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The perception of the territory naturalness an application in the bergamo area

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THE PERCEPTION OF THE TERRITORY NATURALNESS AN APPLICATION IN THE BERGAMO AREA

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ABSTRACT

It is very discussed about the sustainability of urban areas. One of the requests of urban sustainability consists in the capability of the city to preserve around itself a good level of naturalness: A sustainable economy reflects an image of its territory that must represent a landscape of agreeable towns, of intact agricultural mosaics and of a large natural areas patrimony.
Ours research, starting from the proposal expressed from E. Koomen, J Groen, J Borsboom and H Scholten with the work "Modelling the fragmentation of open space. A framework for assessing the impact of land use change on open space" presented at the ERSA Congress in 2002, intends to find the modality with which the naturalness influences the surrounding areas, the zones where nature and population pressure are not in antithesis and the natural areas that risks to be lost.
The goal will be reached applying the concept of "field". The base idea is that the areas with larger "naturalness" constitute a sort of positive virus that influences the surrounding zones.
The GIS-oriented model presupposes the discrete division of the territory and the use of a simple field algorithm applied to an naturalness indicator opportunely studied.
The application , for the validation of the model, has been implemented on the Bergamo's province; choosing a territorial scale that allows to do observations and preliminary evaluations at the level of urban planning to locate large infrastructures.

1. THE NATURALNESS

The first step of analysis consists in the explanation of the concept natural area. The scientific and political debate regarding the landscape has been for long time dominated from a "conservative" approach, founded on the definition of natural environment meaning wilderness to preserve and, if possible, to restore. In recent times has came out the idea that Italian landscape, and in particular Lombard, is a constructed landscape. This idea descend from the consideration that the secular relationship of the man with the nature has changed the naturalness of the territory that is the result of a long process of adaptation and of transformation, the "population pressure" . This speech is more valid if

reported to the areas of marked agricultural tradition as the countryside and the valleys of the “Bergamasca” region.
It is defined “natural area" a part of territory characterised from the absence or negligible presence of constructions as buildings or infrastructures. In this definition areas characterised from extensive agricultural use re-enter in commonly defined "half - natural". In this vision, the presence of human does not come considered a threat for the naturalness.

2 THE METHOD AND THE MODEL

The proposed method has the primary goal to estimate the naturalness of a determined territory considering the modalities in which a “natural area” influences positively also the neighbour areas. The secondary objective is to estimate the vulnerability of the areas that risk to lose their natural connotations because of the population pressure. Introduced the general concept of naturalness it is necessary to describe the steps of the method:

1. subdivision of the territory in areas or cells of opportune dimension,
2. calculation of the naturalness index for each cell with an iteration method, that consider of the indices of the near cells,
3. calculation of the population pressure index for each cell with an iteration method,
4. calculation of the vulnerability of each cell composing the naturalness indices and population pressure indices.

This evaluation can be useful for:

1. To preserve those areas that induce on the territory an effect of "positive field" for the perception of the naturalness,
2. To locate the way of landscaped valence, like panoramic way or to integrate the existing way with cyclable and pedestrian way.
3. To take decision about fragile areas vulnerable defined in order to better integrate the population pressure activities with natural connotations.
4. To carry out the environment impact analysis of new activities on the territory.

In order to realise the model it has been decided to use the potentialities of the software for geographical information systems (Arcview®). This instrument, not only allows to manage territorial database, but also to carry out complex calculations, , on the data and could visualise them on a vectorial cartographic support. In order to estimate the effectiveness of the method it has been decided to realise an application model having as analysis area the territory of the province of Bergamo. It has been chosen this territory, because:

- having characteristic heterogeneous (mountain, hill and plain).
- well known by the authors.

2.1 SUBDIVISION OF THE TERRITORY

The provincial territory has been subdivided in cells 200m x 200m. Such dimension has been chosen in function of the studies on the perception of the territory naturalness present in literature (E Koomen, J Groen, J Borsboom and H Scholten 2002) and considering the territory of Bergamo where, in the forest plain zones, it is difficult to perceive the nature of the territory at of over 200 m. The grid has been created with the aid of an appropriate script ("createmap.grd", available on the ESRI web pages. The grid has been organised to cover a greater area than the province.

