Archaeological risk and spatial analysis. How to compare urban sprawl and archaeological sensibility maps

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Abstract. The famous definition of risk coming from Varnes (1978) (1) expresses that:

$$R = H \times V \times E \qquad (1).$$

It's effective for archaeological risk too. Elements in the expression (1) have the following meaning: H is hazard. It is the probability that an event could happen and cause damages. The urban sprawl could be considered as an element able to cause uncontrolled transformations on the territory and consequently to interfere in a negative way areas with archaeological interest. V is vulnerability and here it is the archaeological and cultural heritage sensibility map. E is exposure. It expresses the value of elements at risk. In this study exposure will be neglected because we are going to consider the same value for all heritage elements.

Keywords. Hazard and vulnerability have been mapped and overlayed with spatial analysis .

1. Introduction

Archaeological risk maps are important instruments for public authority because they are part of the basic knowledge in urban and territorial planning.

In particular two types of risk could be recognized in the interaction between cultural heritage and the territorial planning: 1) risk coming from landscapes transformation and causing impoverishment of cultural heritage 2) risk to stop projects in progress and consequently to lose time and money coming from unexpected archaeological findings.

Some limits in actual archaeological risk assessment occur: in many cases only a spatial catalogue of known cultural heritage is prepared; in other cases good archaeological predictive models are used to decide where to do archaeological survey in the case of development plans (2), but any risk assessment is evaluated; finally sometimes risk factors considered are usually environmental variables (3) while anthropic action is neglected.

So the aim of this paper is to offer a methodology to study interactions between archaeological heritage and the anthropic action, meant as areas interested by the growth of the city.

With this goal the first step has been to study the urban sprawl. This is characterized by a urban growth not controlled, that has different negative effects on the territory from the point of view of planning, agriculture, landscape, ecology and economy. The main one is the soil consumption. Also from the point of view of cultural and archaeological heritage the uncontrolled expansion is a danger for the loss of heritage.

The urban planning tries to control the urban sprawl phenomenon by understanding where new settlements are naturally going to position themselves and by concentrating in that areas, in most of the cases nearly compromised, all new buildings and expansion zones (periurban areas).

It is not so easy to understand where the city is growing spontaneously, also because the urban, periurban and country areas are strictly interconnected and so it is not enough to use a simple contiguity rule to map them. Recent works use spatial analysis to study urban sprawl (4).

The model proposed in this paper, based on (1) and applied on the case study of Matera allows to analyse and map the urban sprawl, it allows to calculate an archaeological sensibility map and finally to obtain the archaeological risk map with the aid of spatial analysis, in particular Map Algebra and Point Pattern Analysis.

2. Methods

Spatial analysis investigates the spatial distribution of phenomena. In this paper are used map algebra and point pattern analysis.

According to (5) map algebra is a high level spatial modelling language, including base elements (operators), complex elements (functions) and formal language (instructions), together with elements needed to program and develop complex models. To deepen map algebra see (5),(6).

In Point Pattern Analysis (PPA) a phenomenon is studied as a point pattern. Two families of PPA have been used: Nearest Neighbor Method (NNM) and Kernel Density Estimation (KDE).

Nearest Neighbour is a distance-based method. It provides information about the interaction among events at the local scale. Nearest-Neighbor Index (NNI) is the ratio between the average distance of N nearest neighbour events (Nearest Neighbor Observed Distance, NNOD) and the nearest neighbour expected distance (NNED), based on a random distribution. If NNI < 1 the point pattern is autocorrelated; if NNI > 1 the point pattern is scattered.

KDE is a three-dimensional function, weighting events within their sphere of influence according to their distance from the point at which intensity is being estimated (7).The estimation depends on the intensity of points, from the kernel function and moreover from the bandwidth. For a wider overview of methods see for example (8).

A natural extension of KDE is KDE Network, where the estimation is evaluated along a network. KDEN could be calculated in different ways; here the SANET software has been used (9).

3. The Case Study

The above explained methods have been applied on the study area of Matera, in Basilicata region (Southern Italy), that is characterized by its location on a small canyon that has been created and named by the Gravina river. Matera's fame is related in particular to the "Sassi", houses excavated into the calcareous rock, but all its municipal territory is rich of cultural and archaeological heritage. The urban sprawl phenomenon could be a danger for the heritage, so it is important to know both the elements and to compare them.

For what concern archaeological heritage, the spatial distribution has been considered. Firstly a database of known elements has been created, then KDE and NNED have been applied together. A NNED=476m has been found and it has been used as bandwidth in KDE. Results have been classified in quantiles and the first 8 quantiles have been considered as sensible areas (fig.1A).

