

Identifying Radon-prone areas in Lombardy: a Geostatistical Approach

Identificazione Delle Aree Ad Elevata Probabilità di Alte Concentrazioni di Radon in Lombardia: un Approccio Geostatistico

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Riassunto: In questo lavoro si propone un metodo di simulazione condizionata per ottenere una stima dei valori di concentrazione di radon indoor nei comuni, a partire da valori rilevati a livello di singola unità immobiliare. L'obiettivo è quello di identificare aree con elevata probabilità di alte concentrazioni dell'inquinante.

Keywords: Radon prone Areas, conditional simulation, change of support problem

1. Introduction

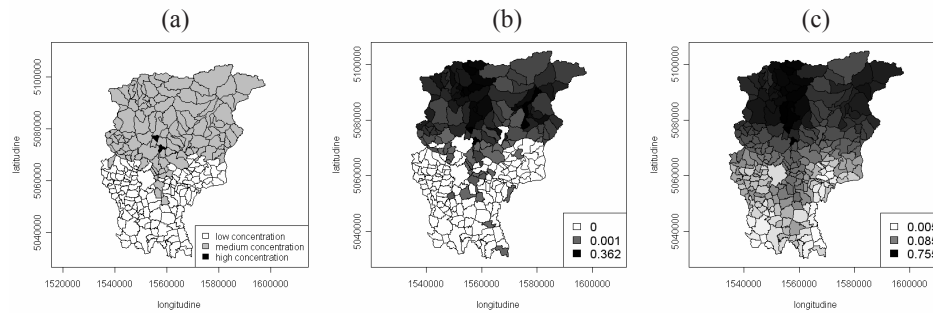
Radon is a natural radioactive gas. It is known to be the main contributor to the exposure from natural background radiations and is also considered to be the main leading cause of lung cancer second to smoking. Indoor radon concentration levels of 200 and 400 Bq/m³ are the reference values above which mitigation measures should be taken in new and old buildings, respectively, to reduce exposure to radon. Monitoring surveys have been undergone in a number of western European countries to identify radon prone areas in order to plan remediation programs. Sampling campaigns provide measures of concentrations detected in any single building included in the sample, while a global measure is necessary for radon prone area identification. This requires an integration of the spatial data from the level at which they are collected (points) to the level at which they are necessary (municipalities). This is known as *change of support problem* (COSP). In this paper we use multiGaussian simulations in order to face COSP and identify radon prone areas using a survey implemented by the agency of environmental protection (ARPA) of Lombardy in 2003. We focus on the district of Bergamo, a region of particularly high radon concentration.

2. Radon prone areas identification

Stochastic simulation provides an effective method to solve the COSP. The block value is numerically approximated by averaging point values simulated inside the block. This requires to define a grid of locations. We built a grid of 2853 points, the minimum

number of locations in a municipality being 4 and the maximum 17. We use the multiGaussian approach to simulate point values. According to this approach the cumulative distribution function at any location is assumed to be Gaussian. In order to guarantee normality, at least marginally, we transform the data to a normal score scale (Goovaerts, 1997). Simulations are performed conditioning by kriging. In other words the value of the simulated trajectory in $\mathbf{s}$ is $T(\mathbf{s}) = Y^*(\mathbf{s}) + S(\mathbf{s}) - S^*(\mathbf{s})$, where $Y^*(\mathbf{s})$ the kriging prediction at site $\mathbf{s}$, $S(\mathbf{s})$ is the simulated value and $S^*(\mathbf{s})$ is the kriging prediction obtained from the simulated observations. In this paper, $S(\mathbf{s})$ is simulated according to the spectral turning bands method (Chilès and Delfiner, 1999). The variogram of the process $\mathbf{S}$ is isotropic exponential and it is estimated on the dataset at hand via weighted least squares. The data are firstly detrended through a GAM model¹. Working on detrended values allows us to use a (global) simple kriging assuming a 0 mean for the process. Once the process is simulated on the grid, the simulated values are averaged for each municipality. The procedure is repeated one thousand times and the probability of getting a radon concentration over the two thresholds of interest is approximated by the proportion of the times we obtain a block value above such levels. Results are reported in figure 1. It is proposed to identify as “high concentration” or “medium concentration” the areas where the probability of having a radon concentration above 400 or 200 Bq/m³, respectively, is higher than 10%. Municipalities are at “low concentration” otherwise. We found only one municipality (whose area is split in two disjoint bits) at high concentration and a clear increasing gradient of the radon concentration from south to north.

Figure 1: Areas classification (a); probability of a concentration above 400 Bq/m³ (b) or 200 Bq/m³ (c)



References

- Chilès D, Delfiner P (1999) *Geostatistics Modeling Spatial Uncertainty*, Wiley, New York.
- Goovaerts P. (1997) *Geostatistics for Natural Resources Evaluation*, Oxford University Press, New York.

¹ We specified a GAM (Generalised Additive Models) model with loess transform of the latitude and longitude of every site. Trend and variogram model were preliminarily crossvalidated against alternative specifications on the dataset at hand.