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Mapping favorability for residential development. Case study: Bucharest Metropolitan Area

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Abstract

The identification of areas with favorability and restrictiveness in the development of residential surfaces represent and useful instrument for local and regional planning, local authorities and population, as it can help avoiding emplacement conflicts at metropolitan or local level. The analysis was based on a series of attributes extracted from topographical maps (1977-1978) and aerial images (2005 and 2008), and considered to be of major impact upon residential surfaces, such as: public services, incompatible functions, road infrastructure, existent residential surfaces, forest, and water surfaces and soils characteristics. For each attribute a score from 1 to 5 was given based on the four orthogonal neighbors method for each cell of two grids: one with a cell size of 500×500 meters (for the metropolitan level) and the other with a cell size of 100×100 meters (local level). Scores have been integrated and the results were mapped, expressing the favorability for developing residential surfaces, with better results at local level, than at metropolitan, where the large surfaces requires a reconsideration of the cell size and an improvement of data availability. This type of analysis can determine the identification of optimal areas for the development of the residential surfaces and the avoidance of environmental sensitive areas.

Keywords: Land use conflicts; environmental attributes; grid; housing; Bucharest Metropolitan Area; Romania

1. Introduction

Residential surfaces represent a main component in the structure of human settlements (either rural or urban), especially in the case of metropolitan areas, spaces characterized by a strong dynamic [1]. The main function of residential surfaces – housing, represents the result of spatial and temporal interaction of social, economical, historical factors and their relation with the territory [2]. Metropolitan areas represent

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geographical spaces that frequently experiences dynamic patterns of land-use change [3] as housing the growing population has resulted in the conversion of open land into urban areas [4] and rural residential areas beyond the urban fringe [5], especially in post-communist countries as a result of the misinterpretation of the market economy [6]. The relationships between the geographical scale of land uses and the socio-spatial scales resulted from the process of capitalist accumulation is directly expressed in metropolitan areas [7], characterized by a high heterogeneity and dynamic. Most environmental conflicts stem from a discrepancy between a certain land use and its neighbors [8].

The implicit assumption behind most studies focusing on environmental justice [9] is that conflicts arise in response to the attempts of some authorities or entrepreneurs to locate locally unwanted land uses [10] near sensitive land uses (most often residential neighborhoods) considering environmental conflicts are part of the metropolitan development processes [11] and therefore sustaining that they do not occur at random in both time and space [12] within the metropolitan area.

This analysis of the residential surfaces distribution in relation with the different factors is quite useful, but not sufficient [13], mainly because these factors interact at a spatial level. That is why we tried to create a favorability map for the development of the residential spaces, especially as between the residential and other types of land covers land use conflicts frequently appear [14], as a result of the different groups and individuals to achieve their goals [15].

The delimitation of areas with environmental favorability and restrictiveness is a useful tool both for the planners [16] (at a regional and local level), for the local authorities and for the population in the intent to avoid the issuance of emplacement problems [9] at a macro-territorial scale (metropolitan scale or at the scale of major urban ecosystems) or at a micro-territorial scale (with a remote projection at the level of some urban and rural tissues) [17].

The suitability evaluation of residential land must be an important tool of the general land use planning [18], as it lays a scientific foundation for a reasonable land layout [19], and can avoid the proximity of residential spaces to a series of major degradation sources (active industrial objectives, waste landfills, catching diseases hospitals), total or partial destruction of green spaces or oil patch development, especially in the peripheral areas. Such an instrument will allow multiple actors collaboratively use GIS and produce policy maps in a participatory way [20], but in practice, often the maps under study are source of conflict [21]. The method starts from a starting point in time as the baseline for advice and develops a set of criteria that specify whether land is suitable for urbanization [20], before applying the criteria to finalize the map, the revision and finalization.

The uncontrolled development of residential surfaces determines an increasing pressure of urban areas upon resources and especially upon ecosystems services [22]. This process leads to a reduction of natural spaces, removing large surfaces from the agricultural use, habitat fragmentation [23, 24] and the spatial expansion of areas affected by problems specific to human environments [25, 26, 27].

The main objective of the paper is to develop a methodology for integrating the environmental and economical land uses influencing the development of residential surfaces. The results of the method are to be expressed in a graphical form, presenting the favorability of developing residential surfaces in certain areas, according to the existing land uses.

