Paolo Fiorucci

Cellular Automata Models for Wildfire-Vegetation Interaction

LifeWatch ERIC

Ministero dell'Università e della Ricerca

Italiadomani PIANO NAZIONALE DI RIPRESA E RESILIENZA

NATIONAL BIODIVERSITY FUTURE CENTER

ISAC

cima RESEARCH FOUNDATION

Thematic group on forest fire within the National Biodiversity Future Centre
Spoke 4

Coordinated by

CNR ISAC & Fondazione CIMA

Participants

CNR IMATI
CNR-IGG
CNR IGAG
CNR IRET
UNIBO
UNIFI
UNISS
UNISapienza
UNITus
CMCC
ISPRA (external)

Context

Human disturbance Natural Rewilding and forest fires

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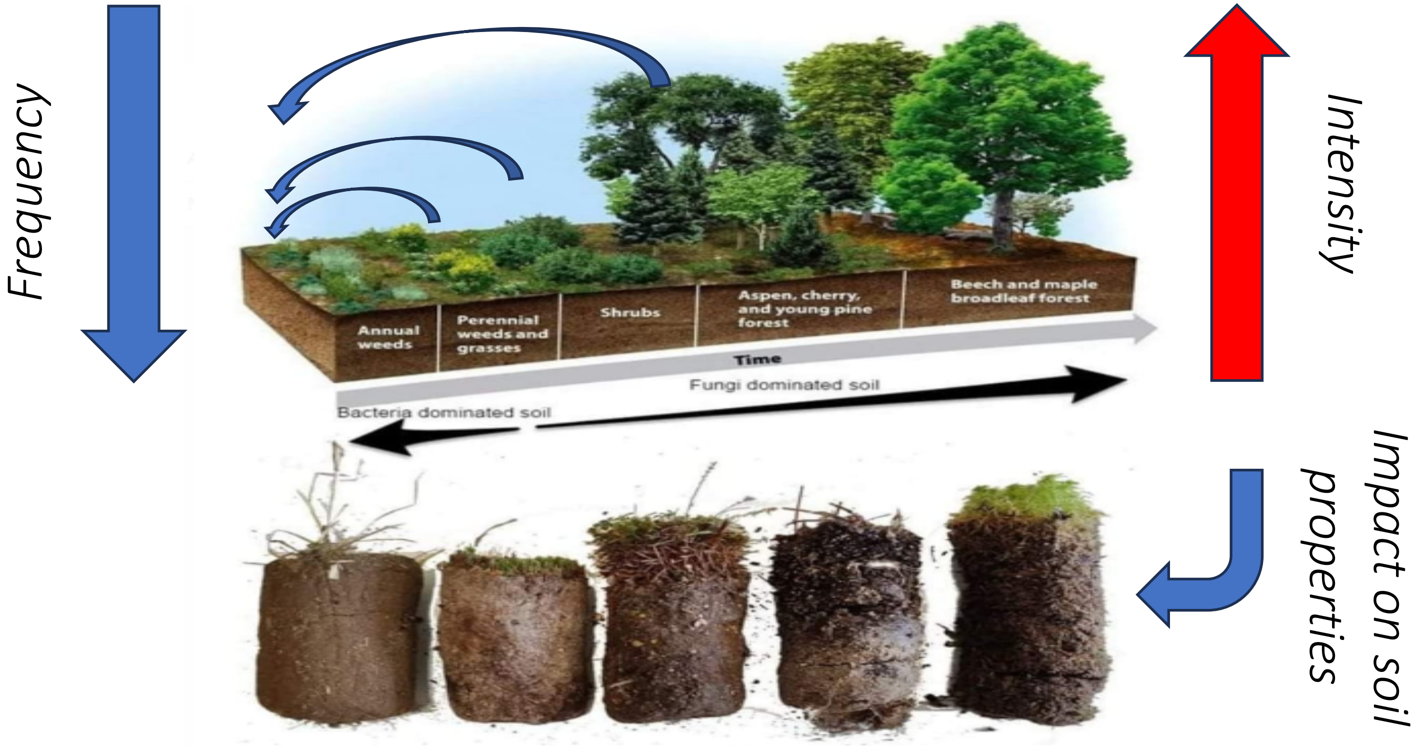
Human disturbance Natural Rewilding and forest fires

