Fire, earthquake, landslide, volcano, flood: a first approach to a natural hazard map of Italy

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Abstract: Several natural hazards have been synthesized in one map to obtain an overall assessment of these phenomena. Space and time coherent data have been searched for: minimum disaggregation available was the province and matching year 2007. Two indices of susceptibility have been calculated for fires and landslides; for seismic hazard the median value of provincial values of maximum ground acceleration has been used. For each index, provinces have been classified in four quantile levels. A weighted average of the three classified levels has been calculated with weights proportional to annual expenditure for every type of event. Results are meaningful at ordinal scale and cannot be interpreted as a measure of risk. Floods and volcanoes have been mapped, too, thus obtaining a global overview of the main natural hazards in Italy.

Keywords: natural hazards, integrated data, composite indicator, overview map

1. Introduction

In a future scenario, territorial information systems could provide an interactive map which crosses vulnerability caused by several natural hazards and the value represented by the population and human artifacts, outlining the concept of "risk". It is possible to figure out a complex integration of hazard maps, vulnerability maps and value maps to represent the spatial distribution of risk, enabling, for example, an individual citizen to evaluate the risk of being in different places. The foundations of this work lay in the answer to a few questions: to what extent can data on various natural hazards be integrated? Do current knowledge and tools enable to build an integrated view of such risks? How realistic and significant can a synthetic measure be?
A first step towards a risk map is the integration of the various hazards. This work aims at providing an integrated framework of natural hazards, through authoritative sources, available at Italian national level in a consistent way, both in space and in time alike. It has been inspired by some previous research aiming at synthesizing different environmental hazards into one global measure (Arnold et al. 2007, European Commission 2007, ISPRA 2008).

2. Materials and Methods

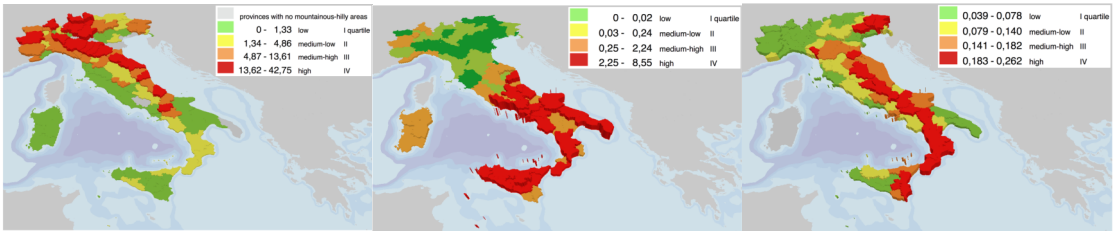
Data are related to very different phenomena and parameters. The minimum territorial unit has been forcibly the province, because, for some phenomena, that was the highest level of detail available for the entire territory. Given the difficulty of correlating data so different in nature and spatial trend, a synthetic index of dangerousness for each type of event has been created. Data are described in detail here below.
▪ *Landslides*: surface of landslide areas in 2007 are published by the National Institute

for Environmental Protection and Research[1]. The ratio between the landslide area and the surface of the mountain-hill area[2] for each Province has been calculated: it represents the quote of landslides in the areas potentially affected by landslides.

▪ *Forest fires*: data on forest areas and burnt forests in 2007, published by the Fire Service of the State Forestry Body, enabled the calculation of a similar index: the percentage ratio between the wooded area affected by fires and the total wooded area in each province.

▪ *Earthquakes*: In 2006 the National Institute of Geophysics and Volcanology published data on seismic hazard in terms of maximum ground acceleration with 10% exceeding probability in 50 years, referred to bedrock, calculated on a grid of points, with a step of 0.02 degrees They measure the acceleration at which the ground is expected to be exposed and are not a measure of seismic risk, which should include also the losses caused by earthquakes, in terms of direct casualties and damages. The 55,689 points on the mainland have been attributed to the corresponding province, except for Sardinia where data were not available. The median of the values of seismic hazard within a province has been used as a synthetic provincial measure. The choice has been made after a thorough exploratory data analysis with the aim of identifying a single summary measure enabling to sort the provinces on the basis of seismic hazard, similarly to what has been done for landslides and fires. However, the size and shape of the provincial administrative areas are such that many provinces have highly variable values (e.g. the province of Reggio Calabria has a bimodal distribution). In such situations, the characterization of the entire province by the median value can be misleading, since the intra-provincial variability is high and it is linked to geo-structural factors, such as capable faults and geodynamic activity.

