A METHODOLOGY FOR ASSESSING SEISMIC RISK
DEPREM RİSKİNİN BELİRLENMESİ İÇİN BİR YÖNTEM

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ABSTRACT

A methodology for assessing the seismic risk through standard and local hazard, vulnerability of physical environment and buildings is presented. As a first step standard hazard, as a probability of occurrence for done intensity earthquake, is evaluated. The local hazard, due to the influence of geological and geomorphological conditions, is taken in account through the amplification coefficients, that can modify the standard hazard. For the evaluation of the vulnerability of physical environment the recent and ancient landslides and zone affected by superficial instability producing active or potential landslide situations are considered. The vulnerability of buildings, defined such as the seismic performance v/s damages, is evaluated through some characteristic parameters. Finally the seismic risk due to the convolution of hazard and vulnerability is eveluated. In this paper the applied methodology and the results carried out for Toscolano Maderno (a small town of Lombardia Region, Italy) are presented.

METHODOLOGY

The present methodology for assessing the seismic risk can be usefull in incuding seismic risk in urban planning and in defining programs for its reduction.

As a first step standard hazard, as a probability of occurrence for done intensity earthquake, has been evaluated. The method for the hazard assessment is based on the following hypoteses:

- seismic hazard at site is fully described by the interoccurrence time distribution $F_t(t)$ and the local intensity distribution $F_I(i)$;
- interoccurrence times t and intensity I are assumed as indipendent random variables (Bernoulli model).

The earthquake occurrence process is represented by a renewal process with probability density function:

$$f_t(t) = p\, f_1(t) + (1-p)\, f_2(t) \qquad (1)$$

The functions f_1 and f_2 may be different from site to site according the data and are chosen in a menu including Exponential, Lognormal, Weibul and Gamma distributions. The estimate of the parameters of equation 1, including p is directly performed site by site on the basis of available data.

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The sequence of events at site is derived from the epicentral parameters listed in an earthquake catalogue; only events producting at site an intensity I greather than or equal to a threshold I_S are used. The threshold value I_S = VI MCS has been assumed in order to consider the events that may produce damage to the buildings. Attenuation models are needed in order to derive local intensity I from epicentral intensity I_O, and, the attenuation model of Grandori et al. (1987) is assumed.

The evaluation of local intensity distribution is performed in three steps. The analysis of the seismotectonic model and the past seismicity leads to the identification of zone that can be characterized by the same distribution $F_{IO}(i)$ on the epicentral intensity I_O. For each group of zones, the type and parameters of the function $F_{IO}(i)$ are determined on the basis of the earthquake catalogue. One of the three types of function is assumed in this analysis (Grandori et al., 1984; 1991):

$$F_{IO}(i) = 1- \exp [- \alpha (i - I_{OS})] \quad (2)$$
$$F_{IO}(i) = 1 - \exp [\exp (\alpha I_{OS}) - \exp (\alpha i)] \quad (3)$$
$$F_{IO}(i) = 1 - \exp [\exp (\alpha I_{OS} - \beta) - \exp (\alpha i - \beta)] \quad (4)$$

The parameters α and β are calculated through the data of catalogue.

Local intensity distribution $F_I(i)$, of the type shown in equations 2, 3 or 4 are determined subdividing each zone in an appropriate number of elementary cells, assuming an uniform space distribution of the events inside the zone and applying to each zone the relevant attenuation model. Finally the assumption of the relation:

$$\ln (y/g) = a I - b \quad (5)$$

between the ground acceleration y and the intensity I allows to derive the acceleration distribution $F_y(y)$ and the corresponding probability density function $f_y(y)$ from the intensity distribution $F_I(i)$, where g is the gravity acceleration, a is equal to .602 and b is equal to 7.073.