Objective

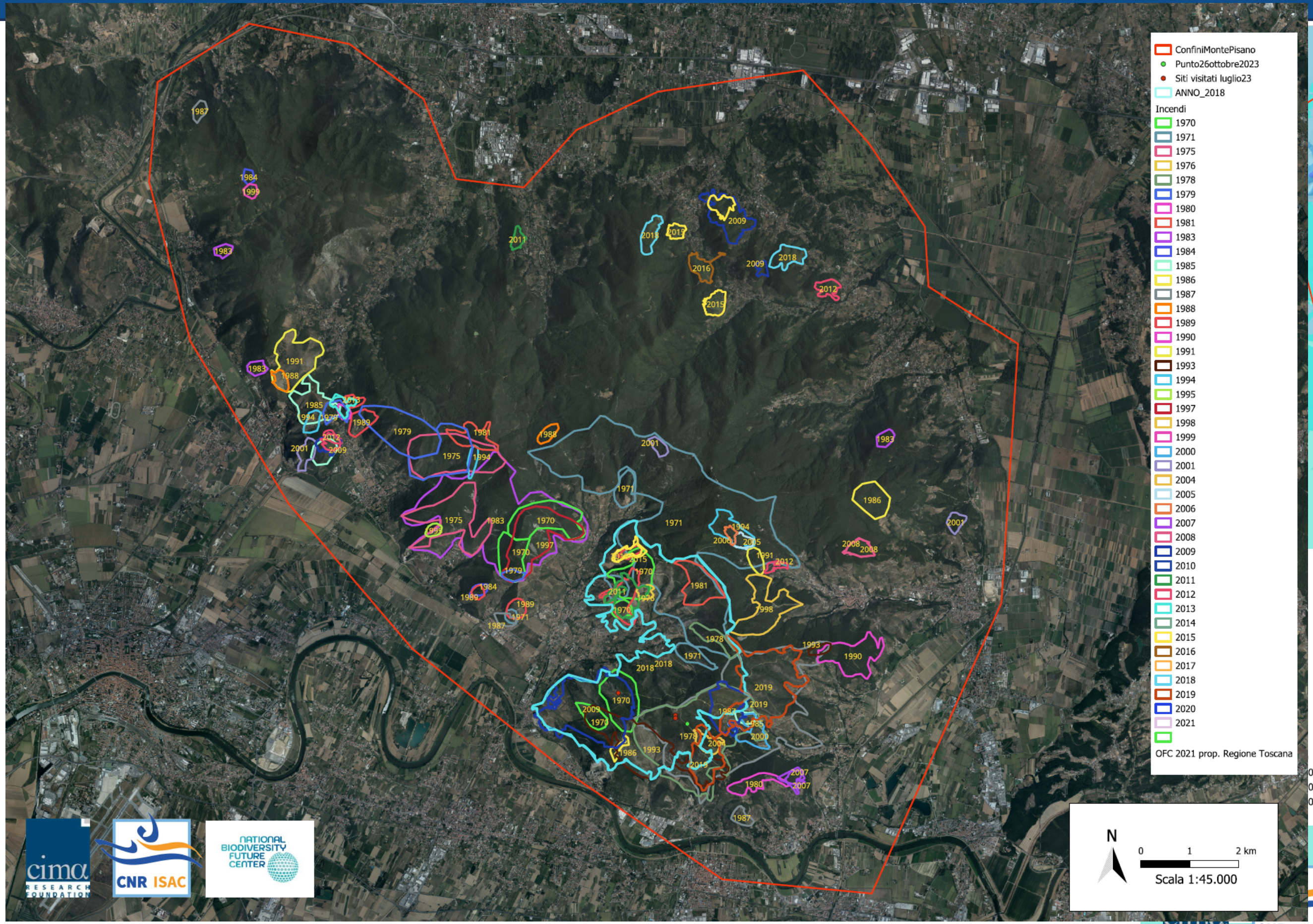
Understand the future dynamic of vegetation cover

