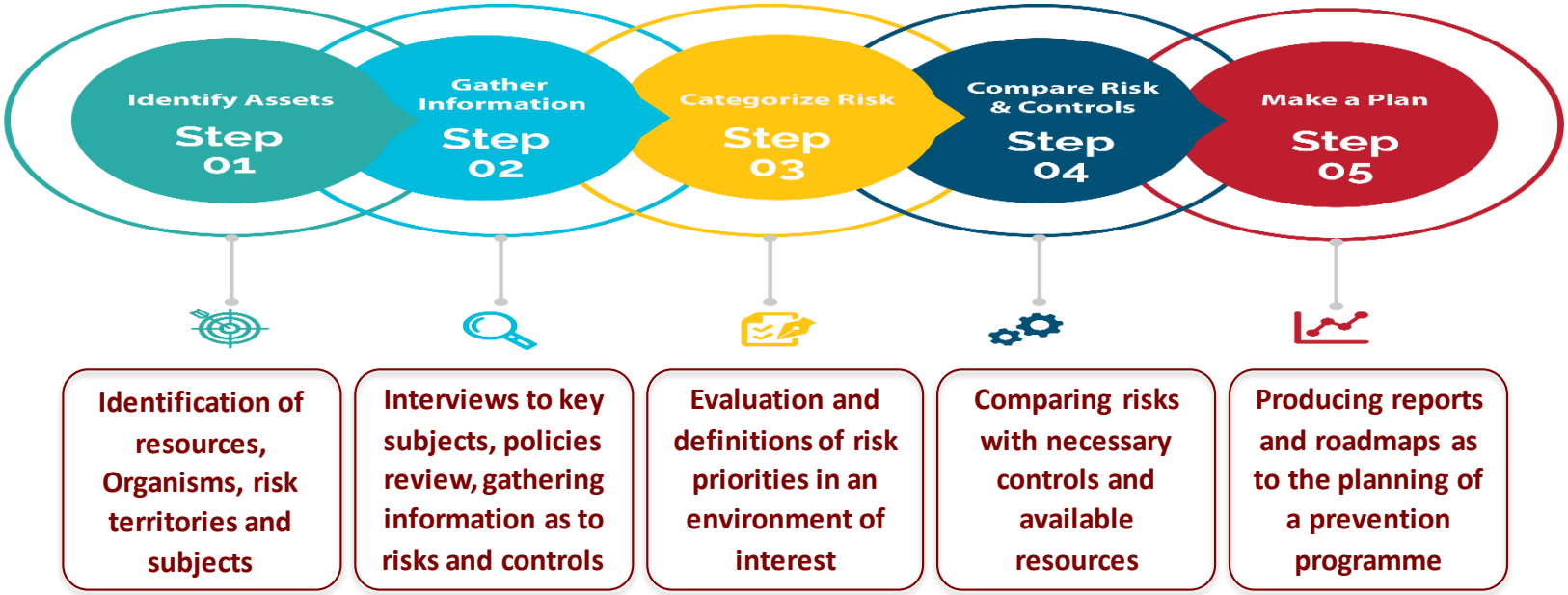


CeRVEnE and the FRAC program

- **CeRVEnE** (Italian acronym for "*Regional Veterinary referral Center for non-epidemic emergencies*") established in 2017 in Campania Region.

  Objective: to improve and protect people health through the timely management of both veterinary and non-veterinary epidemic emergencies related to animal health as well as to food safety

- **FRAC** Program (*Fire Risk Assessment in Campania Region*) presented in 2018 as a project to support Regional Government

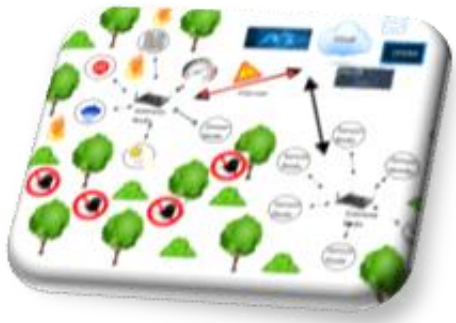


Objectives

To describe the conceptual framework and to introduce some preliminary results of an ICT system capable of addressing a number of technical exigencies all-at-once, in order to support the activities pursued by the FRAC Program

Monitoring the wooded areas under risk of fire in the so-called "Vesuvius' red zone"

*Determine the **OPtimal Evacuation Route for Animals (OPERA)** in case of fire, for each of the animal species living in the red zone*