The local hazard, due to the influence of geological and geomorphological conditions, is taken in account through an amplification coefficient, that can modify the standard hazard. The geological and geomorphological conditions, producing variation on the expected motion, have been identified as: edge area and rocky ridge, producing amplification due to morphological condition; valley with inchoerent alluvium and slope deposits or talus cone producing amplification caused by loose soil overlying a bedrock, and showing high impedence contrast; area affected by lithologic discontinuities producing differential settlements in connection with characters of lithologies; very soft soil producing permanent deformations (Bressan et al., 1986). The evaluation of amplification coefficient or permanent deformation is due to the application of finite elements method with the use of program such as QUAD-4 (Idriss et al., 1973).

For the evaluation of vulnerability of physical environment we have considered the recent and ancient lanslides, zone affected by superficial instability, excessive slope with debris mantle, and excessive slope with rock affected by fractures, that can produce active or potential landslide situations (Bressan et al., 1986; Keefer, 1984). The evaluation of the instability under dynamic condition is due to the application of simplified methods such as Newmark (1965), or to the application of finite elements methods (Cividini and Pergalani, 1994). The results are expressed in terms of expected displacements (Pergalani and Luzi, 1994).

The vulnerability of buildings, defined as the seismic performance v/s damages, is evaluated through some characteristic parameters. In this case the vulnerability of buildings is assessed passing through a preliminary survey on the total amount of buildings and a specific survey on definite statistical significant samples. A conventional vulnerability index V (Benedetti and Petrini, 1984), ranging from 0 (building in accordance with the present code requirement) to 100 (very poor building) identifies the building quality (Corsanego, 1991). Damage models d (V, y) relating damage index d, vulnerability index V and ground acceleration y are assumed (Angeletti et al., 1988; Guagenti and Petrini, 1989).

The seismic risk due to the convolution of hazard and vulnerability has been evaluated in three different ways: in term of expected annual damage, in terms of expected value of the actual cost of first damage and in term of expected value of the actual cost of all future damage. Starting from the average value of the expected damage, given an earthquake, that is computed as:

$$D(V) = \int_0^\infty d(V, y)\, f_y(y)\, dy \qquad (6)$$

- the expected annual damage is:

$$D_p(V) = \mu\, D(V) \qquad (7)$$

where μ is the average annual number of events at site, evaluated from the relevant probability density function of the interoccurrence time $f_t(t)$. This quantity is obviously meaningful if the hypotesis of Poisson processes is assumed; it is still significant in a renewal process if the case of random entry in the process is considered:

- the expected value of actual cost of the first damage:

$$D_1(V, d, t_o) = D(V) \frac{e^{\delta t_o}}{1 - F_t(t_o)} \int_{t_o}^\infty f_t(t)\, e^{-\delta t}\, dt \qquad (8)$$

where t_o is the time elapsed between the last event at the site and the moment when the evaluation is done; δ is the discount rate (Guagenti et al., 1988);

- the expected value of the actual cost of all future damages:

$$D_1(V, d, t_o) = D(V) \frac{e^{\delta t_o}}{1 - F_t(t_o)} \int_{t_o}^\infty f_t(t)\, e^{-\delta t}\, dt \frac{1}{1 - \int_o^\infty f_t(t)\, e^{-\delta t}\, dt} \qquad (9)$$

All the results can be drawn on maps for easier comprehension and use for non specialist technicians, such urban planners and politicians.

APPLICATIONS AND RESULTS

This methodology has been applied in several areas. In this paper the case of Toscolano Maderno, a small town of Lombardia Region (Italy) is shown, the site is characterized by low seismicity level.

The zones that can produce geological and geomorphological influence on the motion, derive from geological, lithotechnical and geomorphological maps. The area is characterized by limestones, marls, marls with clay, alluvial deposits cemented or not. For the geomorphological aspect we mapped the recent and ancient landslides and the area affected by potential instability conditions. The urban area are not directly interessed by these problems. At last we did a map of seismic hazard situations. The most serious problems of the site is due to the presence of alluvial deposits in the urban area, that can produce an amplification due to the impedence contrast (fig. 1).

