Towards the acknowledgment of the urban-rural interface as a spatial category

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***Abstract*—** In recent decades we have been witnessing the end of the urban-rural dichotomy. It is no longer possible to talk only of urban planning and rural planning. A new spatial category has emerged – the urban-rural interface. In Portuguese law – Regulatory Decree no. 9/2009 of 29th May, which specifies the technical concepts for spatial and urban planning to be used in territorial management instruments - there is no reference to the urban-rural interface. The purpose of this work is to contribute towards recognition of the urban-rural interface as a spatial category. A model that allows for the mapping of urban-rural interfaces will be presented, followed by an analysis of the links between urban-rural interfaces and natural risk management. The model presented integrates not only social interaction but also biophysical characteristics. Urban-rural interfaces were found with different spatial signatures, requiring different strategies. The results indicate that urban occupation has not been planned to take the physical conditions of the land into account. Economic factors have become more important than biophysical conditions. There is a need to integrate social and biophysical characteristics into urban-rural interface management.

***Keywords*—** land management, natural risks, susceptibility, urban growth, urban-rural interface

I. Relevance of the Theme

An analysis of Portuguese land management plans reveals the prevalence of the urban-rural space dichotomy. However, more and more spaces can be observed that are neither rural nor urban. Taking into account the soil transformations that have taken place in the last few years, it is no longer possible to discuss only urban and rural planning. The urban-rural interface is a spatial category that requires spatial planning suited to its needs. This spatial category can be described as a patch in which a complex system of flows (of people, production, commodities, capital and information) occurs. S. Pickett and M. Cadenasso [18] use the term *patch dynamics* as an ecological concept that can integrate the various kinds and effects of heterogeneity on soil use.

The urban-rural interface is a changing area containing a high level of interaction between the artificial and the natural, producing a diversified territorial entity. As pointed out by M. Kasanko *et al.* [13], a more comprehensive understanding of urban land use dynamics, and in particular of the extent of urban sprawl or fragmented land use dynamics, is needed. They also stress the need to build new indicators capable of processing data related to urban forms and land use patterns. These phenomena are not easy to understand or to model. Although human-nature interactions have long been recognised, the complex patterns and processes involved in such interactions have not been properly characterised, let alone fully understood [15]. Nevertheless, whenever the interaction between artificial and natural areas does not function in a sustainable manner, there will be major disturbances and hazardous processes will occur.

As far as Portugal is concerned, T. Marques [17] states that the proliferation of built space is a major problem and control of this phenomenon should therefore be a priority in planning processes. Furthermore, the National Programme for Planning and Land Management [3] points out that insufficient attention paid to hazards in land occupation measures and territorial change is a serious problem in Portuguese land management.

In spite of all the changes occurring in our cities, no reference could be found to the urban-rural interface in Regulatory Decree no. 9/2009 of 29 May, which specifies the technical concepts for spatial and urban planning to be used in territorial management instruments under Portuguese law.

The problems and challenges facing Europe's urban areas are interrelated and inseparable from environmental issues [28].

II. Innovative Nature of the Theme

It is our intention to promote an integrated approach towards natural hazards and land use management. Operational urban models designed to analyse or predict the development of urban areas are still primitive in terms of their ability to represent ecological processes and the dynamics of urban ecosystems [1]. In addition, we propose to move from a focus on individual hazards to a multi-hazard analysis. Single hazards do not represent the true situation, which also involves social and economic factors in combination with biophysical factors.

For a long time social scientists focused on human interaction, whilst physical scientists focused on the biophysical characteristics of the territory. As a result of these human pressures on the environment, in the view of T. Toy and R. Hadley [22], active disturbance may take place which requires the effective management of unstable land, as well as an understanding of the disturbance processes through good, accurate planning and best practice measures that can ensure evolution towards a post-disturbance period [21]. Society will also have to find solutions to adjust, incorporate and mitigate the consequences of accidents triggered by biophysical factors. These focuses are especially relevant to the urban-rural interface, as a complex path in highly active transformations in which disturbance processes are particularly common. Hazard-prone areas tend to increase in proportion to imbalances in the ecosystem, boosted by gaps in regulation and delays in the implementation of mitigation measures.

In this work a holistic approach to the problem is proposed. The central assumption of this approach is that urban sprawl puts too much pressure on the environment, causing disturbance and thereby undermining the normal functioning of the territorial system. In order to avoid and mitigate excessive pressure on the environment, it is important to identify the driving forces and actions within the urban-rural interface.

The purpose of the work is to answer the following questions: How should the urban-rural interface be represented? Has urban occupation been planned to deal with environmental disturbance? How specific should risk management of the urban-rural interface be?