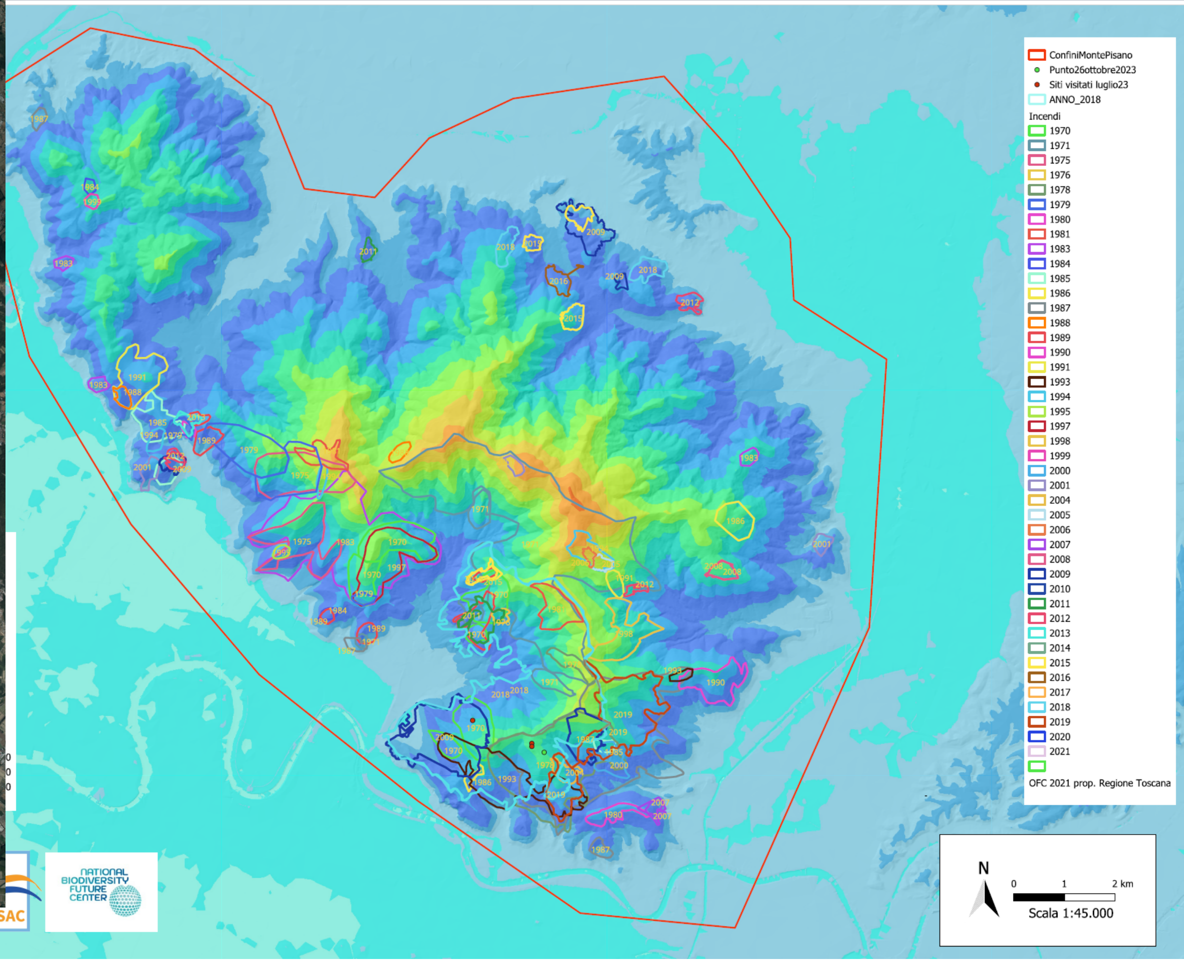
Impacts on vegetation succession



Study area

Monte Pisano – Burn scars available since 1970



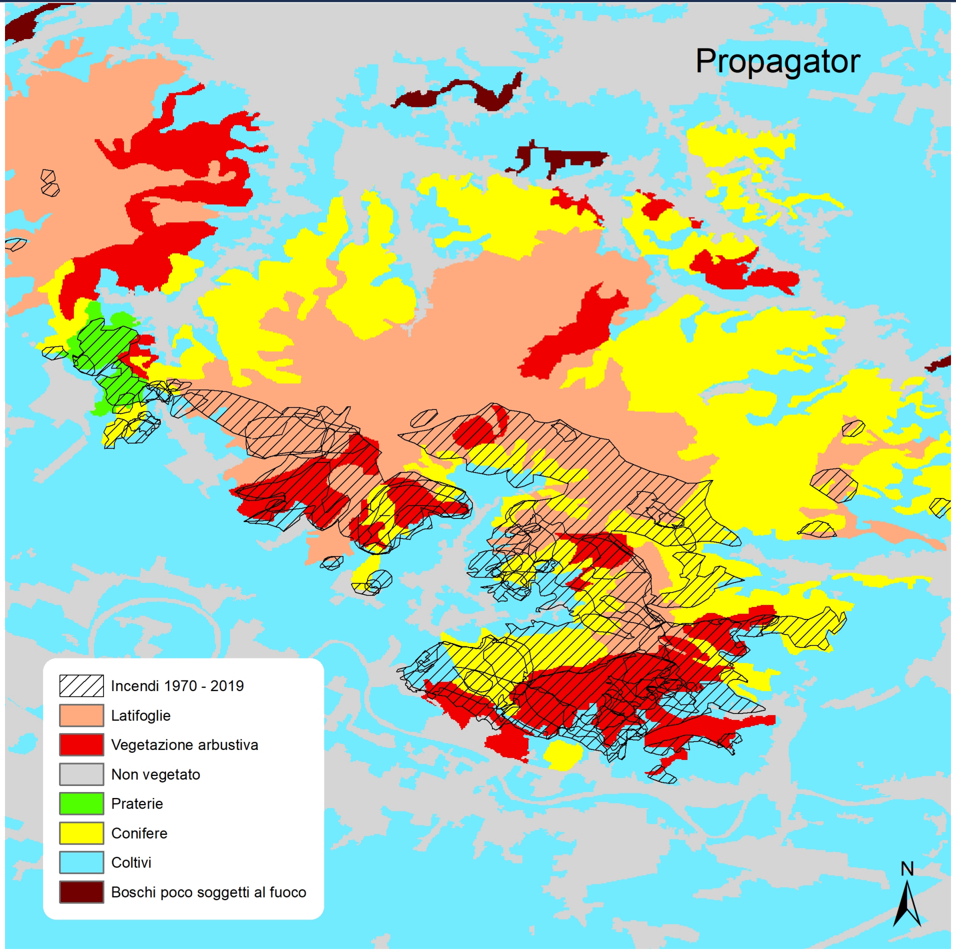


Data

Static

DEM

Soil type



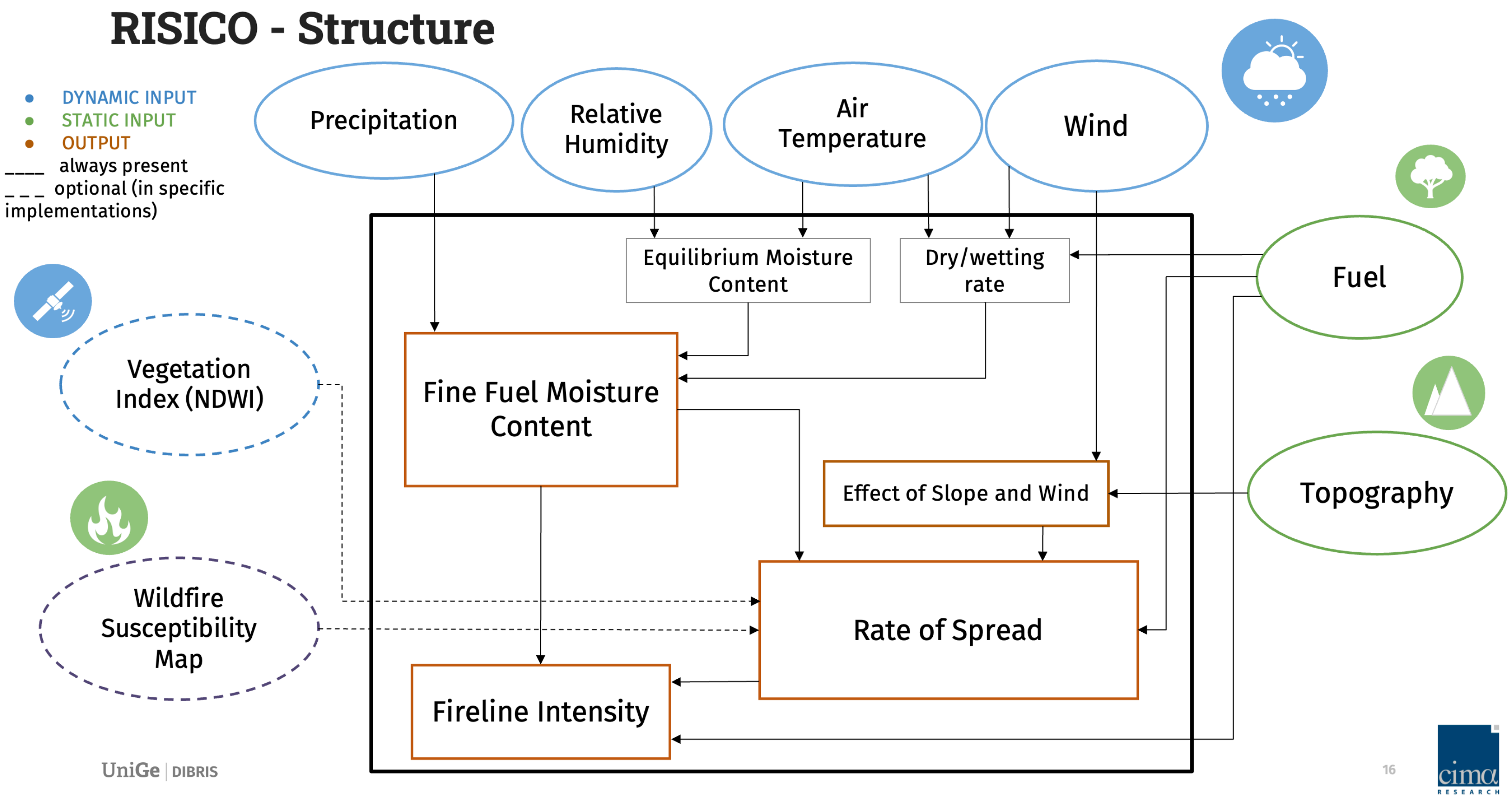