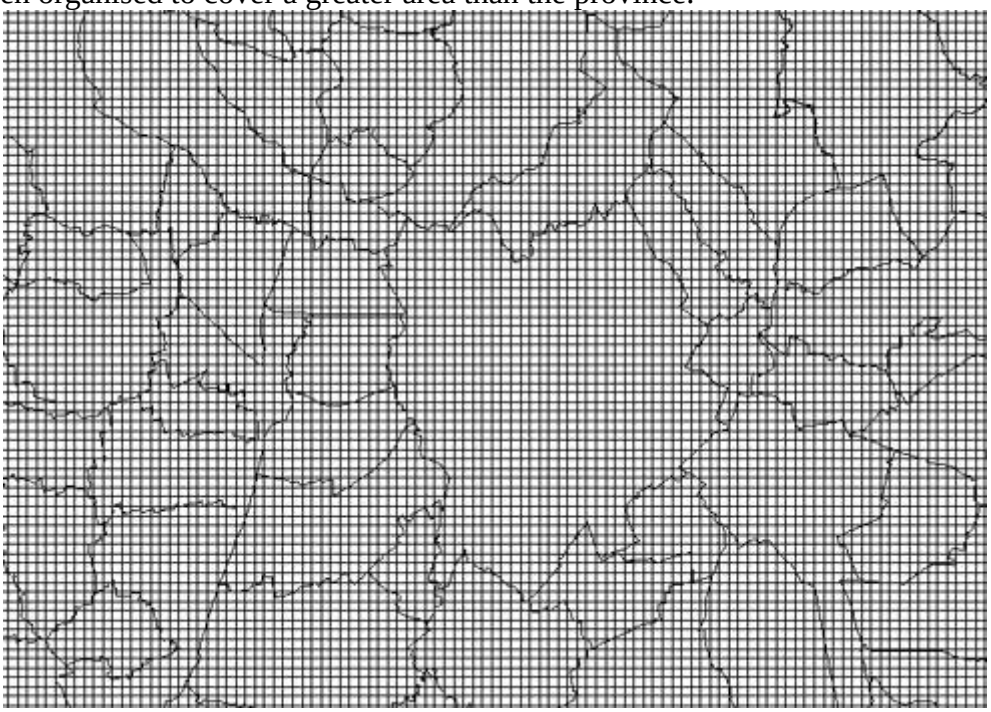

Figure 1: Municipality of Bergamo (to the centre) and Interland with overlapped grid 200m x 200m

2.2 CALCULATION OF THE NATURALNESS INDEX

The calculation of the naturalness index is carried out for every cell, in function of the kind of ground cover. In particular have been considered the values indicate in literature (And Koomen, J Groen, J Borsboom and H Scholten 2002) for the supplied types of cover of the map “CORINE Land Cover” realised on initiative of the European Commission.

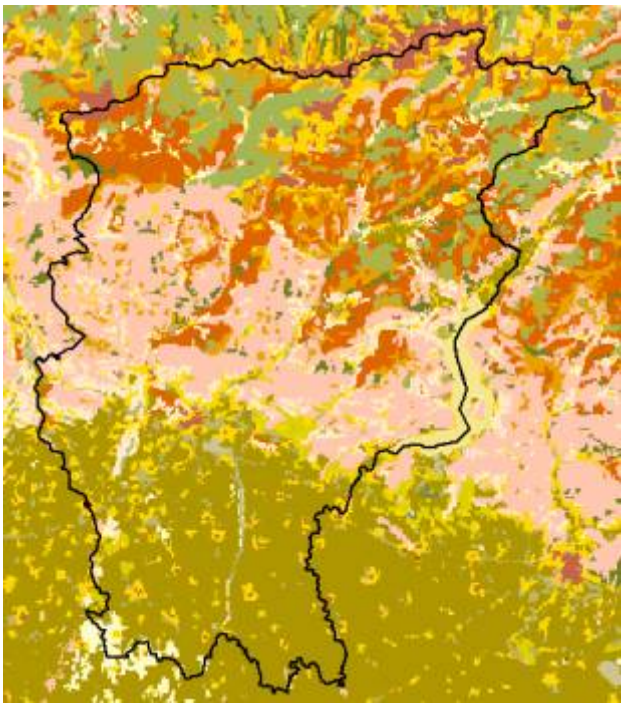

Figure 2: CORINE LAND COVER - Province of Bergamo

Proposed indices assume high values for the areas with greater naturalness (ex. forest) and null values for continuous city areas.

1. artificial surfaces	
1.1. urban fabric	
1.1.1. continuous urban fabric	**0**
1.1.2. discontinuous urban fabric	**0**
1.2. industrial, commercial and transport units	
1.2.1. industrial or commercial units	**0**
1.2.2. road and rail networks and associated land	**0**
1.2.3. port areas	**0**
1.2.4. airports	**0**
1.3. mine, dump and construction sites	
1.3.1. mineral extraction sites	**0**
1.3.2. dump sites	**0**
1.3.3. construction sites	**0**
1.4. artificial non-agricultural vegetated areas	
1.4.1. green urban areas	**1**
1.4.2. sport and leisure facilities	**0**
2. agricultural areas	
2.1. arable land	
2.1.1. non-irrigated arable land	**1**
2.1.2. permanently irrigated land	**1**
2.1.3. rice fields	**1**
2.2. permanent crops	
2.2.1. vineyards	**2**
2.2.2. fruit trees and berry plantations	**2**
2.2.3. olive groves	**2**
2.3. pastures	

2.3.1. pastures	**2**
2.4. heterogeneous agricultural areas	
2.4.1. annual crops associated with permanent crops	**2**
2.4.2. complex cultivation patterns	**2**
2.4.3. land principally occupied by agriculture, with significant areas of natural vegetation	**2**
2.4.4. agro-forestry areas	**2**
3. forests and seminatural areas	
3.1. forests	
3.1.1. broad-leaved forest	**4**
3.1.2. coniferous forest	**4**
3.1.3. mixed forest	**4**
3.2. shrub and/or herbaceousvegetation associations	
3.2.1. natural grassland	**4**
3.2.2. moors and heathland	**4**
3.2.3. sclerophylious vegetation	**4**
3.2.4. transitional woodland shrub	**4**
3.3. open spaces with little or no vegetation	
3.3.1. beaches, dunes and sand plains	**4**
3.3.2. bare rocks	**4**
3.3.3. sparsely vegetated areas	**4**
3.3.4. burnt areas	**4**
3.3.5. glaciers and perpetual snow	**4**
4. wetlands	
4.1. inland wetlands	
4.1.1. inland marshes	**3**
4.1.2. peatbogs	**3**
4.2. coastal wetlands	
4.2.1 salt marshes	**3**
4.2.2. salines	**3**
4.2.3. intertidal flats	**3**
5. water	
5.1. inland waters	
5.1.1. water courses	**3**
5.1.2. water bodies	**3**

Table 1: attribution of the values of naturalness index to various uses of the ground

Have been overlapped, intersected and subsequently joined the grid and CORINNE map.
To each cell defined on the grid has been assigned the destination of prevailing use.
For the calculation of the naturalness index it has been decided to consider the effect of "generated field" on each cell by the surrounding cells. In particular using for the calculation of the index of each cell the following relation:

$$Ni = \sum_{j=1}^{N} Vj * P_{i,j}$$

Where V are the values of naturalness of the surrounding cells and P is an attenuation coefficient (potential), function of the distance.

$$p_{i,j} = \exp(-\beta * d_{i,j})$$

In the application this calculation has been made for five different values of β, each one representative of various critical distance of influence.