According to P. Korcelli *et al* [14] the existing typologies of urban-rural regions can be divided into three categories, based on different criteria that refer to alternative concepts of region and urban–rural relations. The first category is based on the functional profile, with differences depending on the range of functions in each space; the second is related to the level of urbanisation and the morphology of the settlement; and the third focuses on the interdependence and interaction between the urban, periurban, and rural zones of urban-rural regions. The characterisation of the urban-rural interface will be based on the morphology of the settlement, which will be identified using variables such as administrative boundaries, statistical data, land use and land management plans.

The next phase focuses on the links between the urban-rural interface and natural hazards. Urban-rural interface areas and natural susceptibility cartography will be compared, in order to identify links between urban settlements and risk management.

III. Methodology

Building indicators, as accurate representations of environmental or social states or trends easily understood by their target audiences, are considered a methodological challenge by Tom Bauler *et al* [2].

Most of the work presented here was performed using the ArcGis – ArcInfo version 9.2 (ESRI®). The first phase focuses on the urbanisation gradient pattern, based on work carried out by M. Luck and J. Wu [24], adapted to the purposes of our work. Three buffers were defined, whose centroid was the city centre, as defined by the local authorities. The buffers were 2 kms equidistant. The land use data was the Corine Land Cover (CLC) [25], started by the European Commission in 1985, on a scale of 1: 100,000. The CLC90 and CLC2006 versions were used in order to evaluate the evolution of the landscape. The indicators used were: patch density (the number of patches of per ha); the patch size coefficient of variation (the patch size standard deviation divided by the mean patch size, a measure of relative variability); the urban percentage of landscape (the proportion of the total area occupied by urban land use); the largest urban patch index (the proportion of total area occupied by the largest patch of urban area).

Secondly, land use changes were analysed on the basis of overlay mapping of cartography dating from 2005 published by the Portuguese Geographic Institute on a scale of 1:10,000, and cartography dating from 1985 published by the Municipality of Coimbra on a scale of 1:5,000. In this analysis the Urban Consolidated Zone (UCZ) boundaries defined in the Urban Master Plan [4] were taken into account. In the following phase, experimental units were defined, based on a set of indicators. Firstly, a 500 meter buffer was defined around the city border; secondly, the buffer and statistical subsections were cross referenced. The definition of the case studies also took the UCZ into account. On the basis of these indicators, three case studies were defined.

N. Gallent and J. Anderson [7] define the urban-rural fringe as a unique landscape comprising a particular mix of land uses and activities. The diversity of land use was evaluated using the Shannon Diversity Index (SHDI). According to M. Eker and H. Coban [6], the SHDI is a popular measure of diversity in community ecology. SHDI = 0 when the landscape contains only 1 patch (no diversity). SHDI increases as the number of different patch types increases, or the proportional distribution of area among patch types becomes more equitable. In addition, we compared the differences between land use and what had been planned by the local authorities. In the next phase, we constructed an urbanisation rate based on a set of urban rural interface indicators such as the building cost index, construction period for buildings, dwelling density, dwellings per building, housing vacancy percentage, inhabitants per dwelling, number of floors per building, and percentage of urban area. Statistical subsections were used as the unit of analysis. A factor analysis was applied to these normalised variables, based on Principal Components Analysis (PCA).Three factors were retained which explain 70% of the variance, with a Kaiser-Meyer-Olkin measure of sampling adequacy (KMO) of 0.6, and all communalities above 0.6. The first factor explains 32.3% and is related to the building cost index (€/sq). The second factor explains 20.3% and is related to the construction period of buildings. The third factor explains 17% and is related to dwelling density. The data was interpreted so that the higher the building cost index, the higher the rate of urbanisation would be. With regard to the second factor, it was considered that the older the buildings were, the higher the rate of urbanisation would be. An area with buildings constructed in the 1970s is synonymous with a consolidated urban area. Finally, in relation to the third factor it was assumed that high dwelling density will contribute to a high rate of urbanisation.

In addition, areas with higher rates of urbanisation and those with higher levels of natural susceptibility were compared. The natural hazards which affect Coimbra most frequently and are analysed in the land management plans were taken into account: forest fires, floods and landslides. The susceptibility cartography used in this work was produced under the Master Plan Revision of Coimbra on a scale of 1/25,000 [20].

The linking of these methods into a coherent system results in a tool that allows the relationship between the urban-rural interface and the biophysical characteristics to be analysed.

IV. Study Area

In the first phase our study area was the city of Coimbra, following the boundaries set by the local authorities. Coimbra is a municipality located in Central Region of Portugal (Figure 1).