Dynamic

Temporal series of land use/land cover (Ortophoto, Landsat, CORINE, Sentinel2)

Meteorological data (ERA5, other downscaled models)

Burn scars

Hourly Fine fuel moisture content



PROPAGATOR – Model Structure

PROPAGATOR is a Stochastic Cellular Automata model.

The domain is divided into cells. Each cell can assume one of the following three states: unburned (state: 0), burning (state: 1), or burned (state: -1)

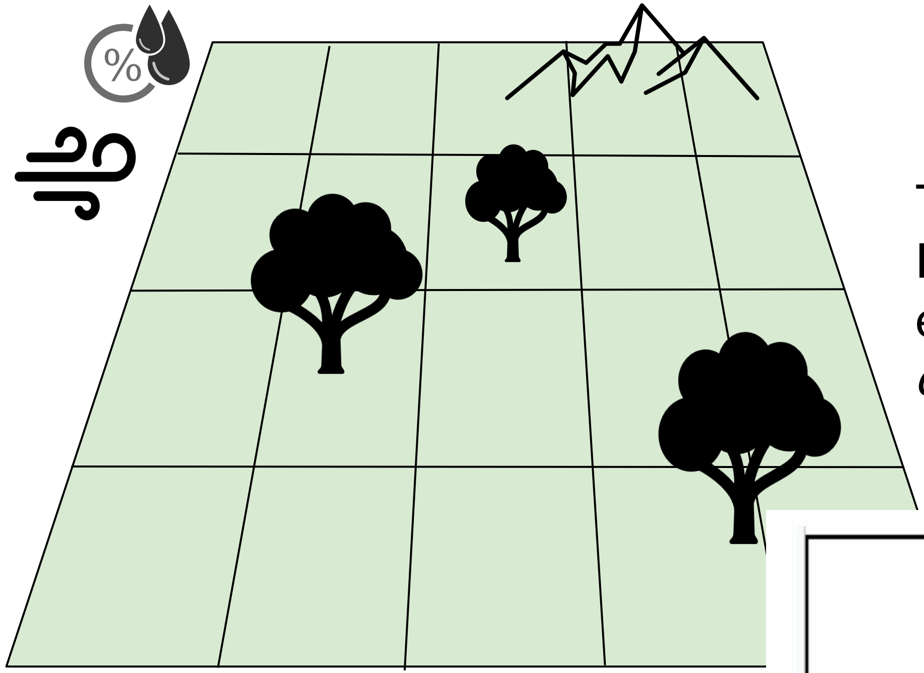
Each cell is associated with different input:

Static input:

- fuel type
- topography (slope, aspect)

Dynamic input:

- wind
- fine fuel moisture content

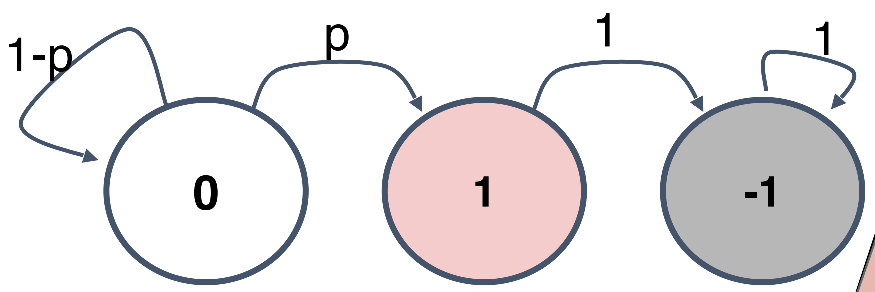


There are **12 fuel classes** in PROPAGATOR, defined according to expected fire behavior (*ML-based fuel classification*)

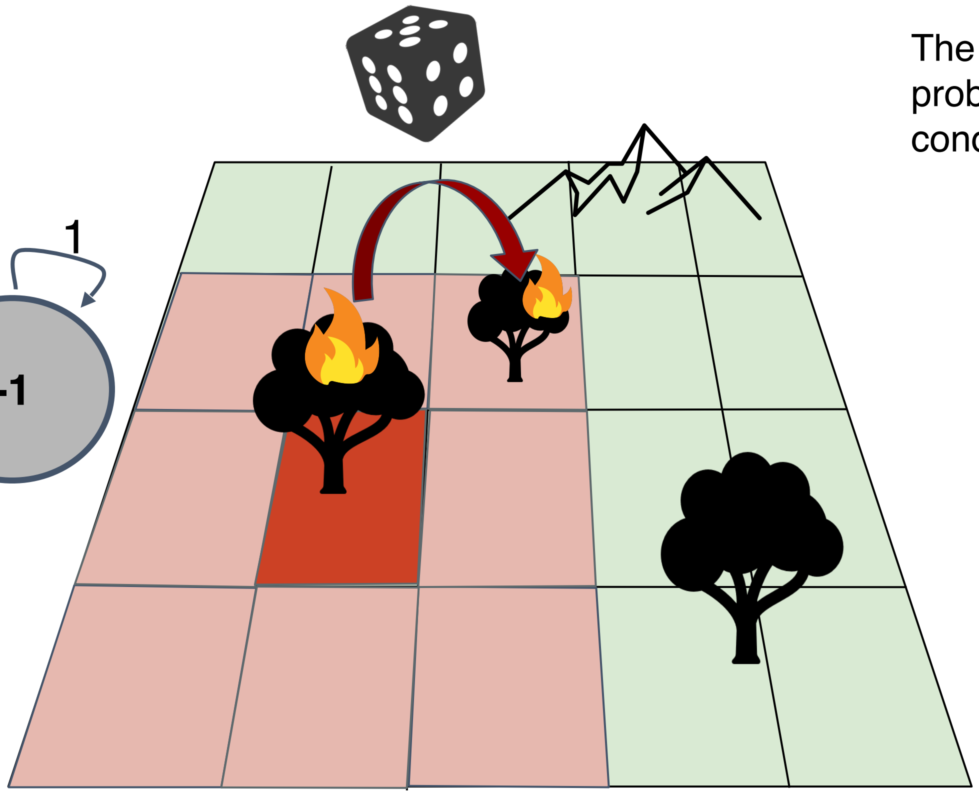
		Vegetation classes			
		Grasslands	Non fire-prone forest	Shrubs	Fire-prone forest
Susceptibility	Low	1	4	7	10
	Medium	2	5	8	11
	High	3	6	9	12

