PeerJ Preprints NOT PEER-REVIEWED

An agent-based model to assess the forest fires dynamic in the southern swiss alpine region

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Abstract

Alpine fires are mainly slope-driven, spreading along the forested steep slopes. Fire ignitions are here highly clustered near anthropogenic infrastructures and this characteristic behavior also affects the definition of the wildland urban interface (WUI). This last is known as the area where houses and other human infrastructures meet or intermingle with wildland vegetation, rural zone or forest. The main objective of the present study is to create a simulation model to assess the forest fire dynamic in pilot area located in the in the southern Swiss alpine region. This allows to investigate, for example, the influence of the mobility of people on the fires occurrences by simulating the daily movement of each single active person; or to simulate the displacement of the firefighters over the territory in order to evaluate the efficiency of different fires fight strategies in time. In this preliminary study the core simulation model has been implemented in GAMA, an open source agent based simulation platform. A long term objective is to conduct a study at global scale, over a wider area (e.g. the entire Canton Ticino), to understand the evolution of the WUI in time, analysing the affecting factors like the population growth or of the urbanisation and land use management.

Introduction

Forest fire hazardous events are assuming an increasing importance especially in relation to urban sprawl, which makes it difficult to outline a border between human infrastructures and forest (Theobald and Romme, 2007). A central feature related to forest fires is the so called wildland urban interface (WUI). This is defined as the area where houses and other human infrastructures meet or intermingle with wildland vegetation, rural zone or forest (Stewart et al., 2007). WUI is largely investigated especially in the U.S., Australia and Mediterranean regions (Collins et al., 2005; Radeloff et al., 2005, Gill and Stephens, 2009; Badia et al., 2011, Caballero et al., 2007). Many efforts have been made in these countries to characterize

and map the WUI with the main goal of protecting housing, which display an isolated, scattered or clustered pattern (Lampin-Maillet et al., 2010), from burning.

Alpine fires have a characteristic behavior which also affects the definition of the WUI. Here wildfires are mainly slope-driven and fire spreads along the forested steep slopes; therefore, even if fire ignitions are highly clustered near anthropogenic infrastructures (Conedera et al., 2011, Vega Orozco et al., 2012 and Zumbrunnen et al., 2009), in most of the cases houses do not burn out. In the Swiss Alpine environment the wildland urban interface shows a specific characteristics as it lies between the urban area and the steep forests, intermingled with agricultural lands, vineyards and unproductive surfaces (Conedera et al. 2015). The evolution of this interface area is principally driven by land use changes, as the urban growth and forest extension at the expenses in particular of cultivated areas.

The first objective of the present study is to create a simulation model acting at local scale to assess the forest fire dynamic in pilot area located in the in the southern Swiss alpine region. By this way is possible to perform highly detailed analysis, as for example: simulating the daily movement of each single active person in order to investigate the influence of the mobility of people on the fires occurrences; studying the efficiency of different fires fight strategies in time, by simulating the displacement of the firefighters over the territory. As second objective, conducting a study at global scale over a wider area (e.g. the entire Canton Ticino), it is possible to understand the evolution of the WUI in time, analysing the affecting factors like the population growth or of the urbanisation and land use management. Canton Ticino is one of the most fire-prone areas of the Swiss Alpine region. Preventive measures to reduce the number of ignited fires were established here in recent times, namely: the reorganization of the fire brigades and the systematic use of helicopters for aerial firefighting (implemented since 1980); preventive legal acts prohibiting burning garden debris and fireworks in the open space (implemented since 1991).

Method and data

A *multi-agent system* (MAS) is a computerized system characterized by multiple intelligent agents interacting within a specific environment. An *agent* is defined as a computational component with its own attributes, actions and behavior, able to interact with other agents. The proposed model is multi-level so that, in reason of the extension of the studied zone, different aspects of forest fires occurring on the territory can be taken in consideration and different operations can be performed during the simulation. Operationally we employed GAMA, which is an open source modeling platform for building spatially explicit agent-based simulations (Grignard et al., 2013). Database, raster and vector files, but more generally, all the georeferenced objects, put into this Multi Agent infrastructure, acquire a sort of “intelligence” which allows them to interact with other elements (agents) and with the surrounding environment (Taillandier et al., 2014). GAMA also allows the multilevel modelling, which means that

different analyses can be executed in the same environment but with a different space-time resolution. In this case, specific type of agents are preview in order to define an host-guest relationship between different levels of agents, macro and micro-species and specific methods; an example is the temporary aggregation of micro-agents which could be used to study the collective behavior of agents in a specific period. GAMA is coded in java and scripts are coded in gaml, which is a high-level and intuitive agent-based language. The ease of spatial data integration, the ease of interaction with databases and the intuitivity of scripting language make GAMA suitable for the implementation presented in this study.