DSN

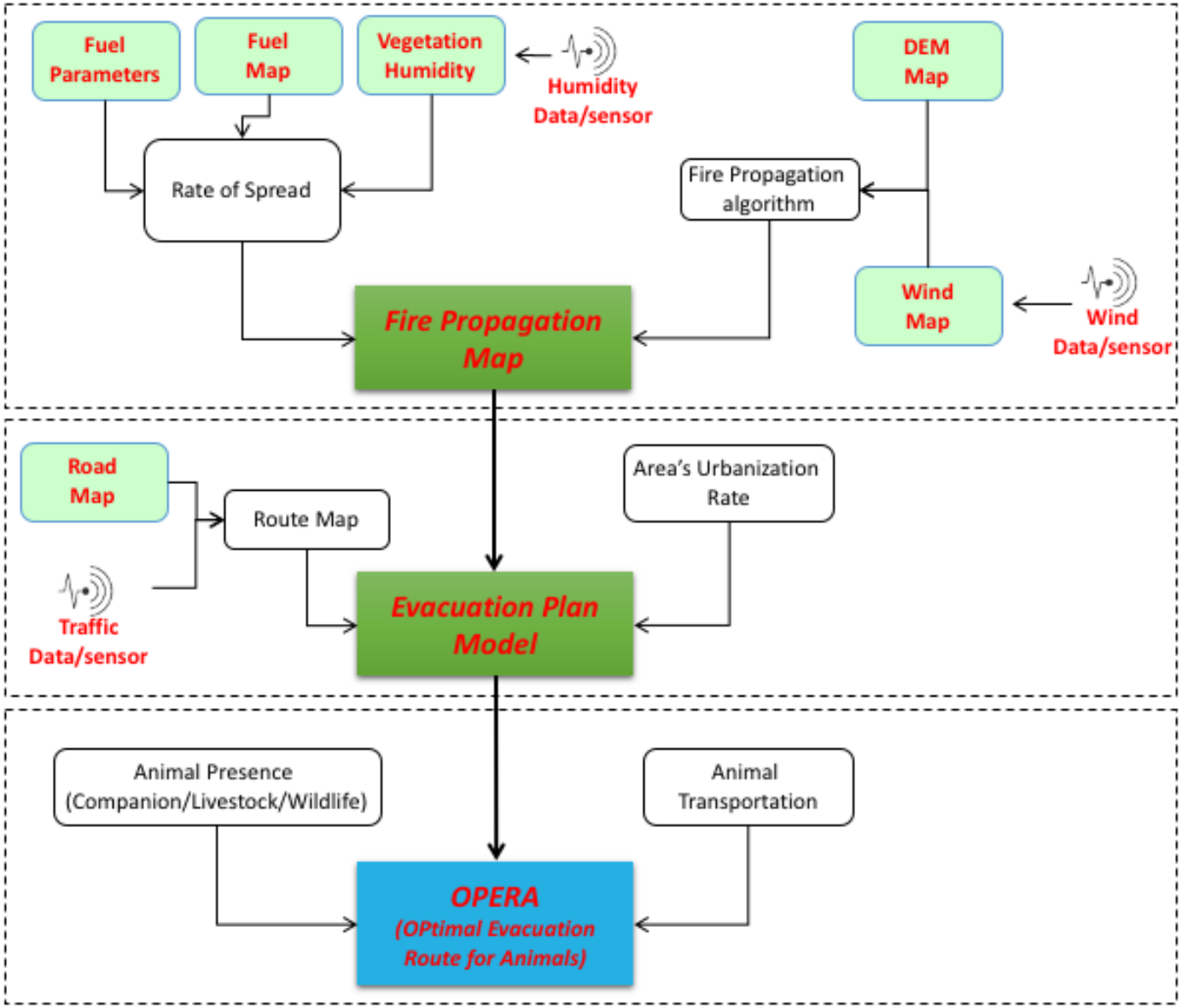
+

Simulation

+

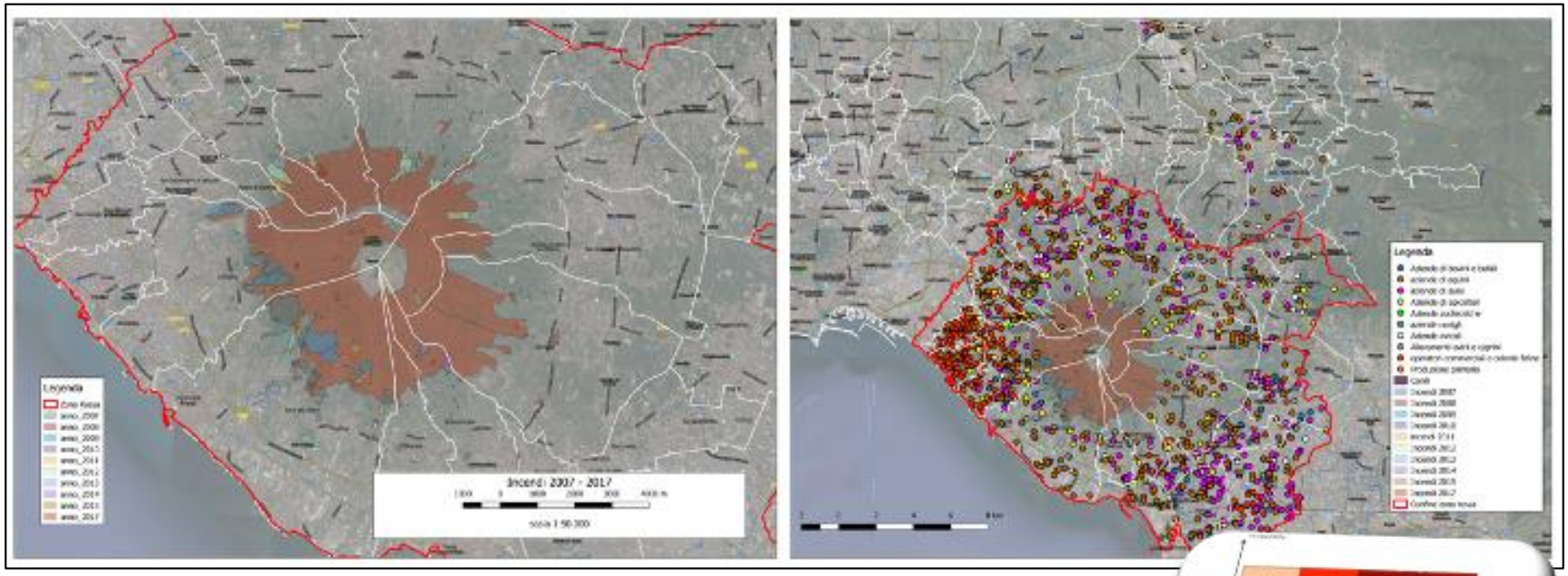
GIS

Work Methodology



Vesuvius Area mapping

- A first extended mapping of the territories surrounding the Mount Vesuvius was performed during the years 2018 and 2019 with a twofold purpose:
  - *(i) detect and count all the farming activities concerning poultry, sheep and goats, cattle, bees, swine, and equines;*
  - *(ii) figure out a reliable map to classify the different fire risk areas.*



Network requirements

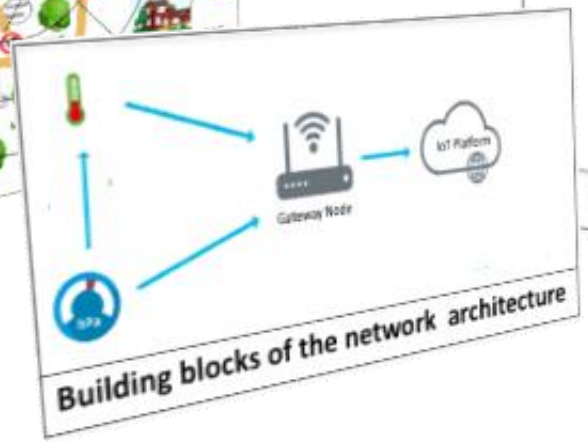
- **Wireless Sensor Networks (WSN)**, capable of effectively gathering information from the surrounding environment through a number of *smart sensing nodes*, i.e. sensors complemented with processing capabilities.
- A variety of parameters can be of interest for early detection and monitoring of fire in forest areas:

  volumetric water content and suction in soil

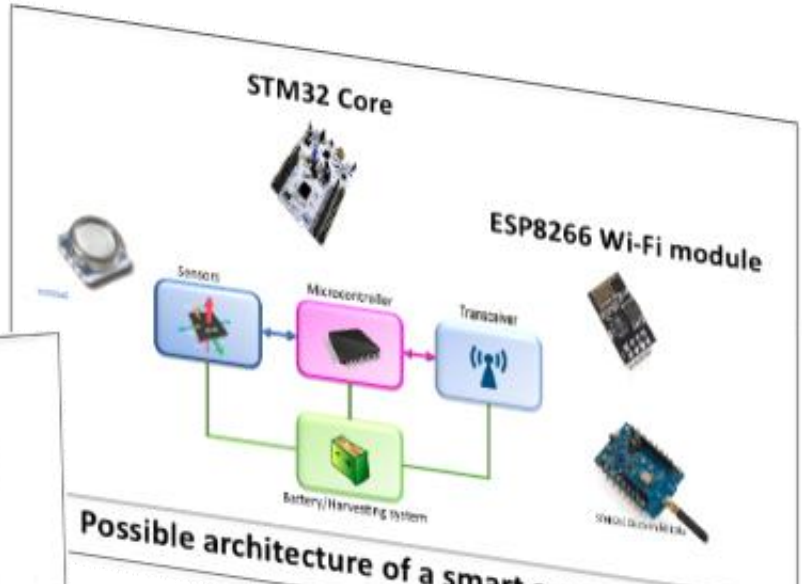
  atmospheric pressure, temperature, wind direction and speed, relative humidity

  infrared/visible/ultraviolet radiation intensity

  …



Building blocks of the network architecture



Possible architecture of a smart sensor node

Fire Simulation tool
TIGER MEG

- **Scope**

  Fire propagation tool: from ignition point to run time fire contour line

- **Aim and objectives**

  Education

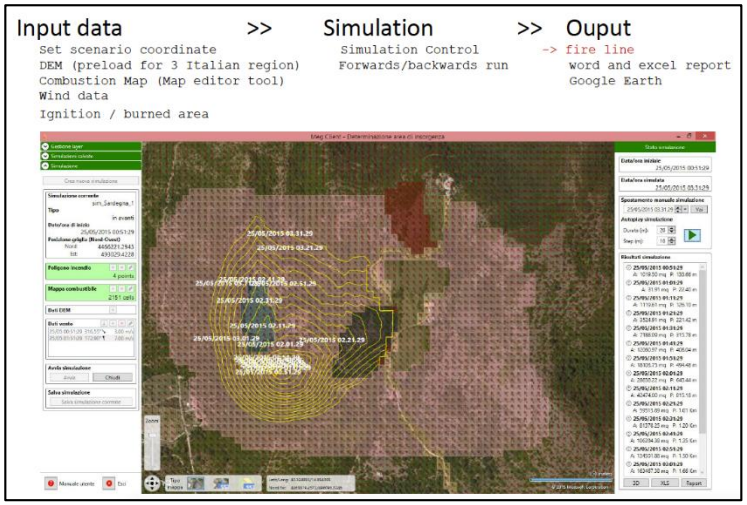
  Training and brainstorming (pre-fire and post-fire analysis)

  DSS Ready to use, easy to use

- **Use the available data base (input data and map)**

- **Model integration: combustion model, wind model, fire perimeter model**

- **Time simulation: >> faster than real event**



Route Optimization

- The **OPERA** is defined by means of an **arborescence optimization problem**, to be solved for instance via label setting-correcting algorithms

Let then G = G (N, E, φ) be an oriented graph, where:

- N = *nodes*: set of all the accessible road junctions in the Mount Vesuvius' red zone;
- E $\subseteq N \times N$ = *edges*: roads that connect two consecutive junctions/nodes. It can be stated that: $e_k = \langle n_k, n_{k+1} \rangle$;
- $\varphi: E \rightarrow [0,1]$ = *weight function* (normalized) that assigns to each edge a value of intensity of traffic flow (defined in the continuous interval from 0 to 1).

Let moreover be:

- $t \in [0, t^*[\subset [0, +\infty[$ a discrete time interval, where t* represents the final moment of the simulation;
- $n_{k,t_i} \in N$: junction occupied by the k-th token at the moment t_i.

ρ = 0 (the junction n_k has already been reached from the fire at the moment *t*)