PROPAGATOR – Model Structure

The fire propagation process can be thought as a **stochastic contamination process**



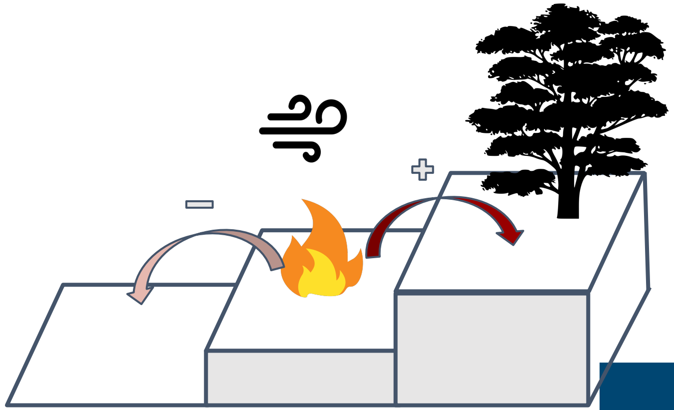
Automata diagram



8-Moore neighborhood

The fire spreads to nearby unburned cells with a probability that depends on the boundary conditions:

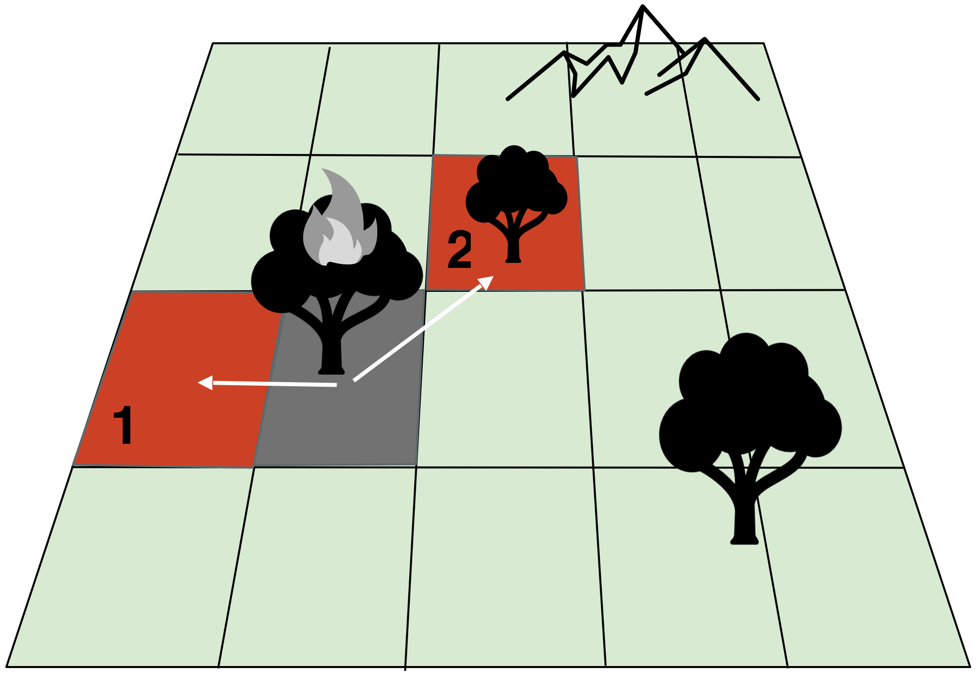
- it depends by the fuel type
- it is promoted in the uphill direction and decreased in downhill direction
- it is promoted in the wind direction and decreased in the opposite direction



PROPAGATOR – Model Structure

BURNING TIME

- Once the propagation process identified the ignited cells, the time of jumping is computed;
- The burning time is computed according to conditions of the involved cells (fuel, slope) and the boundary conditions (wind, fuel moisture);
- the ignited cells are then scheduled accordingly.