BETA E DISTANZE CRITICHE	
0,01	3,7km
0,0075	4,6km
0,005	5,1km
0,00375	5,3km
0,0025	5,6km

Table 2: calculation indices

The maps of naturalness have been obtained. The values are represented by a colour scale. Every map differs from the others for the value of β. It can be noticed that increasing β the perception of naturalness decrease because of the decreasing of the critical distance.

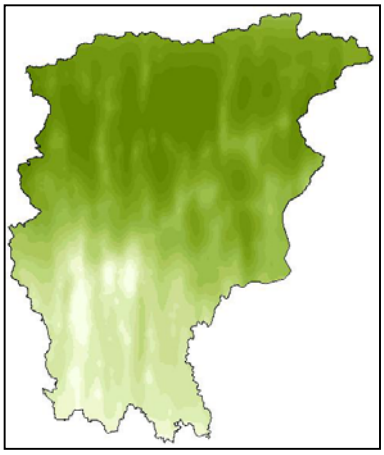

Figure 3 β 0.0075

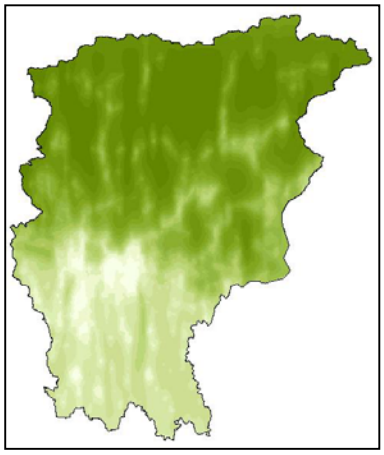

Figure 4 β 0.01

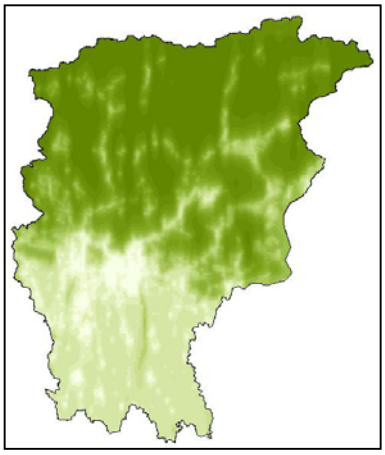

Figure 5 β 0.005

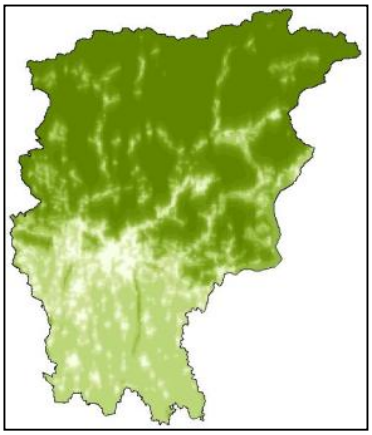

Figure 6 β 0.00375

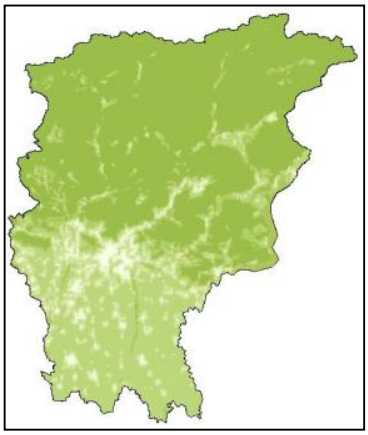

Figure 7 β 0.0025

2.3 CALCULATION OF THE POPULATION PRESSURE INDEX

With the goal to estimate the vulnerability of the “natural" territory it has been decided to estimate for each cell of the grid also a population pressure index that consider the distribution of the population on the territory. The urbanised areas are the only layer of CORINNE Land Cover to consider in order to calculate the population pressure index. Because the population pressure index of each cell will be proportional to the population density, has been necessary to estimate it with the following procedure:
From the territorial grid have been eliminated all the cells that they did not have prevailing destination of urban type. Therefore, having considered the data regarding the whole population for each municipalities and knowing the number of urbanised cells present in the municipalities, has been estimated the density of population for each cell. In this way a map that represents the urbanised areas associated to the relative data about the density of the population has been obtained.

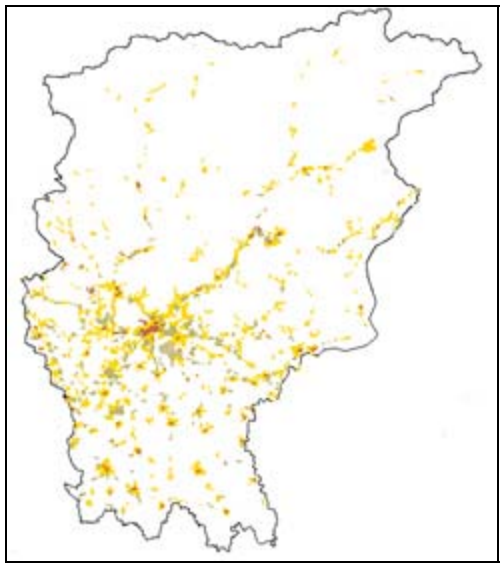

Figure 8 Density of the urbanised areas of the province of Bergamo

Analogous to the calculation of the naturalness index, it has been then applied the potential function in order to estimate of the possibilities of expansion of the urbanised areas. The population pressure index is:

$$A_i = \sum_{j=1}^{n} W_j \cdot p_{ij}$$

Where W is the value of density of the surrounding cells and P is an attenuation coefficient, function of the distance.

$$p_{ij} = \exp(-\beta \cdot d_{ij})$$

In the application calculation is carried out for five values of β representing various critical distance of influence.