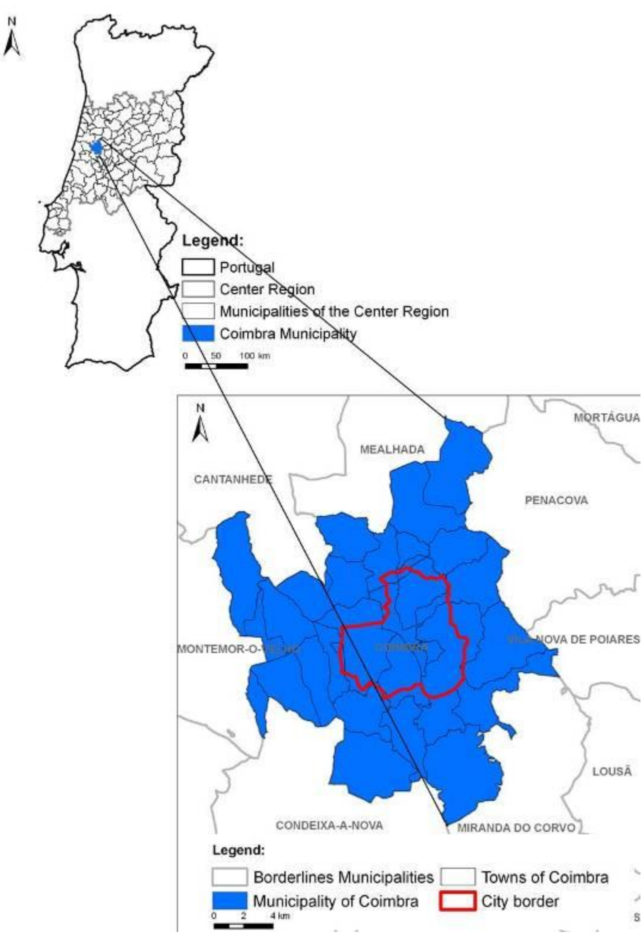

Fig. 1: Geographic location

According to the General Population Census [11], as well as the latest estimates from 2008 [12], two-thirds of the residents in Coimbra live in the city, a fact which is even more significant given that the city represents only 16% of the total area of the municipality.

The Urban Master Plan [4] only considered 25% of the city to be consolidated. According to the authors, this classification was defined on the basis of population density and number of households.

Only a few works deal with the dynamics of small urban areas [23]. In spite of being a small urban area, the city of Coimbra possesses a fairly heterogeneous urban space. Figure 2 shows the location of the rings used to study the urbanisation gradient pattern.

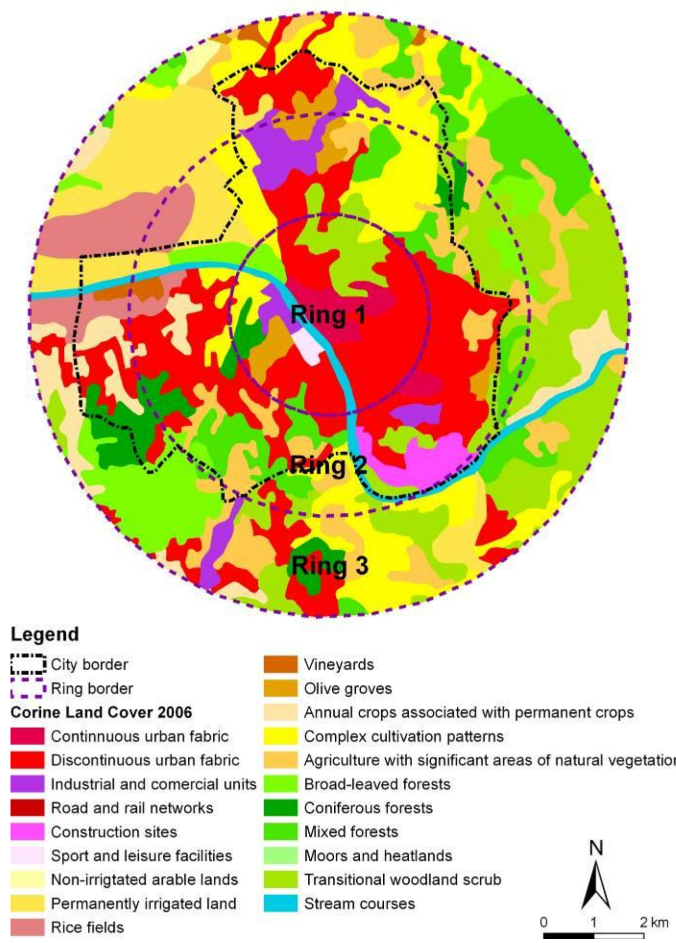

Fig. 2: Location of the rings and Corine Land Cover 2006 [25]

The patch density in Ring 1 is considerably lower than in Ring 3, indicating a higher level of fragmentation in the lower level. Through data analysis (Table 1), we concluded that it was possible to identify a lot of changes within a radius of 6 km. Concerning the urban mean patch density size in 2006, in Ring 1 it is 129 ha, in Ring 2, 151 ha (higher than in Ring 1) and in Ring 3, 51 (almost a third of the value of Ring 2).

Comparing the 1990s data with more recent data, it may be concluded that Ring 1 is the most stable area in which fewer changes were registered, and Ring 2 is the most unstable area.