Forest fires information came from the forest fire database of Switzerland (http://www.wsl.ch/swissfire/) developed in a joint effort by WSL (Swiss Federal Institute for Forest, Snow and Landscape Research) and FOEN (Federal Office for the Environment). Information about features in the landscape (road network, railway, building and forest) came from the Topographic Landscape Model TLM elaborated by the Federal Office of Topography (Swisstopo). Census of population, dwelling and enterprises was provided by the Federal Statistical Office (FSO). Data referring to the period 1990-2015 will be used.

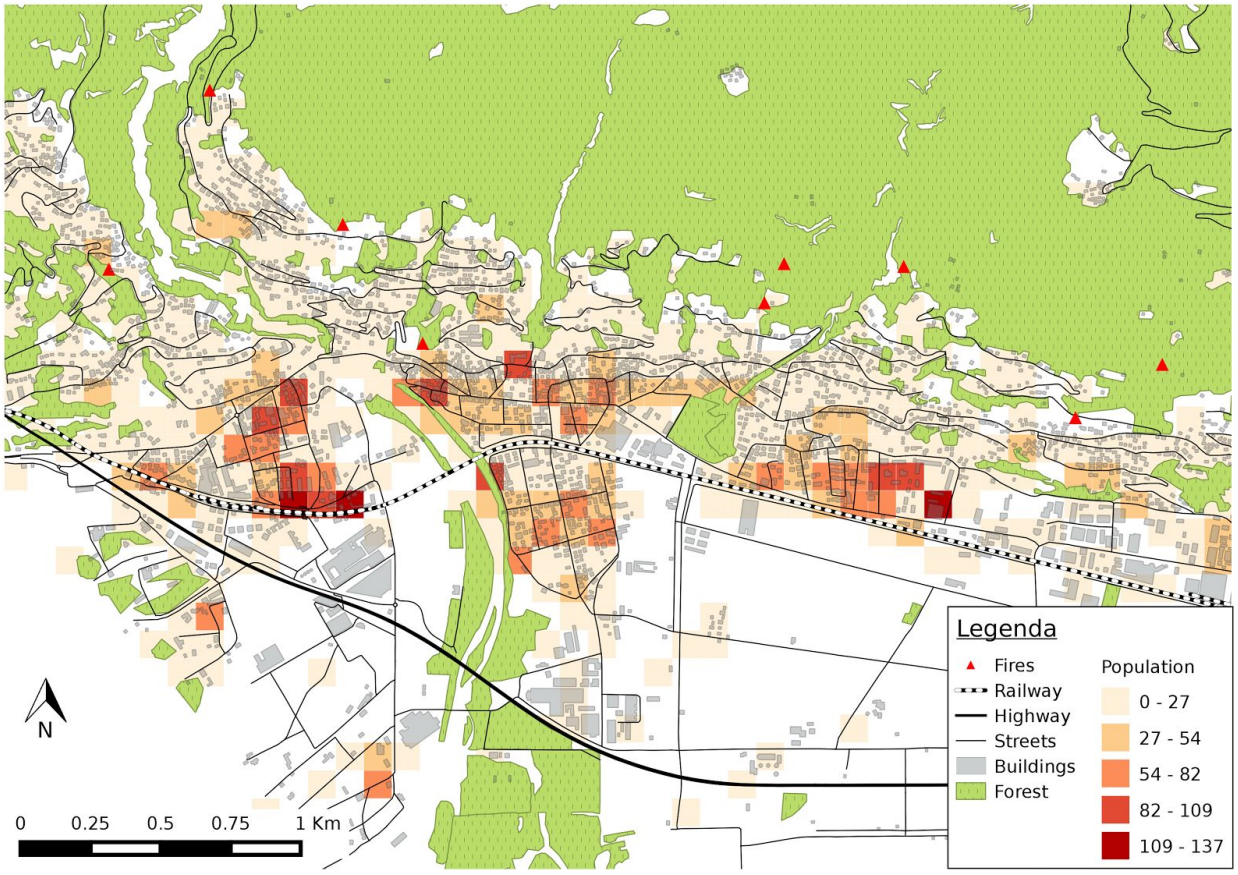

Figure 1. An example of data: population (census data - 2000), forest area, infrastructures and forest fires occurrences (1990-2015) in the suburbs of Locarno.

Results

The first result achieved in this preliminary study is the implementation of the simulation model (large scale). The model is formalized as a script of GAMA written in gaml language, and it works as showed in the workflow below (Fig. 2).