For what concern the urban sprawl analysis, they have been considered:

1. areas protected by laws because of their environmental or landscape importance or for other constraints. All these areas have been added with map algebra and a map of bound areas has been obtained (fig.1A).

2. areas where the city is naturally growing have been found by considering:

a. the proximity between buildings, that is areas with medium density of constructions. This has been done by calculating the NNED (equal to 85m), by considering it as bandwidth in the KDE and by selecting areas with a density included between 0.1 and 3.0 habitation for hectares. The minimum has been chosen because it characterize rural areas. The maximum value is the lower density value for urban areas, the already planned city (fig.2A). b. the proximity of buildings to existing roads. A KDEN has been calculated and consequently roads have been classified in three classes, with low, medium and high density of buildings around them. A Straight Line Distance (SLD) around these three classes has been plotted, around them: for class 1 no distance has been considered, for class 2 a distance of 200m has been considered, for class 3 a distance of 400m has been considered (fig.2B).

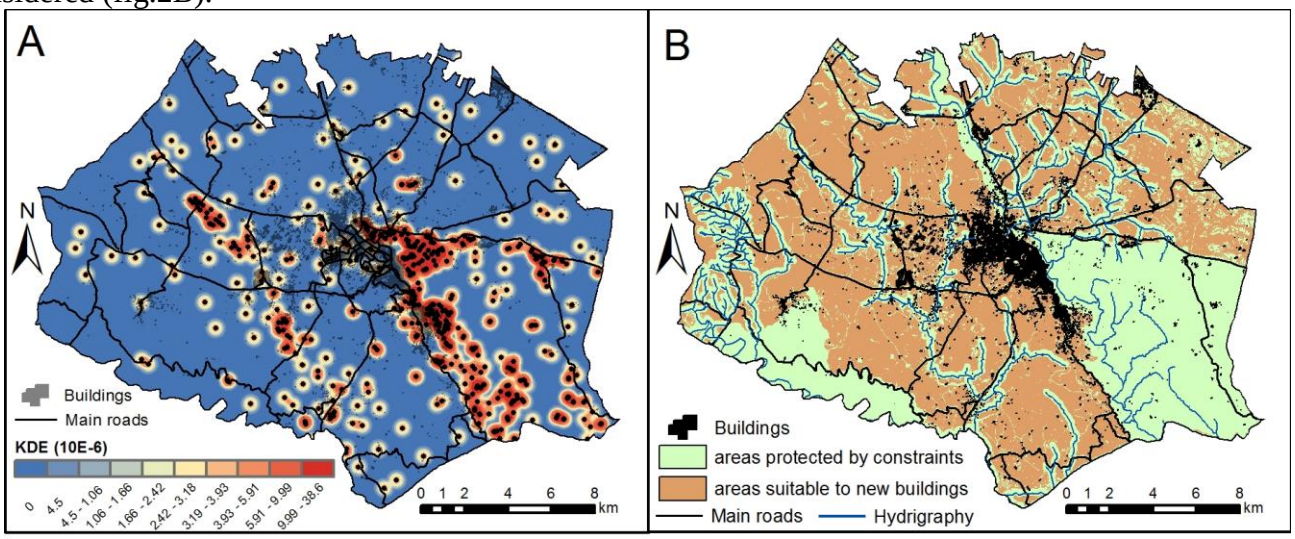

Figure 1. A) Cultural and archaeological sensibility map**.** B) Areas protected by laws.