Areas	Patch density (n/ha)		Patch size coefficient of variation		Largest urban patch index		Urban mean patch size (ha)		Urban area percentage	
	1990	2006	1990	2006	1990	2006	1990	2006	1990	2006
Ring 1	0,33	0,28	1,2	1,2	23	27	119	129	48	61
Ring 2	0,9	0,9	0,9	1,3	7	12	114	151	21	36
Ring 3	1,2	1,2	1,5	1,4	1	3	24	53	5	11

Table 1: Indicators of urbanization gradient pattern

On the basis of the urbanisation gradient pattern indicators, it is possible to identify different land use types and their relation to the city centre. However, with regard to changes in landscape structure, too many questions remain unanswered. The interpretation of such a landscape pattern analysis must consider the possible effects of scale [24].

One of the questions that emerges is how the city is growing. An analysis of the area constructed between 1985 and 2005 shows that most of the constructed area from this period lies outside the Urban Consolidated Zone (UCZ) boundaries (figure 3).

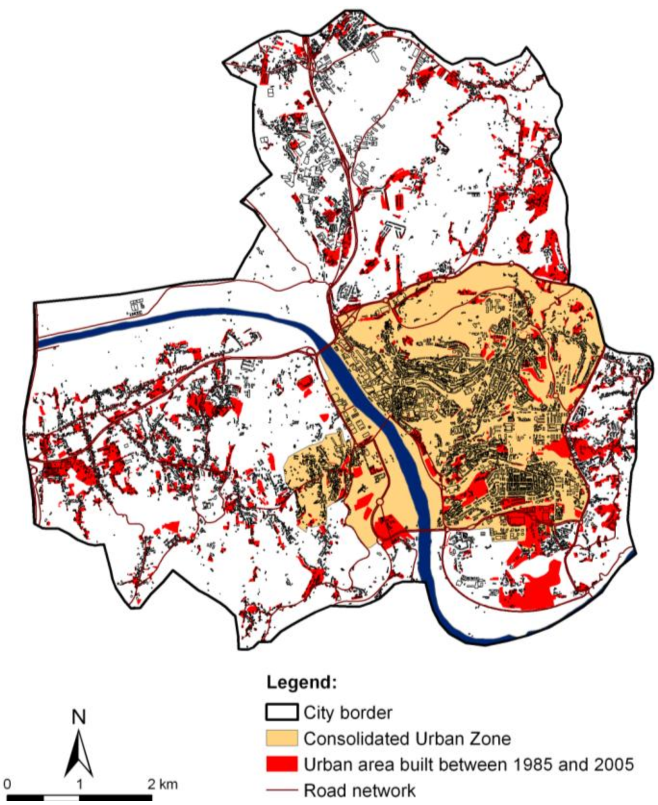

Fig. 3: Urban area built between 1985 and 2005

Urban growth in the northern area is different from the urban growth in the southern area. In the northern zone, urban areas developed along main roads, whereas in the southern area urban growth can be viewed as the consequence of sprawl and the natural growth of the historical city.

In addition to these two areas, in the west of the UCZ there are urban areas that seem disconnected from the rest of the city, some of which can be considered leapfrog development. Nevertheless, in most cases in the western zone urban growth emerged from older settlements. In the northern area there is a mixture of social housing and industry as a result of the land management policy implemented by the local authorities. According to the land management plans, industry has been developed in the northern area since the 1940s. Therefore, industries and warehouses with a strong, negative visual impact now characterise the landscape. These areas are unattractive places to live in with low land value, which may have contributed to the local authorities' decision to build social housing there.

According to A. Tavares and L. Cunha [20], urban expansion in Coimbra is associated with construction in areas with lower geotechnical suitability, characterised by greater instability in relation to landmass movements and an increase in the volume of soil embankments and underground construction. This has direct or indirect implications on water change through soil sealing, the trimming of natural drainage channels and the occupation of the flood plain with buildings. It is our intention to confirm whether this is happening in the urban-rural interface.

Three case studies were defined (figure 4): the North: Case A; the East: Case B, and the West: Case C. Case studies are important for gaining an understanding of the complex relationships between the social and natural systems which landscape and land resources change [24].