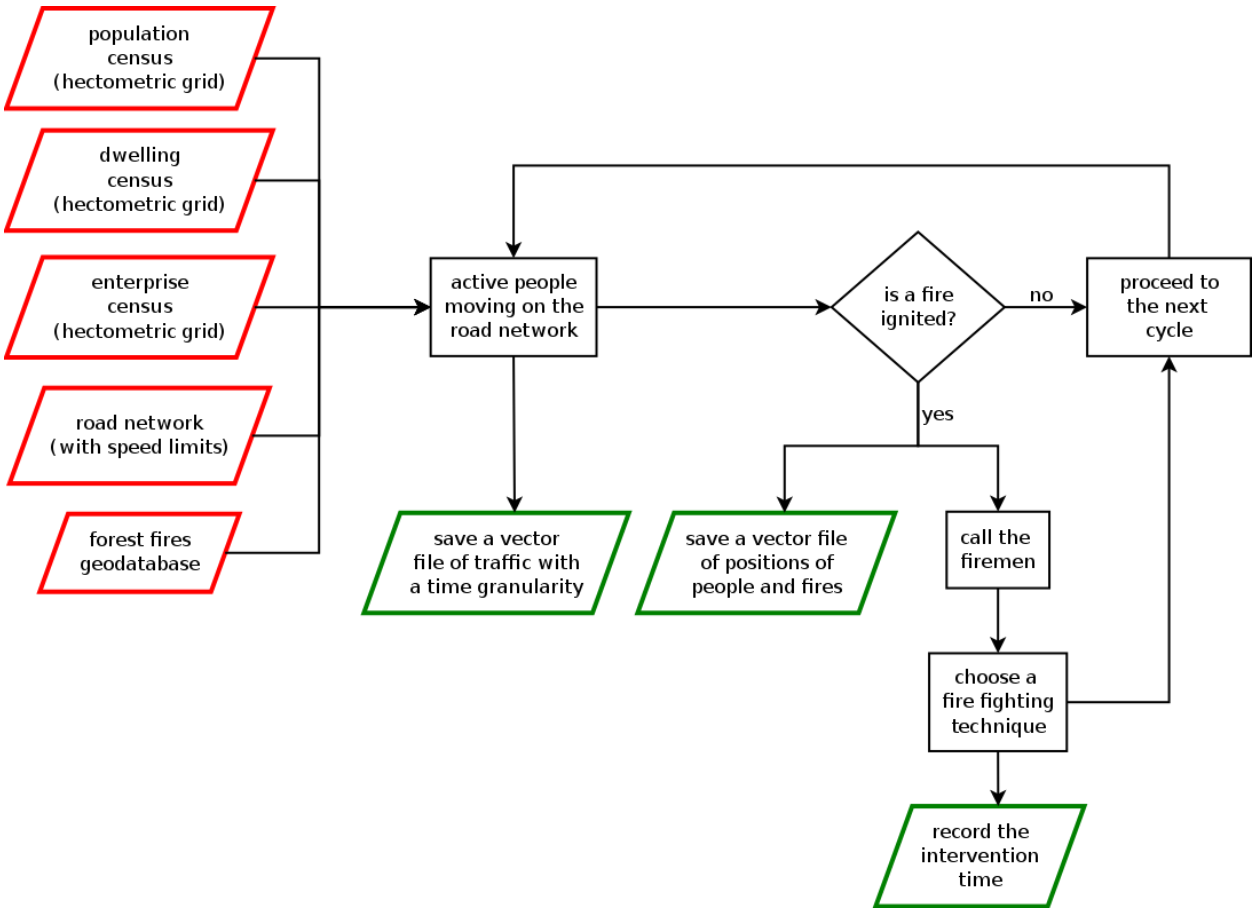

Figure 2. Workflow of the model at large scale. In red the input and in green the output of the model.

This analysis has a double scope: 1) perform a visual correlation between the ignition of fires and the human presence; 2) investigate the efficiency of firefighters intervention.

Starting from the input data, they are imported in GAMA from some shapefiles (point shapefile of fires, point shapefile of hectometric grids, line shapefile of roads and so on). Once data are loaded in GAMA, all the imported elements become agents, agents people are created and the processing consists in a spatio-temporal simulation which begins with people moving on the road network (e.g. from home to work, from home to schools, from home to recreational spaces). Each segment of the road is characterized by different speed limits for highway, roads and tracks and the movement of the agent responds to the

shortest path route logic. The frequentation of each zone is captured periodically by specifying a temporal granularity, which could vary in reason of the time extension of the simulation. When a fire occurs, a caption of the current situation is automatically done, the current status of the system is recorded into agents and they are saved in shapefiles in the way that both agents and fire position are given in output. Once the fire is ignited, the intervention of firefighters is simulated. By choosing the fighting technique (in reason of the techniques available in the nearest fire station), the intervention time is stored in a table.

Conclusions and outlook

The next step of this study, consisting in the development of the global scale model for the assessment of the WUI at level of Canton Ticino, is still in progress. The model aims at understanding the temporal evolution and the drivers of the WUI dynamics under the influence of human-driven land use changes and fire-prevention allocations. Results from these analyses can aid to assess the impact of the urban and population growth on the evolution of the WUI.

The efficiency of the implemented system will be evaluated once the validation phase will be concluded and the data obtained could be statistically elaborated and correlated with other environmental factors (e.g. wind speed and direction) in order to elaborate more complex analyses.

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