The indexes for landslides and forest fires are both composition ratios, perfectly comparable in general terms, except for the reference period: for landslides it has its upper limit in 2007, but it also includes landslides originated in previous years and still active, while for forest fires only areas burned in 2007 have been considered. The indicator of seismic hazard has a completely different nature: it represents the median value of ground acceleration within a province.



Landslides Forest fires Earthquakes

Figure 1: Hazard indexes by province - Italy, 2007

To bring the indicators back to a common scale, for each of the three hazard indices, provinces have been classified according to their position in the national ranking with regard to distribution quartiles: 25% of the provinces with low values, 25% medium-low, 25% medium-high, 25% high values (fig. 1). This can be viewed as an extension of the normalization method for indicators above or below the mean.

Finally, a synthetic measure of the joint dangerousness of the three events has been calculated in order to obtain a single integrated map of the various hazards: it has the

[1] IFFI project - Inventory of landslides in Italy.

[2] The mountainous-hilly areas have been calculated by using National Institute of Statistics data on Italian municipalities at 2009.

advantage of offering a synthetic view of the hazards for all the natural disasters considered at provincial level.
To take into consideration the different impact of events in terms of damage, estimated annual costs incurred in Italy because of these events have been used as weighs. In other words, to each of the three natural disaster index a weight has been assigned, proportionally to the severity of the outcomes, assessed in billions of euros of damage per year. For forest fires, an estimate of € 0.6 billion[3] spent in 2007 has been used, for earthquakes a cost of € 3.4 billion[4] and for landslides the value of € 1.5 billion[5] per year have been estimated. Weights, interpretable as relative severity coefficients, have been calculated as the ratio between the annual cost per event (landslides or earthquakes) and annual expenditure for fire events, i.e. the less expensive event. These are the values: Fire-weight = 1, Landslide-weight = 2.5, Earthquake-weight = 5.7. In order to differentiate the values and widen the range of provincial indicators, the sum of weighted values of the three indices has been chosen. The formula is:

$$[1] \qquad H = Fw * F_{ire}\text{-}i + Lw * L_{andslide}\text{-}i * + Ew * E_{arthquake}\text{-}i$$

The implication connected with linear aggregation, i.e. that there are no synergies or conflicts among the different aspects considered, seems acceptable. The composition method is elementary, one could say rough; this is because, at this preliminary stage of the research, the desired output didn't want to be a ranking of provinces, but rather a classification of provinces into four ordinal classes to be mapped.
To complete the picture, floods recorded in 2007 and areas potentially affected by volcanic eruptions have also been represented on the map. Volcanoes are concentrated in few areas of the country and it would have been pointless to calculate the danger in all the provinces. For floods, unfortunately, it was not possible to calculate an indicator similar to the others, since no areal pieces of information on affected and potentially affected zones were available for the entire country.

3. Results

This first synthetic map of natural hazards in Italy highlights the danger deriving from the relatively young geological age of our peninsula. High values of the synthetic index are observed along the Apennine ridge and in alpine areas still tectonically active, i.e. Friuli Venezia Giulia in the north-east. The map is strictly connected to the morphology and the active geodynamic processes and it identifies the southern provinces as characterized by high hazard levels, since they are subject to dangerous natural phenomena with high destructive potential (earthquakes, landslides, volcanoes). Such phenomena have different degrees of freedom, and often do not occur in a cyclical way, i.e. times of recurrence cannot be calculated or predicted. The synthetic index draws a geography of hazard that may be useful for planning actions or for directing resources aimed at mitigating the effects of such phenomena. Unfortunately, the level of data disaggregation (province) is not adequate to identify any smaller "black spot".