We did a numerical analysis, using QUAD-4 (Idriss et al., 1973), a finite elements program and an expected artificial accelerogram, for evaluating the possible amplifications. The investigated section is shown in fig. 2, and we did different analysis considering two geometry of alluvial deposits. The first one is characterized by damping equal to .05, density equal to 1.76, and S wave velocity equal to 300 m/sec. The second one is characterized by the same damping and density but by values of S wave velocity equal to 300 m/sec on the top and 700 m/sec on the bottom. In fig. 1 the results of this analysis are shown and the value of probable expected maximum amplification due to the analysis is presented.

For the evaluation of vulnerability of buildings, through a fast survey on total amount of buildings, using some characteristic parameters such as: structural typology, age of construction, number of floors, the statistical significant samples are identified. Then on the samples we did a specific survey, using characteristic parameters such as: type, organizazion and quality of resistant system, conventional resistance, foundations, diaphragms, configuration in plan and in elevation, non structural elements, damages and decay, and we calculated the vulnerability on such buildings using vulnerability models (Benedetti and Petrini, 1984; Gavarini and Angeletti, 1984). Passing through a classification of all buildings (more than 2.000) vulnerability values were extended to whole built. The results are presented in fig. 3, and show, in general, low values of vulnerability.

The results of the value of seismic risk are shown in fig. 4 for the expected annual damage, considering amplification, in fig. 5 and 6 for the expected value of actual cost of the first damages, considering amplification or not; in terms of ratio between expected damages and cost of new edification. The results show that the more frequent values in the case of annual damage with amplification are 1/10.000-1/1.000, in the case of expected value of actual cost of first damage with amplification are 1/1.000-1/100 and 1/100-1/10, in the same case without amplification are 1/10.000-1/1.000. As the maps show, the value is higher if in the analysis is considered the influence of amplification, and this influence is more higher in the case of low vulnerability.

AKNOWLEDGMENTS

The Lombardia Regional Government financially contributed to a project, the authors wish to thank S. De Andrea and N. Padovan for the help furnished in selecting and arranging basic documents used for this paper.