$\beta = 0.5$	=> d = 1.1 Km
$\beta = 0.4$	=> d = 1.2 Km
$\beta = 0.3$	=> d = 1.3 Km
$\beta = 0.15$	=> d = 11.8 Km
$\beta = 0.09$	=> d = 17.6 Km
$\beta = 0.05$	=> d = 26.5 Km

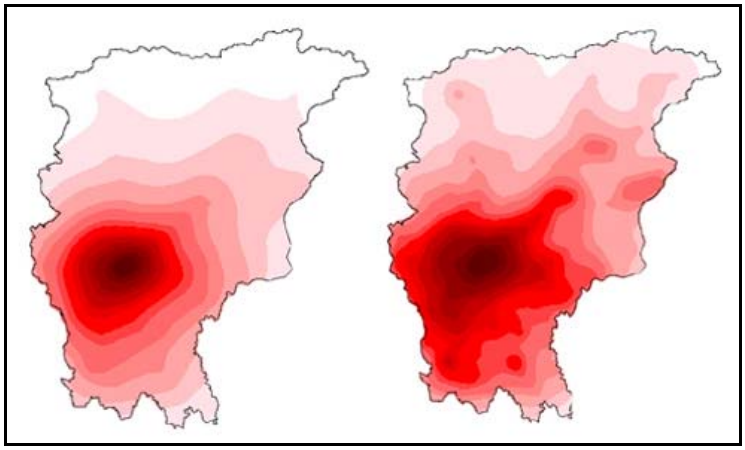

Figure 9
$\beta = 0.05$, d =26.5 Km (left) e $\beta = 0.09$, d = 17.6 Km (right)

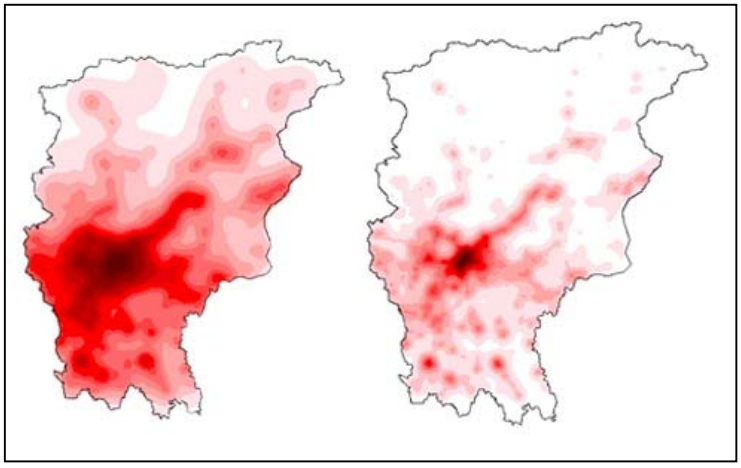

Figure 10
$\beta = 0.15$, d = 11.8 Km (left) e $\beta = 0.3$, d = 1,3 Km (right)

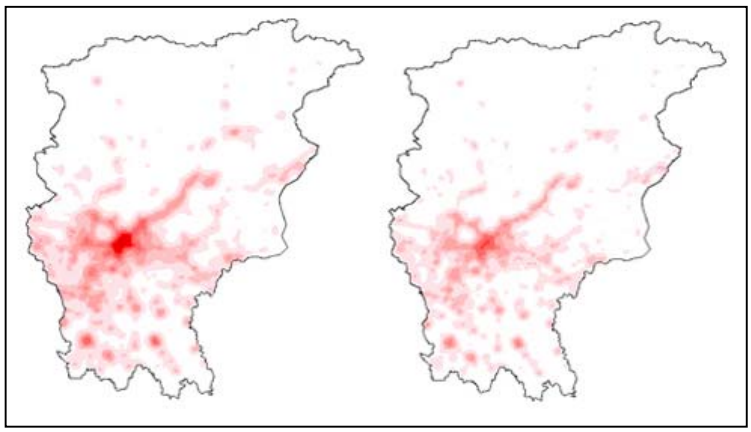

Figure 11
β = 0.4, d = 1.2 Km (left) e β = 0.5, d = 1.1 Km (right)

The maps are very different each other, even if some common characteristics are noticed: the town of Bergamo is always the point with potential more elevated, leaving from which the map is vanished more or less quickly in function of the value of the medium distance.
The first and last map does not turns out significant results, but are useful in order to comprise the weight of the medium distance and in order to choose the best β. In fact in the first map the potential of the city of Bergamo is so high that the concentration of the population in the surrender municipalities isn't estimable.

2.4 CALCULATION OF THE VULNERABILITY

Making an analogy with the theory of the risk analysis, we can assume that the Vulnerability is the product of the population pressure index of the territory (meant as probability of losing the resource "naturalness") and naturalness index (meant as possible level of consequent damage of losing the "naturalness" of that portion of territory). Therefore, using the values previously it calculates to you and it standardises to you, is proceeded to the esteem of the vulnerability of each cell, applying the simple relation:

$$V = A * N$$

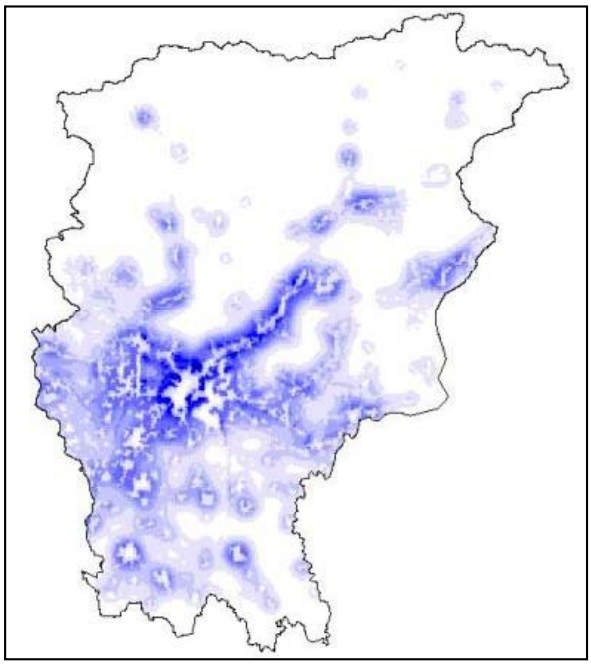

Figure 12: vulnerability map

3 RESULTS

The realised application case for the Bergamo area has allowed to better estimate and to calibrate the assumed and proposed model.

3.1 THE NATURALNESS INDEX

In particular, for the appraisal of the naturalness index are chosen as index of "perceived distance" the values of β, 0.0075 and 0.0025. In first case (β = 0,0025) a detailed image is obtained. This image represents the perception of naturalness of the surrounding and immediately useful areas. In fact, as it can be noticed from the following images, the zone with lower naturalness in the city of Bergamo corresponds to the urbanised zone . The urban green zones at this scale can change the perception mitigating punctually the effects of the constructed ones.

Figure 13: Urbanised

Figure 14: β 0,0075

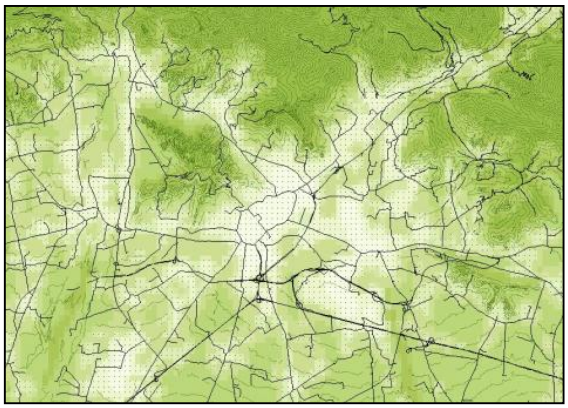

Figure 15: β 0,0025

From the second representation (β = 0.0075) vanished perception emerges. The naturalness is perceptible from a greater distance and becomes visual perception. In fact from the centre of the city of Bergamo the presence of hilly high natural valence zones like the park of the “Colli di Bergamo” is perceived. Observing the maps of naturalness for the whole province the difference between the northern zone of the province and the southern one emerges. The two tonalities of green evidence the two predominant morphologic characteristics of the territory: the mountains zones in the north are less accessible and populated; the plain zones more populated and used for agriculture. It is remarkable the correspondence of the higher naturalness zones with those which has higher density of contour line.

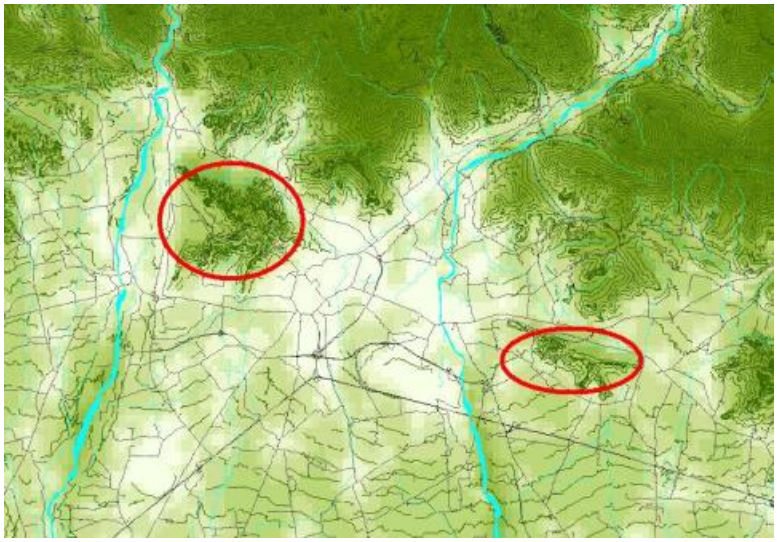

Figure 16: map with contour level

It is evident the negative influence of the urban continuous at the entrance of the valleys in correspondence of Bergamo and in the directions of Lecco and Milan.
It could be noticed that, besides the hilly area before the mountains band [pedemontana], the urbanised has developed along the valleys. In the mountain and plain zones the growth has followed a more punctual expansion; the two amble differs from the dimension that has had the phenomenon.
The overlapping of other layer on the maps has underlined ulterior correlation. As an example the visualisation of the road net it has concurred to characterise those with a greater landscaped interest.

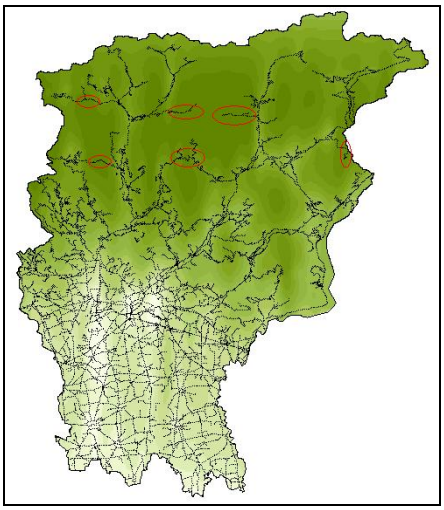

Figure 17: natural road

The rivers, in the northern part become preferential way of development (the valleys are always been more pleasant of the slope) in the plain zone become ecological corridors of remarkable interest: an obvious case is the case of the park of the Serio one.