[3] A study conducted in Spain by WWF estimated a cost of 5,500€ per hectare of forest burnt. As in 2007 in Italy 116,602 hectares were burnt, the total annual expenditure incurred due to fires is estimated to be €0.6 billion.
[4] According to the Italian Civil Protection "earthquakes which struck the peninsula [Italy] have caused substantial economic losses, assessed for the last forty years in approximately 135 billion euros".
[5] According to data coming from the Census of landslides from 1918 to 1994 (32,000 landslides surveyed) conducted by the National Research Council (CNR) - Project GNDCI AVI - the damage caused each year amounted on average to 1 or 2 billion euro.

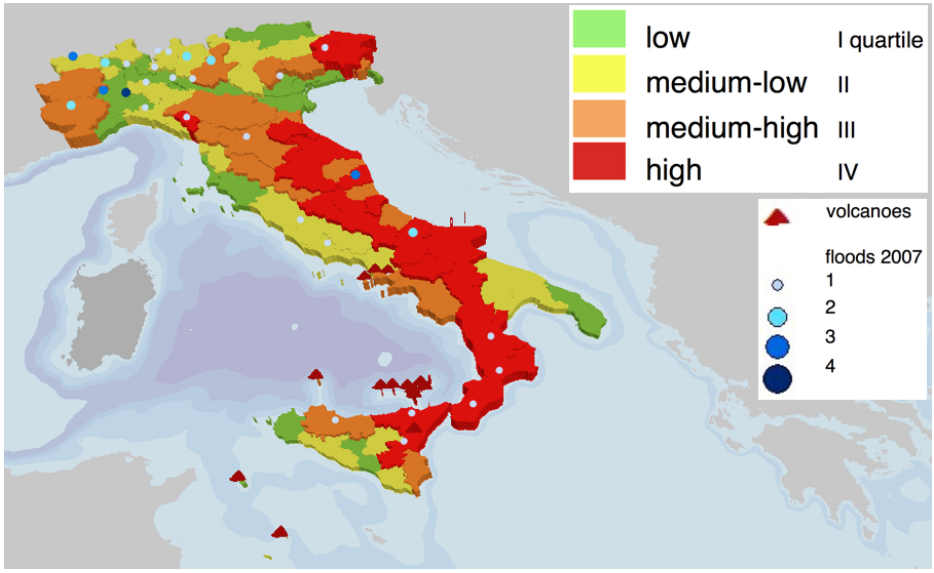


Figure 2: Synthetic natural hazard index by province - Italy, 2007

4. Concluding remarks

The calculation method and the system of weights are subjective and only enable to arrange provinces in a rank made of four values. The result does not allow a fine evaluation of the global hazard in quantitative terms, since it is significant only in ordinal scale, i.e. the numerical differences between the indices of two provinces are not significant, neither can this be interpreted as a measure of risk. Furthermore, the expected period of recurrence of the phenomena is not taken into account. Alternative normalization, weighting and composition methods could be used to evaluate the performance of different composition procedures (OECD, EC, JRC, 2008); Multi Criteria Evaluation (MCE-GIS) could be performed, too (Chen et al., 2001). Anyway, beyond technical statistical issues, the major point here seems to be the scarce availability of spatially detailed, comparable and timely information. Nevertheless, despite these limitations, the final map offers a synthetic view of the natural hazards at provincial level and has the advantage of a comprehensive look at all the natural disasters taken into consideration - fires, earthquakes, landslides, volcanoes, floods - based on standardized methods for the entire country.

References

Arnold M., Dilley M., Deichmann U., Chen R.S., Lerner-Lam A.L. (2005) *Natural Disaster Hotspots: A Global Risk Analysis*, The World Bank.

Chen K., Blonga R., Jacobson C. (2001) MCE-RISK: integrating multicriteria evaluation and GIS for risk decision-making in natural hazards, *Environmental Modeling & Software*, Vol. 16, Issue 4, p. 387-397.

European Commission (2007) *Armonia: Assessing and Mapping Multiple Risks for Spatial Planning - Approaches, methodologies and tools in Europe*, Lancaster University, Department of Geography.

ISPRA Institute for Environmental Protection and Research (2008) *Environmental Data Yearbook – Natural and Anthropogenic Hazard*.

OECD, European Commission, Joint Research Centre (2008) *Handbook on constructing composite indicators: methodology and user guide*, OECD Publishing.