Fig. 1 - Map of seismic hazard situations and isoamplification zones

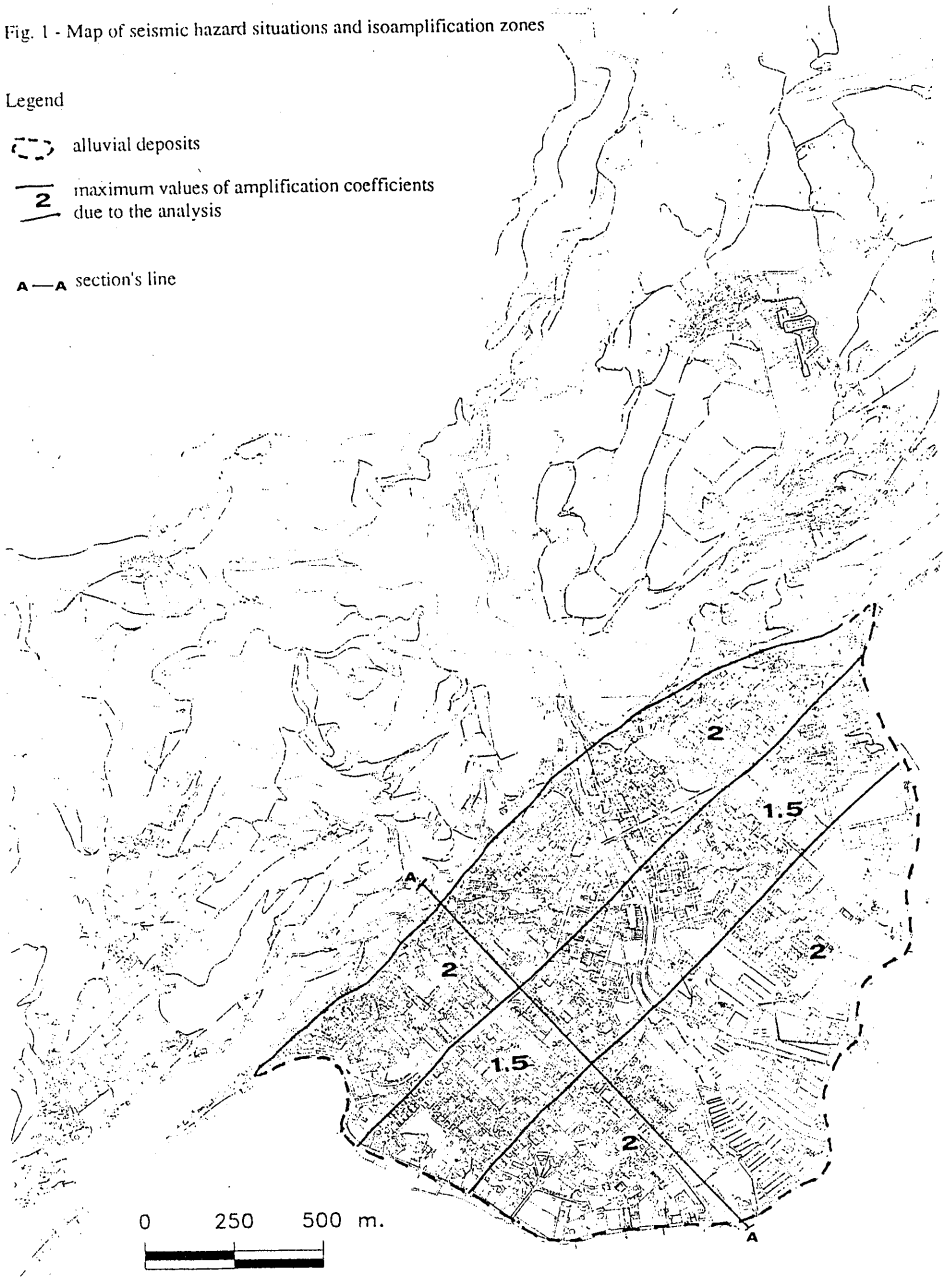
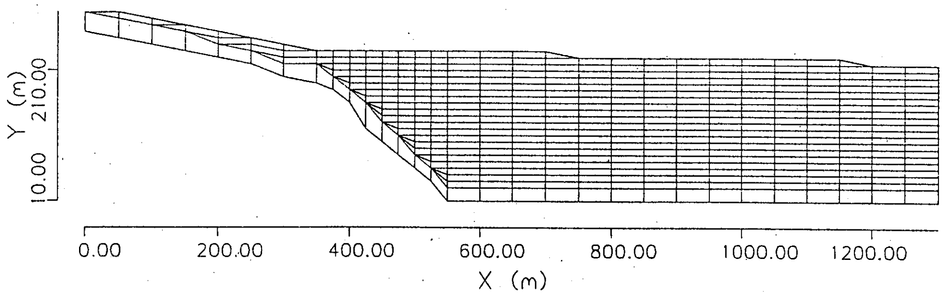
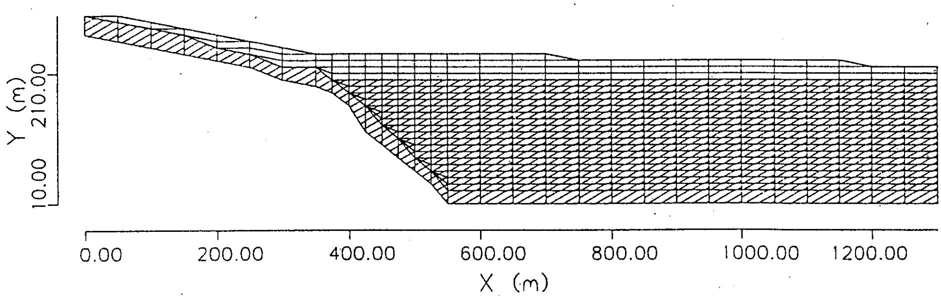