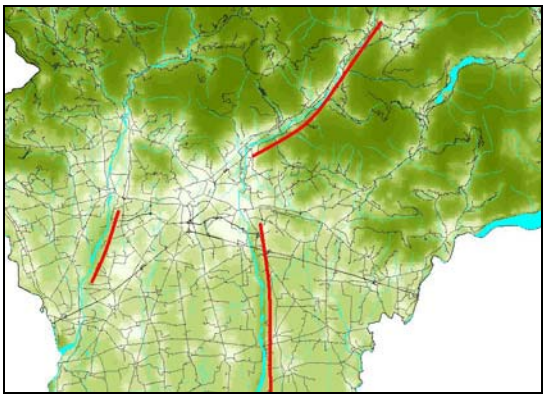

Figure 18: ecological corridors

3.2 THE POPULATION PRESSURE INDEX

As for the naturalness index, the value of β, is linked to the medium distance. It has been chosen, for the observations, to use the results correspondents to the values of β = 0,15 (d = 11,8 Km) and of β = 0,3 (d = 1.3Km). The observations are analogous for the two values considered. The difference are in the degree of damping of potential: in the first case it is smaller, in the second greater.

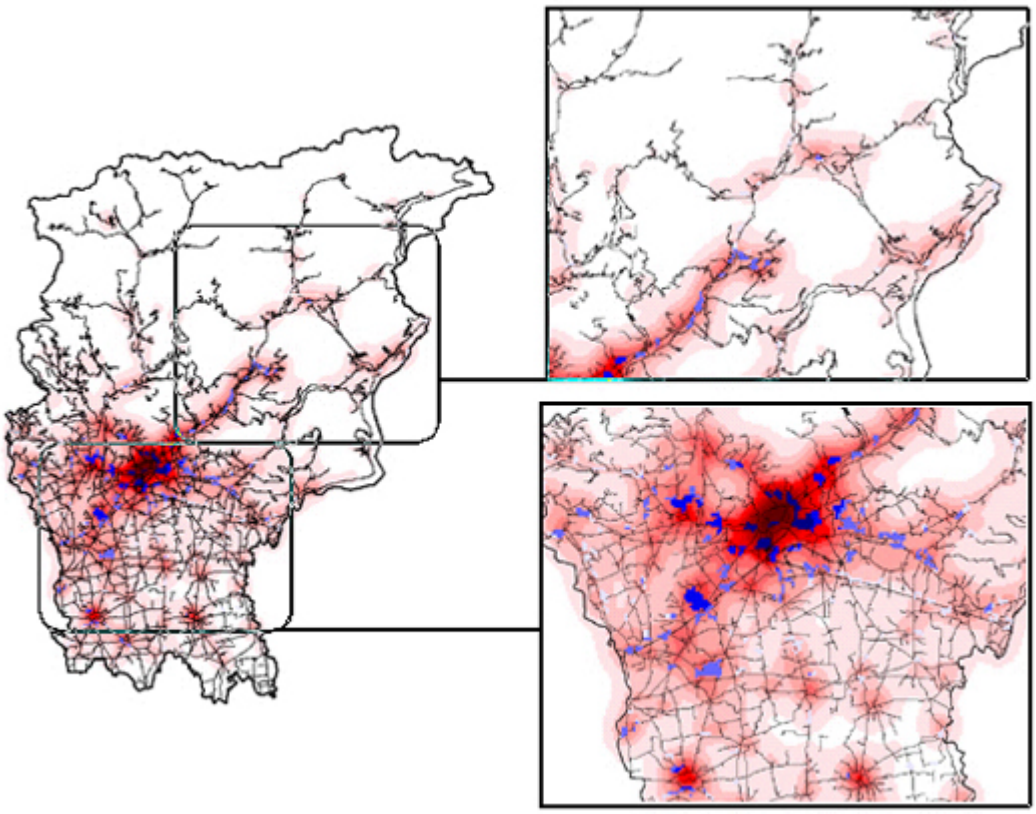

Figure 19: Overlap potential map with industrial areas β = 0.3

The naturalness of a territory often is put in danger from the presence of dangerous and polluting human activities, therefore it has been decided to estimate, beside the vulnerability, also the possible risks for population and nature deriving from the presence of such activities. In particular putting in relation the presence of roads, dangerous activities, population.

The first analysis is been the overlap of the map of potential with the layer representative of the road nets of the province of Bergamo. Regarding to the potential, it is evident the great difference between the northern part (hilly and mountains) and that southern part (plain) of the territory: the first is characterised by a lower index than the second zone.

In fact, the greater part of the population is concentrated in the low part of the province, where are more services. An analogous reasoning can be made for the road nets: thick in to south, more oadsteads in the north.

The cluster of the information allow to make some considerations about the relationship between the population pressure of the province and the risk deriving from the pollution of dangerous substances. It is observed that, in case of accident, the northern areas the potential has a lower value, that means a smaller involvement of the population, but also there are less road nets and in many places the valleys represent the only connection with the city. That means that the interruption of a road can provoke the isolation of entire municipality for more days.

The analysis is specular for the southern part of the province: here the road nets are numerous and allow alternative ways, but the high value of potential indicates an involvement of a high number of individuals.