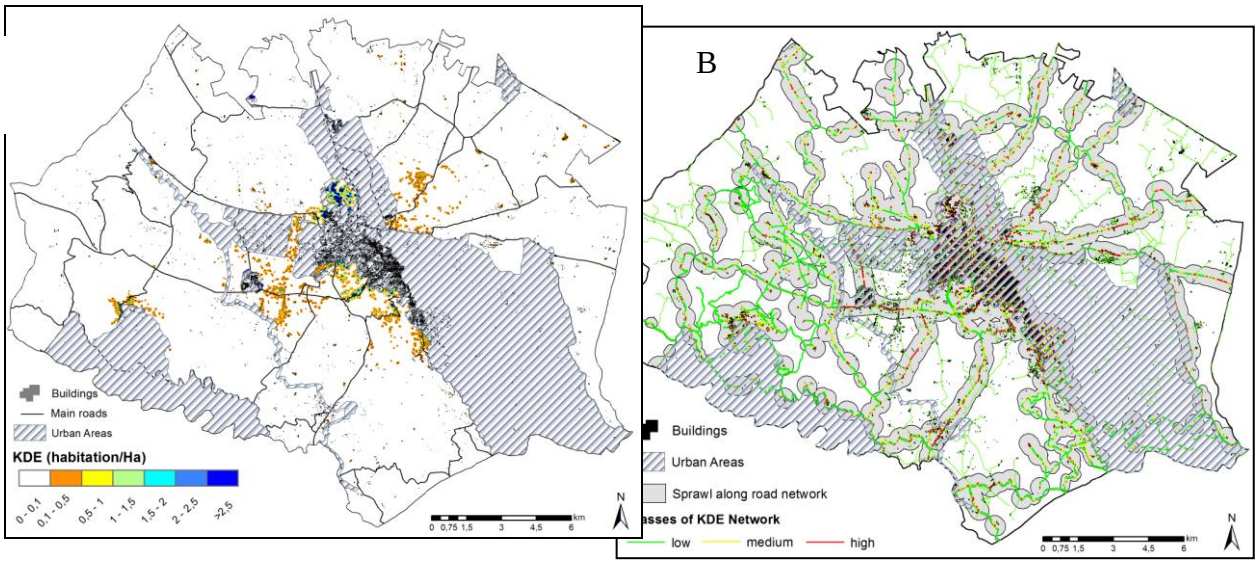

Figure 2. A) KDE of buildings around the urban area. B) Urban sprawl valued around roads.

4. Results and conclusions

Maps obtained have been overlayed with map algebra according to the flow chart in (fig.3) to obtain a risk map showed in (fig.4). Three risk classes have been found: the lower one represents

areas protected by constraints and so with low risk; the higher one is the intersection between the heritage sensibility map and areas with urban sprawl; the medium one is the remaining areas.

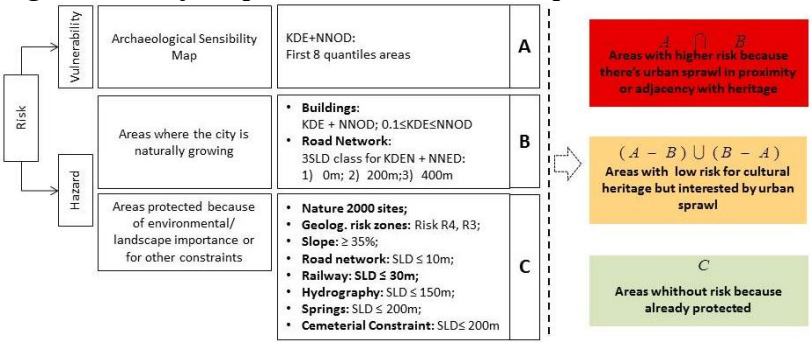

Figure 3. Flow chart resuming the procedure.

In conclusion the use of spatial analysis could be an aid to map the urban sprawl phenomenon, to compare it with the distribution of archaeological heritage and to find areas most exposed at risk.

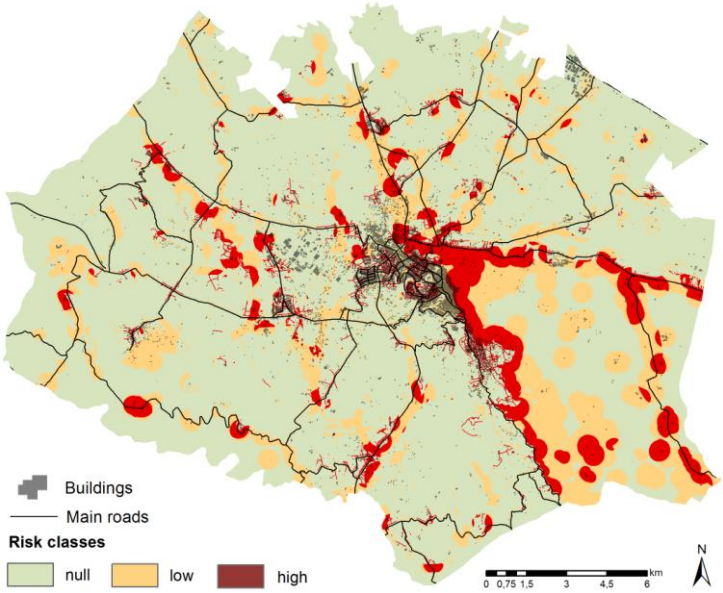

Figure 4. The final archaeological and cultural heritage risk map.

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