Fig. 2 - Geometry of the investigated section



damping	density	S wave velocity
0.05	1.76 t/mc	300 m/sec



damping	density	S wave velocity
0.05	1.76 t/mc	300 m/sec
0.05	1.76 t/mc	700 m/sec

Fig. 3 - Map of vulnerability of buildings

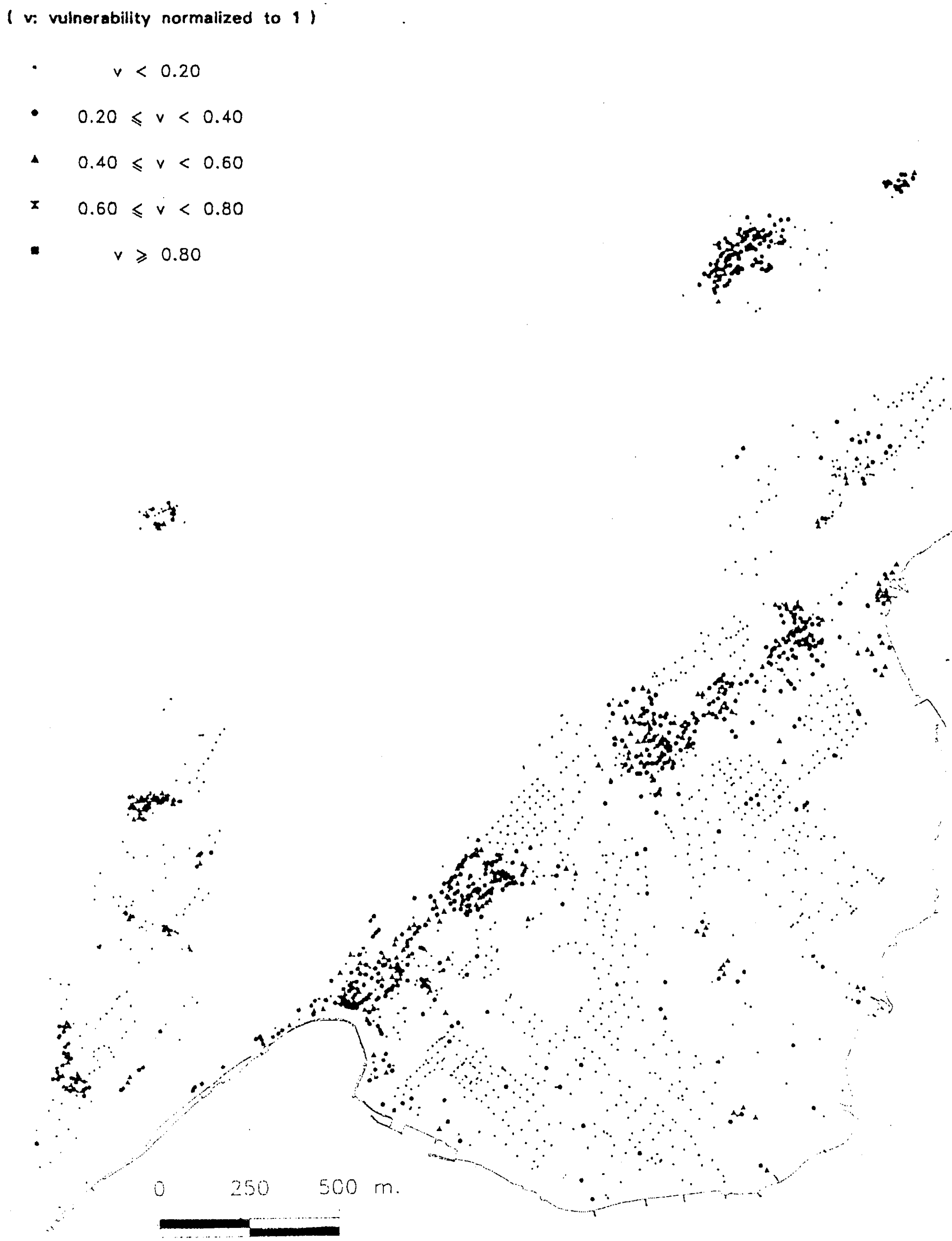


Fig. 4 - Map of risk: expected annual damage, with amplification

(r: ratio expected damages/cost of new building)