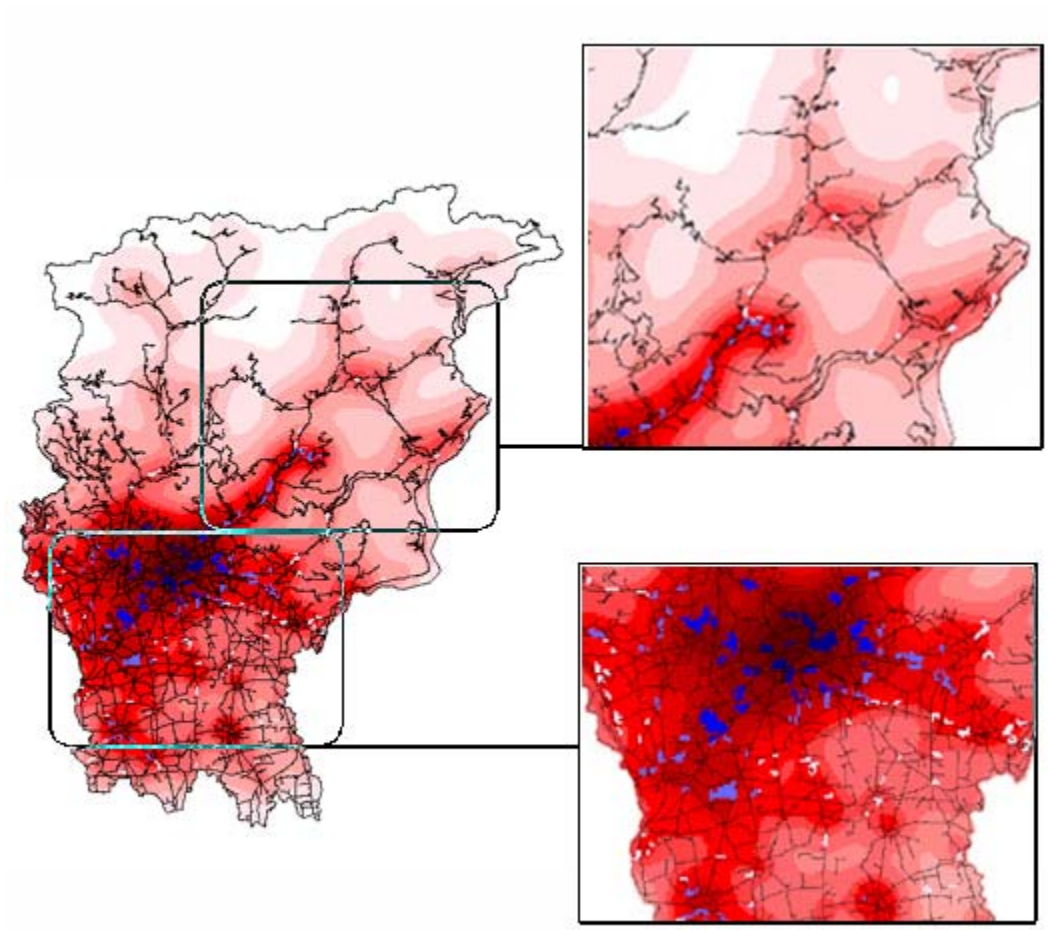

Figure 20: Overlapping of potential and industrial areas. β = 0.15

The second analysis regards the overlapping of the industrial areas on the map. It is clear that they are concentrated in prevalence in the south part of the province, in correspondence of the axis constituted from the A4 highway. At the same time it can be observed that in these areas the value the potential of the population is higher. The urban planning would have to consider also these aspects, but the obtained maps evidence the presence of industrial areas and residential population. In order to better comprise the relation between population pressure and industrial risk it has been “weighed" the industrial areas. In the previous figures the industrial areas have been represented with a colour scale. An area will potentially "dangerous" (in the image dark blue colour) much more it will be near zones whose potential is higher. It will be less "dangerous" (in the image blue colour) if far from the zones with higher potential. In figure 21 is represented a zoom on the city of Bergamo. It can be observed an high value of the potential in the centre and a strong industrial presence in the zones of the Interland.

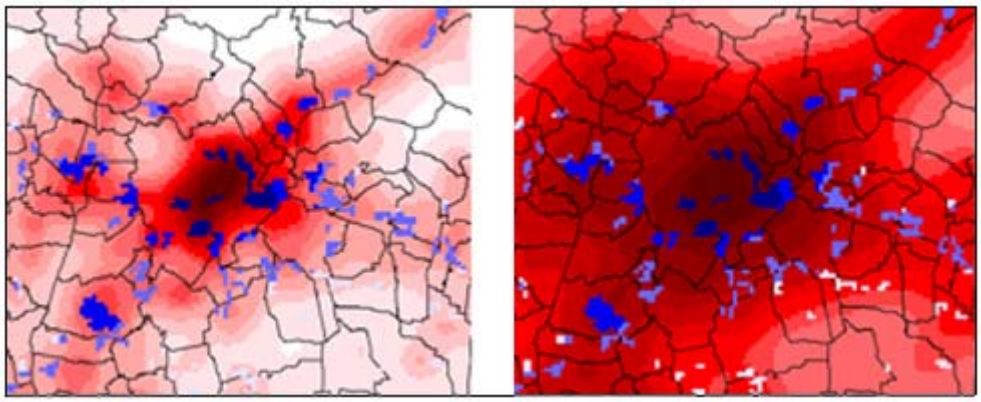

Figure 21: Bergamo β = 0.15(left) β = 0.3(right)

3.3 THE VULNERABILITY

Arranging the naturalness and population pressure indices a mapping of the vulnerability of the territory has been obtained. This map represent those zones where the population pressure risks to overwhelm the natural and landscaped valence of the territory.