The simulation time proceeds according to an event-based paradigm

PROPAGATOR – Model Structure

INPUT

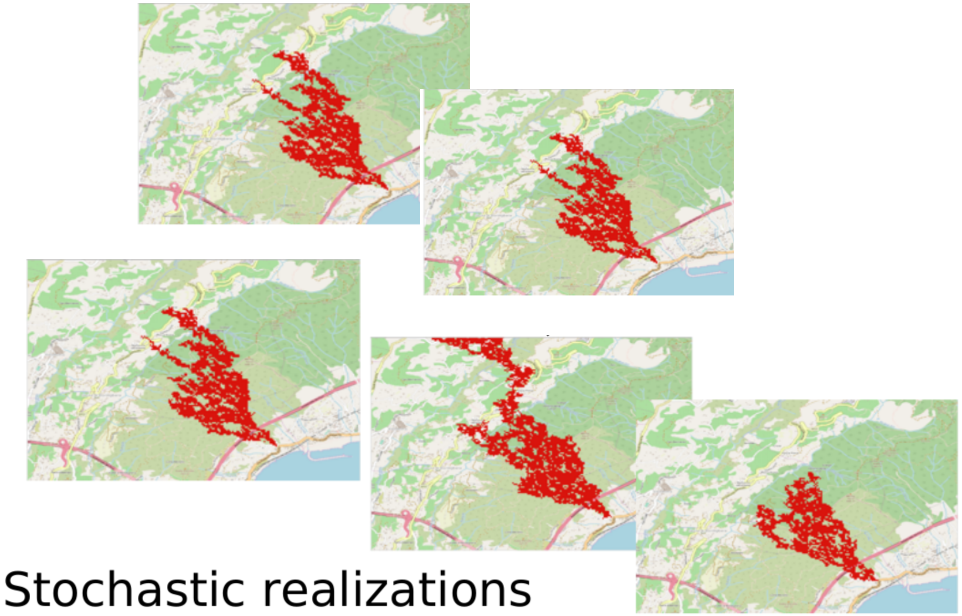
Static input:
- ❑ ignition points/firelines/ polygons
- ❑ fuel map
- ❑ topography (DEM)

For each time step:
- ❑ wind
- ❑ fine fuel moisture

Montecarlo Approach

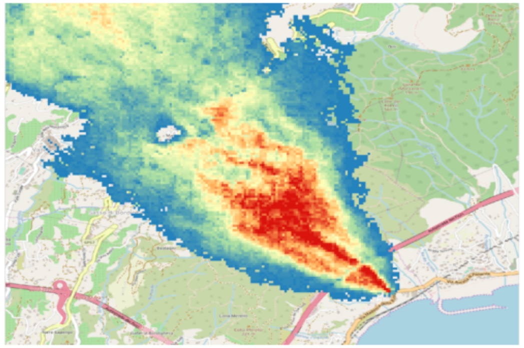
PROPAGATOR model

The model compute 100 realizations of the same forest fire



Stochastic realizations

OUTPUT



For **each time step**:
- ❑ fire probability maps
- ❑ rate of spread maps (mean max)
- ❑ fireline intensity maps (mean, max)

To do list

Definition of vegetation cover maps (4 vegetation classes) derived from data available

Simulation of all the fires occurred → fire intensity maps

Based on the above data

Training a ML model (RF) to fill the gap in the time series of vegetation cover based on:

- Available past vegetation cover maps
- Yearly Climate indexes
- fire intensity maps
- Time since the last fire
- Number of fires occurred
- Minimum time between consecutive fires
- Soil type
- DEM

To do list

Future projection of ML model to predict yearly vegetation cover driven by future climate projections
Generation of random ignitions accordingly to current fire frequency to simulate fire impacts driven by fire weather conditions derived from climate projections

In parallel the simulation framework will be coupled with a process based model of vegetation recovery after the fire and vegetation succession in absence of fires

LifeWatch ERIC 2024 Thematic Service Workshop Series

Thank you for your attention!
Any questions?

Taxonomy | Brussels, Belgium, 30 January 2024

Climate Change Impact on Biodiversity Patterns | Lecce, Italy, 21-22 February 2024

Animal Movement and Biologging | Ostend, Belgium, 22 March 2024

Biogeography | Bologna, Italy, 4-5 April 2024

Biodiversity Observatory Automation | Ljubljana, Slovenia, 11 April 2024

Habitat Mapping | Aveiro, Portugal, 3 May 2024