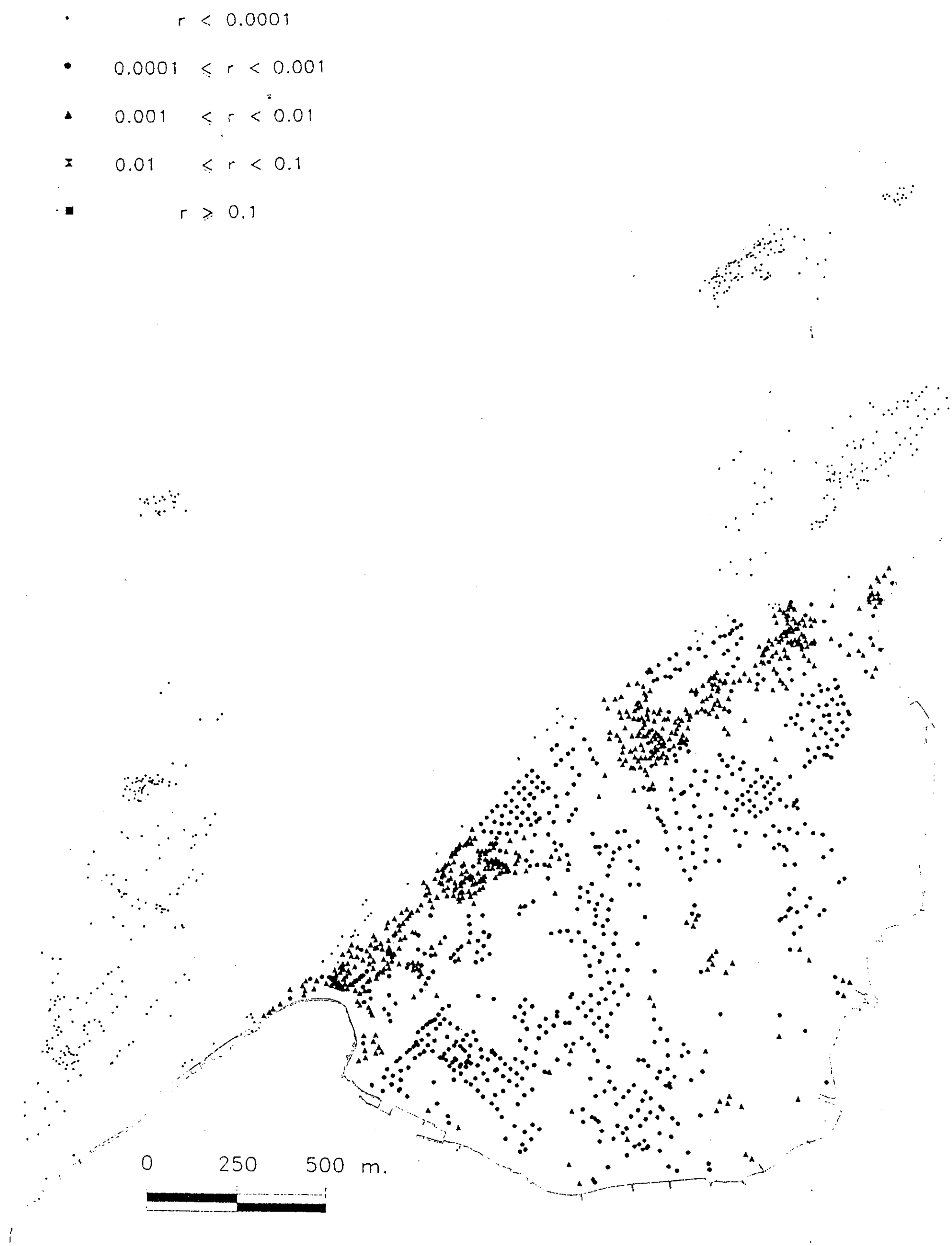


Fig. 5 - Map of risk: expected value of actual cost of the first damages, with amplification