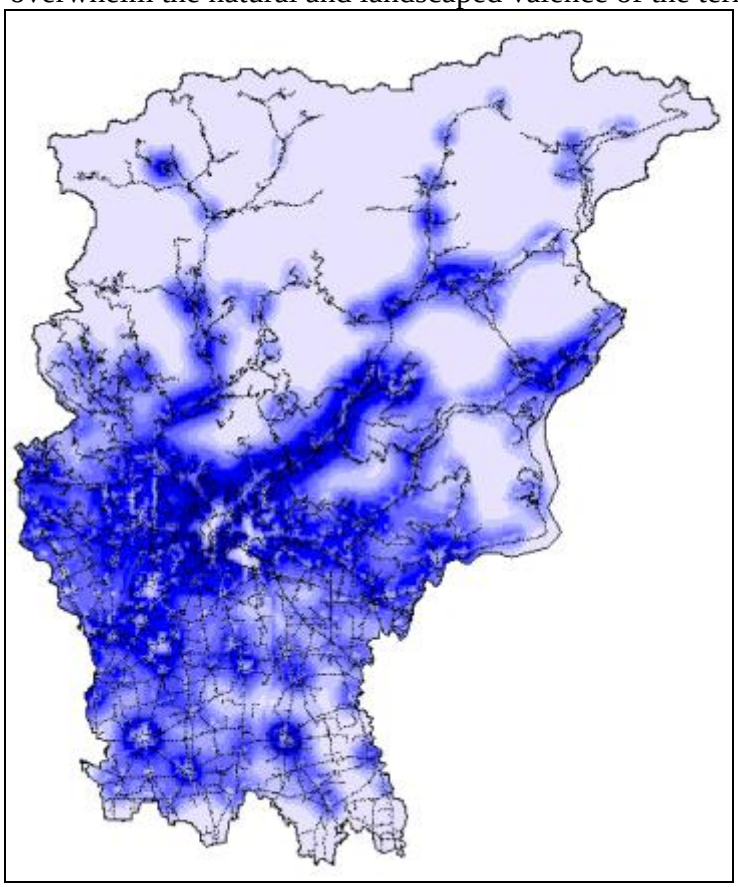

Figure 22: vulnerable areas

By the images can be noticed that the areas with higher vulnerability are the peripheral ones. They are the more susceptible zones to changes. They can develop in two directions: one to consolidate the urbanised character the other to contain it.
Analysing in detail the map some anomalous situations can be found, in particular in the northern part, where the urban continuous in the bottom of the valley risk definitively to separate the two mountainside creating a barrier to “ecological" corridors.

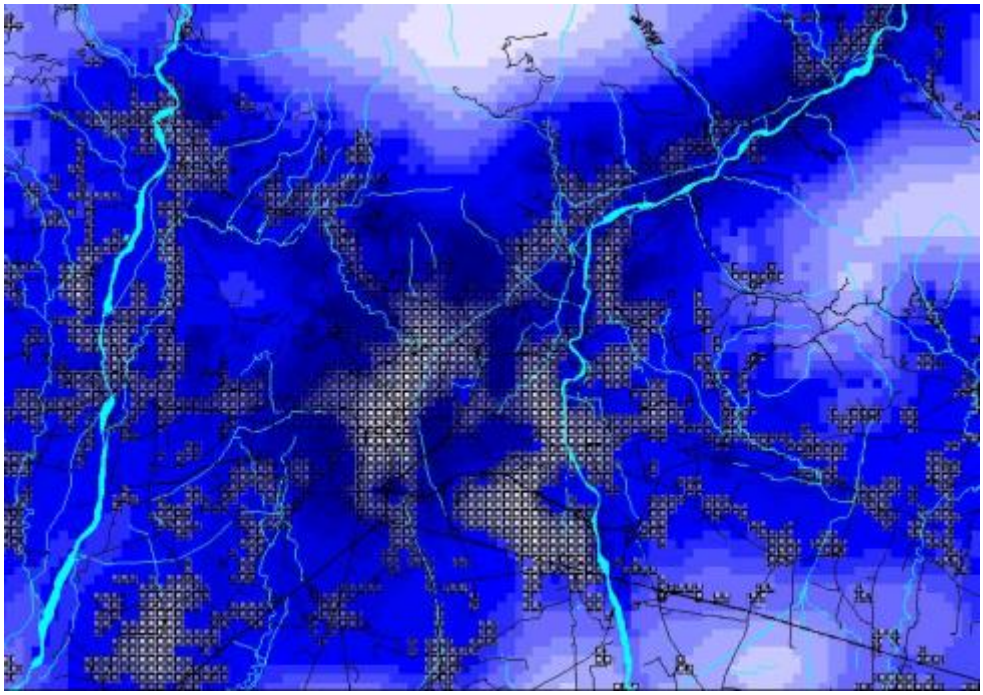

Figure 23: urban vulnerable areas

4 LIMITS OF THE ANALYSIS AND FUTURE DEVELOPMENTS

This study can be considered as an attempt to formalise the sensibility factor of territory useful for the strategic environmental analysis.
Such evaluation, in fact, dealing variables of qualitative type is often subject to the discretion of the experts. The main limit of this analysis consists is the choice of the criteria for the evaluation of the naturalness index. In fact, such index would have to consider beyond the kind of cover of the ground, also of the objective perception of naturalness of who inhabits and attends the territory.
The range of modelling tools today available, as the models of "soft-computing" that exceeding the mathematical equations, treats qualitative and fuzzy data, about lessical information and conceptual relations, seems to orient more the modelling to the intentional of the subjects.
Therefore another development of the research could be the application of these techniques for the location of the emergent and sharing elements of a determined natural landscape. For example, using textual statistics, it is possible to analyse an open questionnaire subordinate to a meaningful champion of population resident trying to pick

the elements that constitute the perception of naturalness in the imaginary collective. The weight of the cells that contain these elements therefore will be assigned in function of the importance (or frequency) estimated for every single element.
Moreover another limit of the proposed model consists in not to consider the morphology of the territory and of the perception of naturalness that derives from "visibility of some important elements. In this case, another development consists in modifying the proximity relations considering the quota of the ground.

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