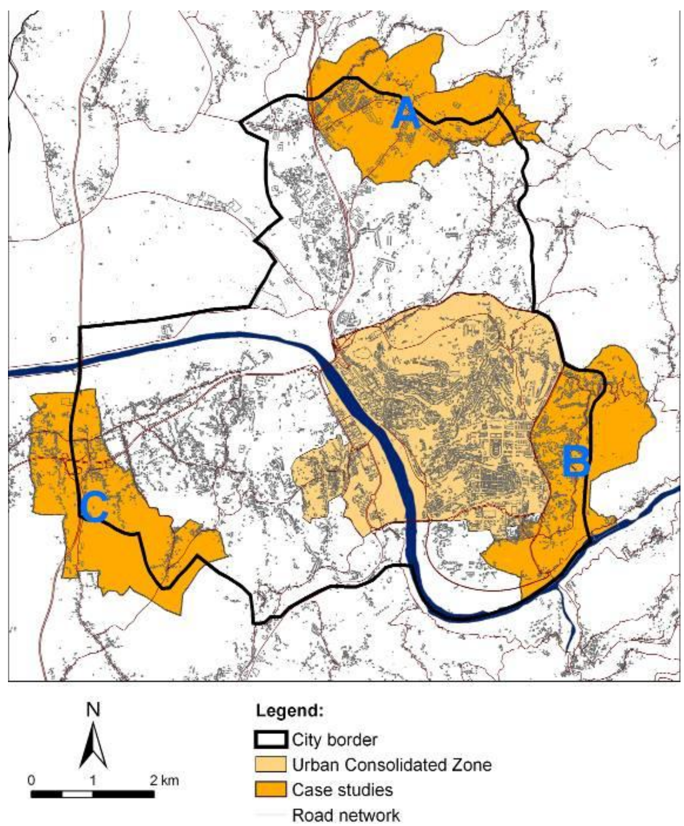

Fig. 4: Selected case studies areas

An analysis of Table 2 shows that the case studies have similar areas, the average being 538 ha.

Case	Area (ha)	Population density (inhabitants per ha)	Dwelling units per building
A	540	9,5	1,9
B	511	22,7	2,6
C	563	6,9	1,2

Table 2: Population density and dwelling units per building

Indicators such as population density present different values. With regard to population density, the figure for Case A is double that of the other two cases. Case B is the most heterogeneous area in terms of population density and dwelling units per building. In Case B the standard deviation is much higher than in the other cases. Nevertheless, the population density presented by the three case studies is much lower than the 82 inhabitants per hectare shown in the UCZ.
With regard to population density, and in accordance with M. Lobo [16], Cases A and C may be classified as para-urban areas, and Case B as a low density urban area. The experimental units were also characterised by taking into account land use and Master Plan Zoning.

IV.1. The experimental units – land use and land management

The experimental units present very similar SHDI values; the average value is 1.6, indicating a high degree of diversity of land use (Table 3). Although the SHDI is high, it is possible to identify different features in areas that are inside the city border and those outside (Figure 5). In Case A it is possible to observe a consolidated settlement inside the urban perimeter, whereas once the city bounder is crossed, it is possible to see what N. Gallent and J. Andersson [7] would call a limited amount of housing consisting of a fragmented ribbon development along the road network. Moreover, in Case B, most of the urban area is inside the city border.
In spite of the urban-rural interface being defined as a mix of land uses, in the case studies it is still possible to identify patterns and relationships with the city.

Case study	SHDI
Case A	1,52
Case B	1,63
Case C	1,57

Table 3: SHDI of the cases study

An analysis of the Master Plan zoning (Figure 6) confirms that the areas within the case studies have been planned as transition areas within the urban and rural areas. In Cases A and C, there are industrial settlement areas. In Case B, the city border defines most of the residential zone.

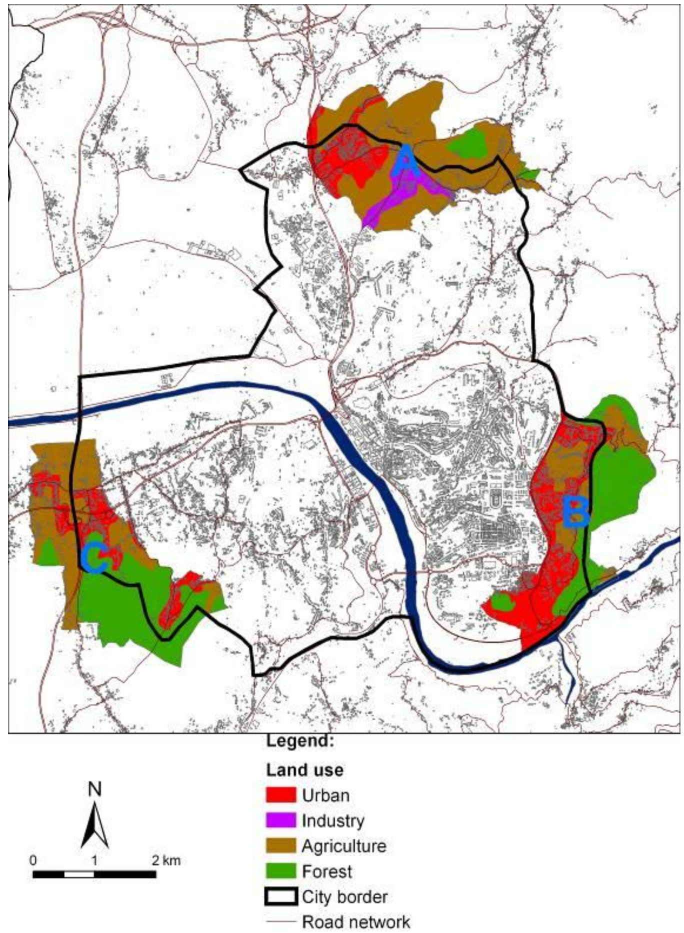

Fig. 5: Land use

By comparing land use and Master Plan zoning (Table 4), it can be concluded that the local authorities are seeking to promote a greater mixture of land use than actually exists. The area in Case A is dominated by agriculture (66%); however, the local authorities planned that only 10% of the area should be occupied by agriculture.