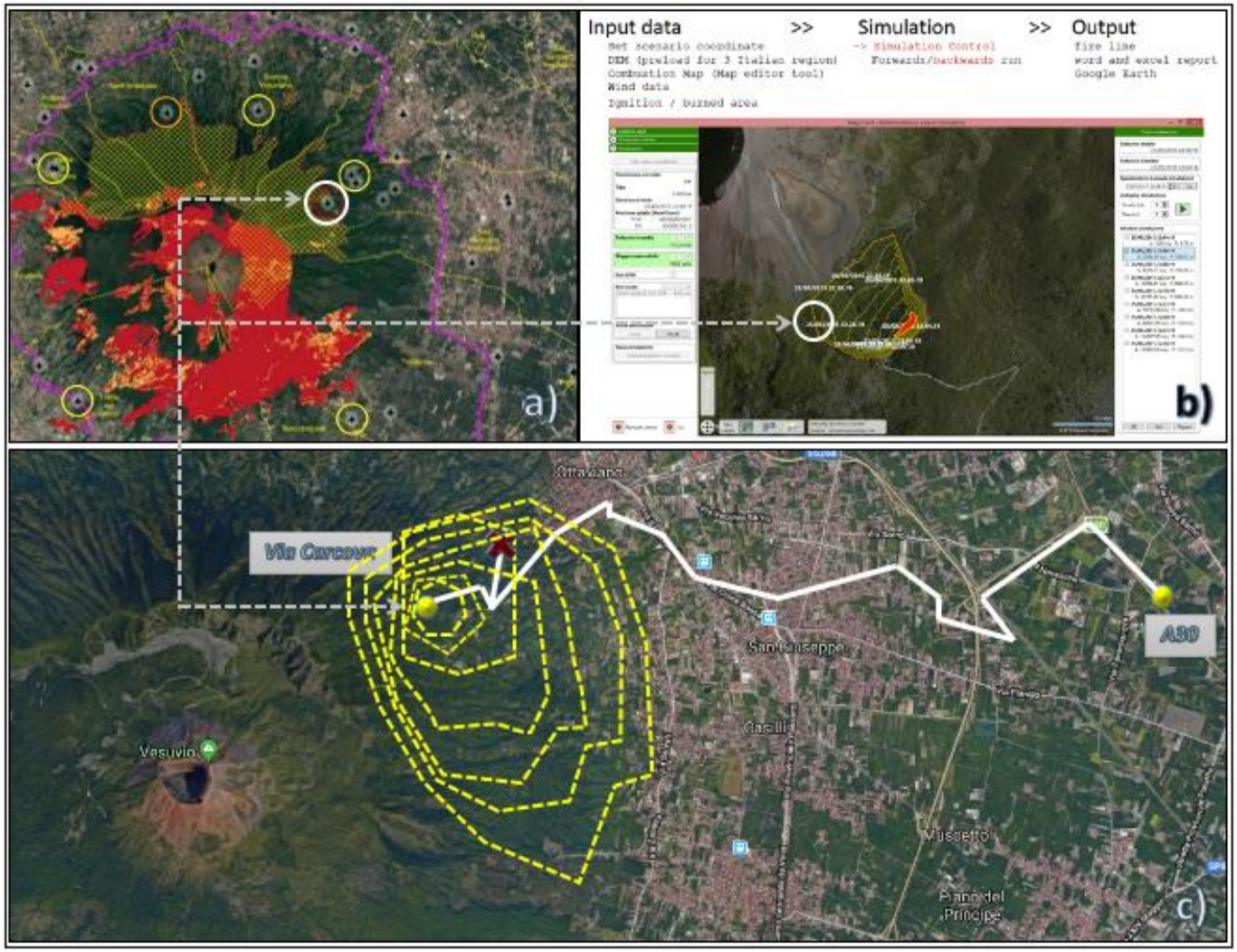
ρ = 1 (the junction n_k hasn't been reached from the fire at the moment *t* yet)

- **OPERA** ≈ problem of minimum path

$$OPERA = min \sum_{k=1}^{N} \rho(n_{k,t_i}) \neq 0$$

Preliminary Results
The beekeeper case

- ***First-case scenario***: beehives transportation is less problematic in terms of general set up and execution



Road between two consecutive junctions

Area interested from the fire propagation at $t = t_i$

Concluding remarks

- According to the principles introduced with the Disaster Management Cycle, the ICT system can positively impact on the following phases:

  Planning/Pre-disaster*: helping the organization of effective actions for disaster mitigation, thanks to the possibility to pre-visualize escape routes so that timely and effective safety protocols can be figured out for each different animal species living in the interested area.*

  Disaster*: (i) detection of precursory signals, which serves in short-term hazard prediction and in the activation of early warnings; (ii) offering real-time synoptic views on the affected areas, thus providing the necessary damage-related information to increase knowledge about loss distribution in the entire involved ecosystem.*

  Recovery/Post-disaster*: low-cost monitoring and evaluation of the recovery and reconstruction actions offered by remote sensing imagery. The monitoring is carried out through the analysis of a time series of satellite imagery that can be used e.g. to track the vegetation recovery after a wild fire.*

Thanks for the attention!

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