(r: ratio expected damages/cost of new building)

· r < 0.0001

• 0.0001 ≤ r < 0.001

▲ 0.001 ≤ r < 0.01

x 0.01 ≤ r < 0.1

■ r ≥ 0.1

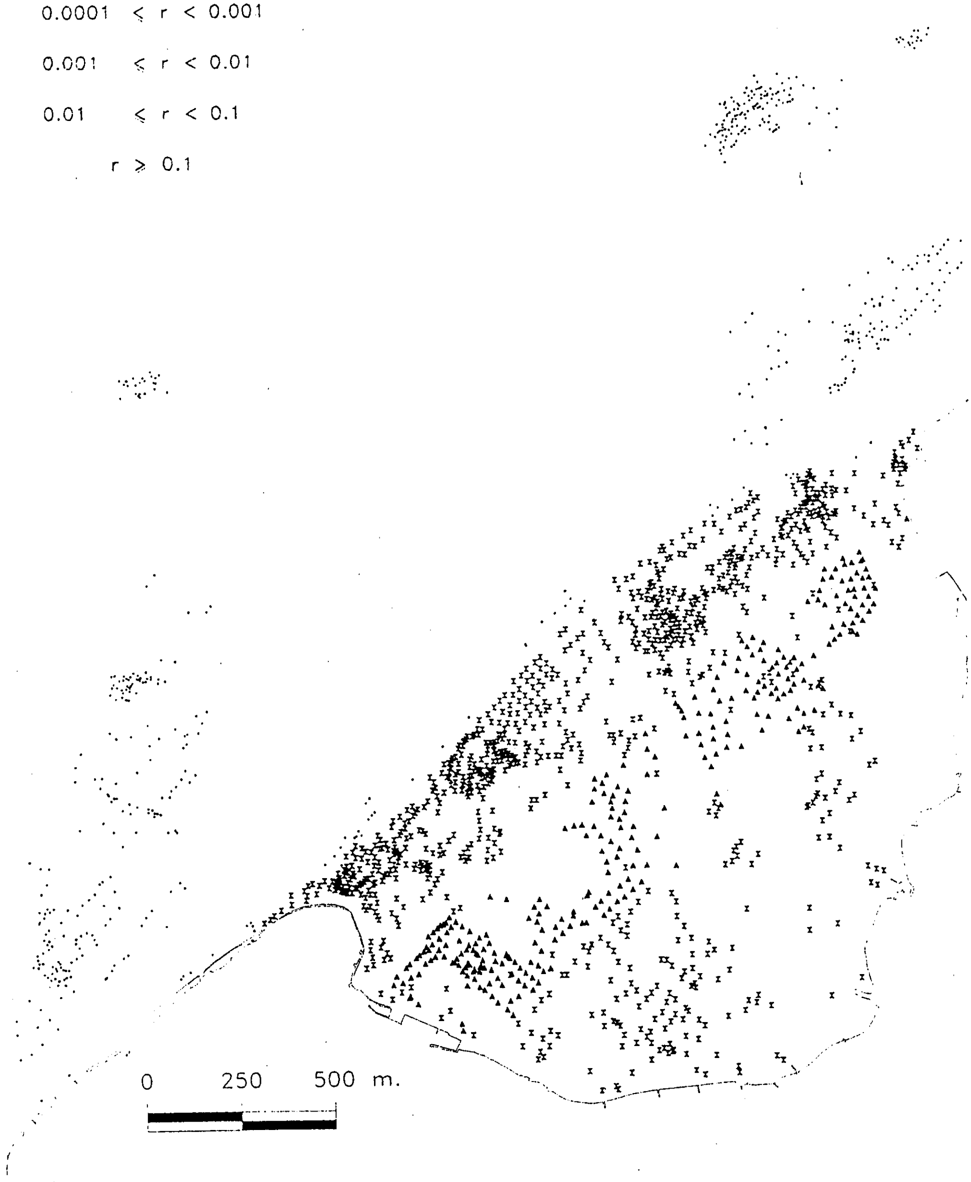
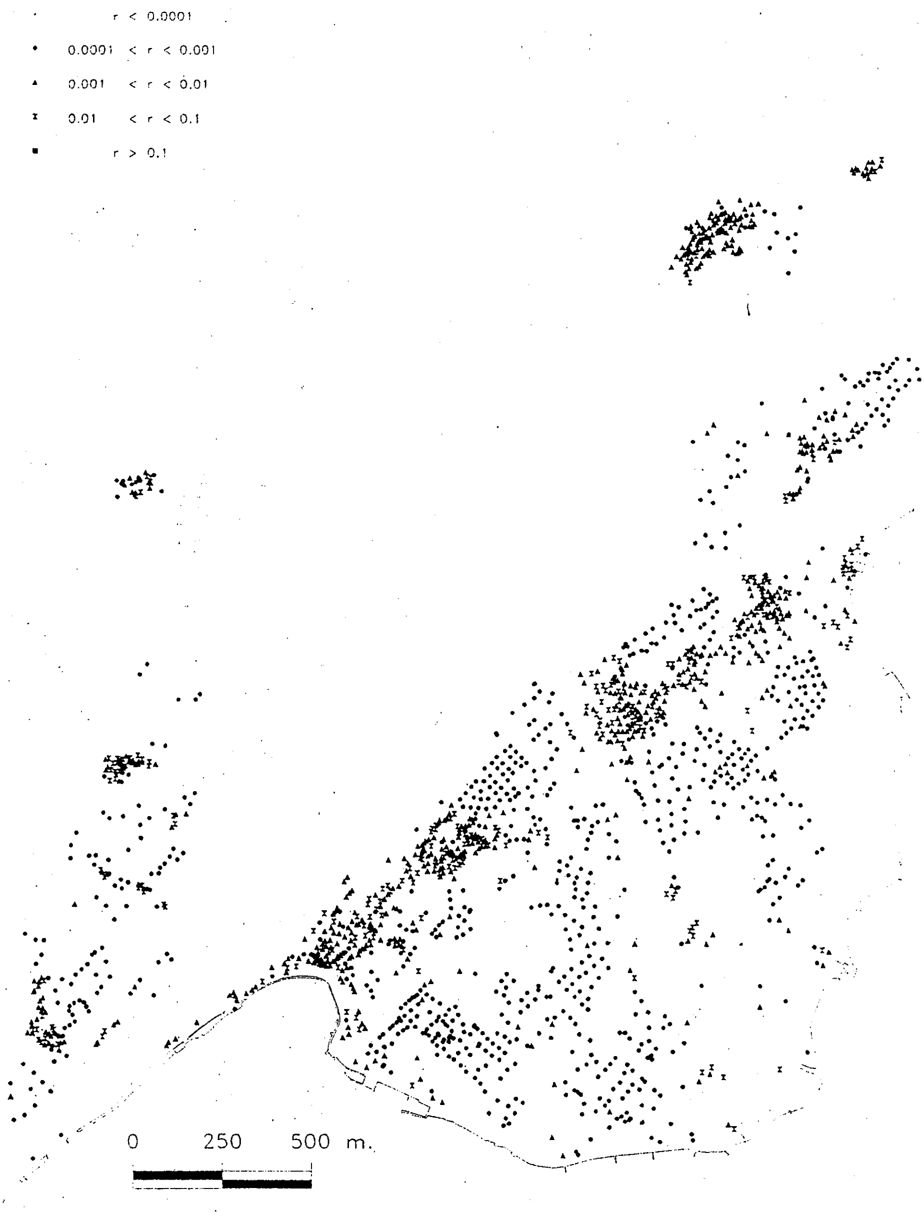


Fig. 6 - Map of risk: expected value of actual cost of the first damages, without amplification
(r: ratio expected damages/cost of new building)



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