Designation	Case A		Case B		Case C	
	Land use (%)	Master Plan (%)	Land use (%)	Master Plan (%)	Land use (%)	Master Plan (%)
Agriculture	66	9,3	20	2	36	18
Forest	5	31,4	36	22	45	34
Green urban area	0	0	0	23	0	0
Industry	10	17,4	0	0	0	9
River	0	0	2	2	0	0
Urban	19	35,1	42	51	19	39
Urbanisation retaining	-	6,8	-	0	-	0

Table 4: Land use and Master Plan Zoning

Although, Cases A and C show the same percentage of area occupied by urban soil, it is possible to identify different characteristics in Figure 5. The urban soil in Case C is much more fragmented. Case A has only one urban patch, whereas Case C has more than one and the patches are smaller.

The data analysed in Table 4 does not take added surface into account; it is not a three-dimensional analysis. In Case B, in spite of the percentage of urbanised area - 42%, lower than the 51% planned – in some plots it can be seen that the construction index has been exceeded, meaning that there is a greater built area than planned.

To sum up, the zoning criteria are based on density morphology and the urban-rural dichotomy.

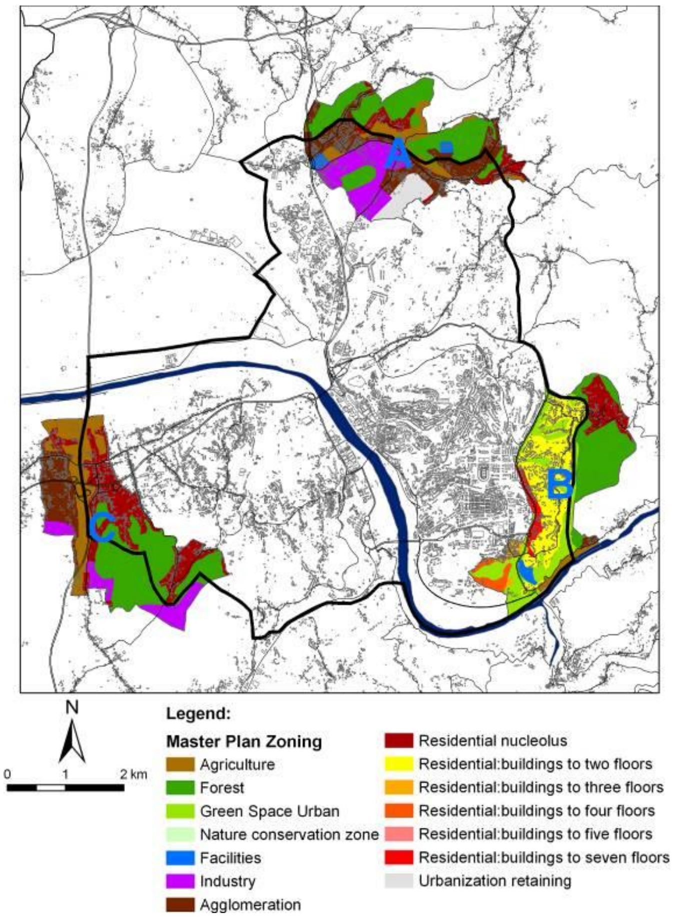

Fig. 6: Master Plan Zoning

V. The urban-rural interface and natural risk management

Concerning the rate of urbanisation, Case A is the most heterogeneous. The spatial relationship with the city border is important but it is not a decisive trend in terms of urban morphology. Case C, in spite of its relationship with the city border, presents a very low rate of urbanisation. Proximity to the UCZ is, however, quite relevant in Case B.

An analysis of Figure 7 shows that the three case studies are quite different. Case B is an urban-rural interface, in which it is possible to identify areas which, due to proximity to the UCZ, are being absorbed by urban environment. On the other hand, Case A is an urban-rural interface which, although furthest from the UCZ, is subject to urban pressures.

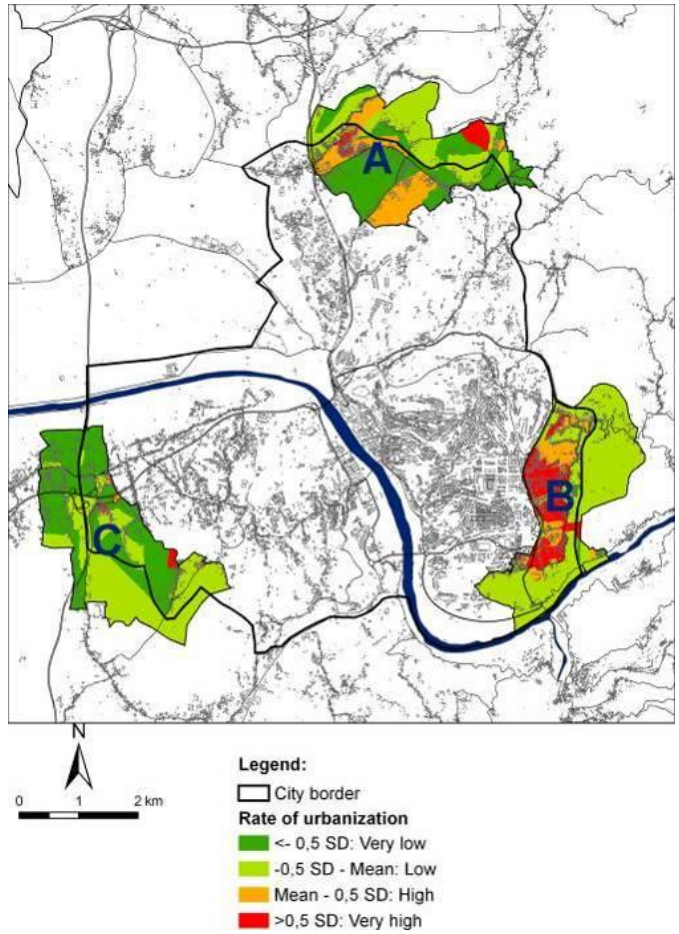

Fig. 7: Rate of urbanisation

Regarding urban morphology, proximity to urban consolidated areas is more important than proximity to the city border. Among all the variables included in the model, the first factor explains 32.3% and is related to the building cost index (€/sq.). Economic variables play a very important role in the urban-rural interface, which can be problematic. The accelerated pressure for profit-orientated use of open space means the potential of derelict land, devalued land and fragmented left-over land is not considered [27].

In the following phase, it is our intention to confirm whether the more densely populated urban rural fringes make the best residential areas, in terms of natural susceptibility, defined as the probability of the occurrence of a particular spatial phenomenon in a given area based on land conditioning factors, regardless of the period of recurrence [9].

An analysis of Figure 8 raises the question: how can areas with higher rates of urbanisation also have higher levels of susceptibility?

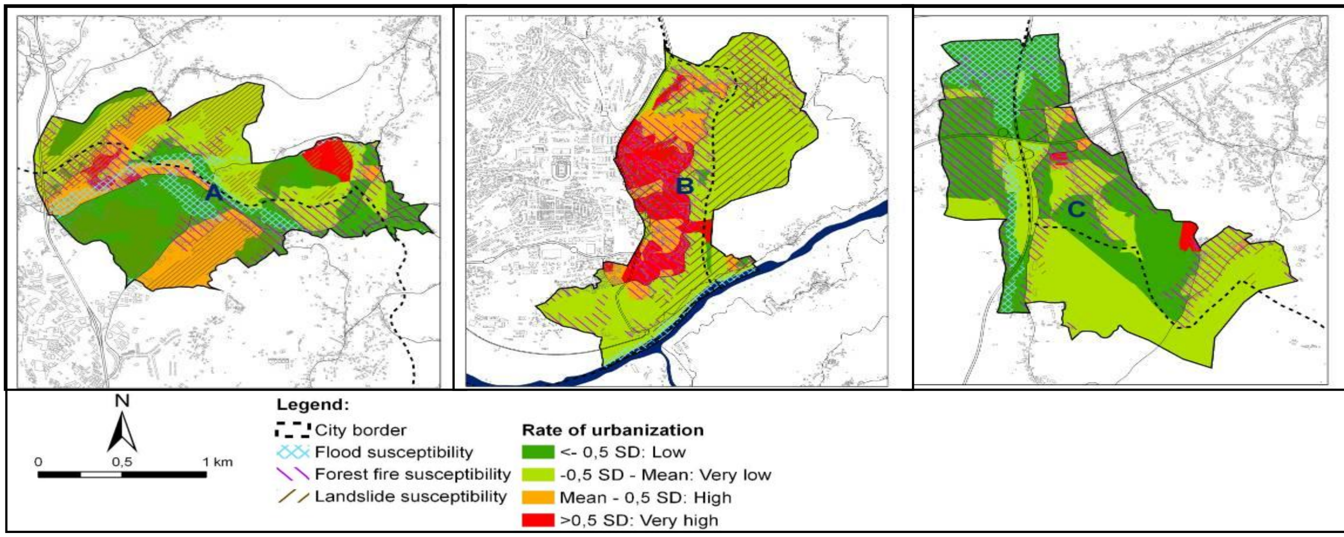

Fig. 8: Rate of urbanization and natural susceptibilities

Case A, one of the areas with a higher rate of urbanisation, presents a high level of flood, as well as landslide, susceptibility. As it is a densely occupied area, although only 11% of the area presents a high level of flood susceptibility (Table 5), there have been several problems reported in recent decades.

In Case B, 60 ha of its area presents a high rate of urbanisation, as well as a high level of landslide and forest fire susceptibility. From the data analysis it is possible to conclude that Case B is the case study with the highest percentage of area presenting high levels of susceptibility; meaning that the densely occupied areas are also the most dangerous.

Case C is different from the other cases studies, presenting the area with the least high levels of susceptibility (Table 5). Moreover, in Case C two different types of hazards do not coexist in the same area. Yet despite this, Case C is the case study with the lowest rate of urbanisation.

Case study	Susceptibility (%/ha)		
	Forest Fire	Flood	Landslide
Case A	33	44	11
Case B	48	47	4
Case C	39	1	14

Table 5: Percentage of area with high level of susceptibility

One of the variables included in the assessment of the urbanisation rate was the cost of housing, Case C being the area where this is lowest. Although its physical characteristics are more suitable for urbanisation than the other cases, Case C is the area with the lowest population density.

VI. Conclusion

The definition and location of the urban-rural interface is more complex than the mixture of land uses, and it remains an area that is neither urban nor rural. Firstly, the urban-rural interface was analysed on the basis of an urbanisation gradient pattern. The results identified different landscape patterns and relationships to the city centre. However, this methodology was assumed to be inadequate to detect changes in landscape structure. In the following phase, a tool was formulated that integrates a social and a biophysical approach. The unit of analysis was no longer the entire city, but three case studies, defined on the basis of a set of variables, with an average area of 538ha.

The three case studies have different spatial signatures and even within the area covered by each one, it is possible to observe different landscapes. In most of the situations, proximity to the UZC emerges as more important than proximity to the city border. In the analysis of the three case studies, Case B has the highest urbanisation rate. Nevertheless, this is not linear, otherwise Case A would be more similar to Case C. The previous analysis of the urbanisation gradient pattern is not without its uses, since it provides an overview of the entire city and its fringes. Thus, scale plays an important role.

Case B is both the most urbanised area and the case study with the highest levels of susceptibility. This fact indicates that urban occupation has not been planned to take the physical conditions of the land into account. By comparing land use, the Master Plan zoning and susceptibility cartography, it was concluded that there are cases where buildings were constructed in areas with high levels of hazard with the consent of the local authorities. Even more worrying is the fact that the urban expansion in the case studies occurring between 1985 and 2005 took place in areas with a high level of susceptibility. During this period, the urban area of Case B and Case C increased by 23% and 21% respectively and we are therefore talking about a problem in progress. The role of the local authorities in terms of urban planning, land management policies and landscape policies is decisive [26].

Nevertheless, solving this problem is not the exclusive responsibility of the land management authorities; it also requires the involvement of the local public and it is therefore important to provide awareness sessions. The model presented allows priorities to be defined on the basis of the social and economic characteristics of the territory, as well as the biophysical characteristics.

Risk management in the urban-rural interface must be different from that in other areas: due to the mixture of land uses and functions, the interventions are more complex. With regard to this issue, one of the main topics is scale; in Portugal, the scale used in rural areas is a broader than the one used in the urban areas. The urban-rural interface needs fine-scale information, in some cases even finer than that which is used in urban areas, in order to assess how urban and rural uses are linked. Unfortunately, most of the current discussions concerning urbanisation and sprawl in outer urban areas are limited by the use of coarse-scale data aggregated at state or county level [10]. In this work, the assessment was carried out on the basis of the sub-statistical section unit (the smallest unit adopted by the Portuguese Statistics Institute), but this does not provide an answer to all questions, such as the function of each building. However, solutions such as a detailed gradient analysis are expensive, require a lot of time and effort and, in most cases, cannot be applied to other areas. Furthermore, factorial analysis is quite useful as it identifies the redundant variables and the most important characteristics of the different urban-rural interfaces.

As we were able to confirm, the urban-rural interface is a spatial unit that demands methodologies appropriate to its particular circumstances. Recognition of the urban-rural interface as a spatial unit can reduce sprawl and prevent urban growth in areas with a high level of susceptibility. It is not feasible to apply construction indexes as high as those in urban areas, nor as low as those in rural areas, to these areas.

In urban-rural areas, given the complexity of the patterns and the mixture of different types of land use, risk management becomes difficult for several reasons. Firstly, the hazard assessment models are often dysfunctional, due to lack of data and rapid changes to systems. Secondly, significant changes in landowners, landholders and public land-users leads to difficulty in recognition by the actors involved. Thirdly, there are the changes in knowledge and in best practices to reduce hazards and risk mitigation by the land-use professionals or by the community and finally, the fact that regulation of risk management involves a time lag and a historical sequence of dangerous processes for new formulation.

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