2. Methodology

2.1. Study Area

The Bucharest Metropolitan Area is situated in southern Romania, and contains 98 Local Administrative Units of level 2 (LAU 2), from five different counties [28], having a total surface of approximately 5080 km^2.

Being situated in the central part of the Romanian plain, the substratum is characterized by the presence of loess and alluvial deposits, the slopes are reduced, and the climate is temperate continental (with average annual temperatures of 10-11.5^{0}C, and precipitations of 550-650 mm) [1].

The natural land covers, consisting mainly of deciduous forests and natural grasslands, with surfaces of water bodies, have been replaced in centuries of human pressure [22] by large agricultural surfaces (above 75% of the total surface) and human settlements.

The residential population of the metropolitan area consists of 566 700 inhabitants, at which are added the approximately 2 million inhabitants of Bucharest [17]. The metropolitan area has an average density of 111.5 inhabitants / km^2 [29], and the economical profile is dominated by the secondary and tertiary activities concentrated in Bucharest (21.7% of the national GDP).

In the Bucharest Metropolitan Area, 13 of the 98 LAU 2 are cities (excluding Bucharest), representing 14.76% of the metropolitan surface and concentrating 31.44% of the total population [2].

Residential surfaces occupy a total of 193 km^2, increasing with 39.41% from 1970 to 2005 [2] and being dominated by the type of compact single households (representing more than 55% of the total metropolitan), whereas collective residential surfaces represent just 2.3% - a percent in continuous increase due to the development of numerous new privately owned residential projects.

2.2. Background data

In the analysis of the spatial and temporal dynamics of the residential surfaces and other types of land-covers we used GIS techniques, based on the existing cartographic materials: 92 topographical maps with a scale of 1:25 000 realized in 1977-1978 after the topographical surveys from the previous years; and also the aerial images realized in 2005 and 2008 (www.ancpi.ro, accessed at 20.10.2011) which cover the entire Bucharest Metropolitan Area.

These materials have been geo-referenced and digitized using the program ArcGIS 9.3 – ESRI information regarding residential surfaces, forestry and aquatic surfaces, industrial activities and services, traffic roads network etc were extracted from them and transformed into spatial shape files.

Additional information were extracted from the Corine Land Cover database of Romania, available for the years 1990, 2000 and 2006 as a database with a minimum represented unit of 25 hectares, the patches being delimited by polygons labeled with the main type of land use [30].

During the extraction process we also realized a delimitation of residential surfaces existing in the Metropolitan Area of the Bucharest Municipality in 4 main types, slightly differentiable on the satellite images and aerial photographs and on the basis of their characteristics in the field, subsequently: (1) *collective residential* (characterized by blocks of small and average height, P+1, P+2, found mainly in urbanized areas), (2) *pavilion residential* (single households of P, and P+1, found in compact neighborhoods alongside commercial and services functions), (3) *isolated residential* (determined by groups of houses under 5 units, separated by open lands or other surfaces from the main residential areas of the locality) and (4) *residential complex* (developed after 1990 and especially between 2000 and 2007 by private developers).

2.3. Methods

The information concerning residential surfaces included both surface, spatial location and their typology. Therefore, the 4 identified typologies have been differentiated based on the topographical maps and aerial images.

As we considered a grid network best suited for analyzing spatial elements [31], two grids have been built up: one at a metropolitan level, with a cell dimension of 500 m (and thus a total surface of 25 ha) and the other for the 12 case studies (Fig. 1) from representative localities, with a cell size of 100 x 100 meters (and a surface 1 ha). The grids have started from a point chosen randomly in the north-western part. In every grid scores has been given (as in the table 1), in a different column for each of the seven attributes that have been taken into account, on the basis of the method "*four orthogonal neighbors*" [32] starting from the cell where the respective attribute could be found.

In the analysis we started from seven main attributes extracted from the topographical maps and aerial images: s*ervices* (represented by the hospital/dispensaries, schools, churches, city halls), *incompatible functions* (whether it comes to industrial areas, large warehouses or cemeteries), *road transport infrastructure* (national, county and local roads), e*xisting residential surfaces* (expression of the public utility presence whose quantification is really hard to achieve and who tries to detect the planning development probability), *forests* and *aquatic surfaces* (as oxygen generating surfaces improving environmental quality) and *soils* (viewed from the topo-permanence / topo-stability perspective and also from their humidity degree that represent adverse elements for housings).

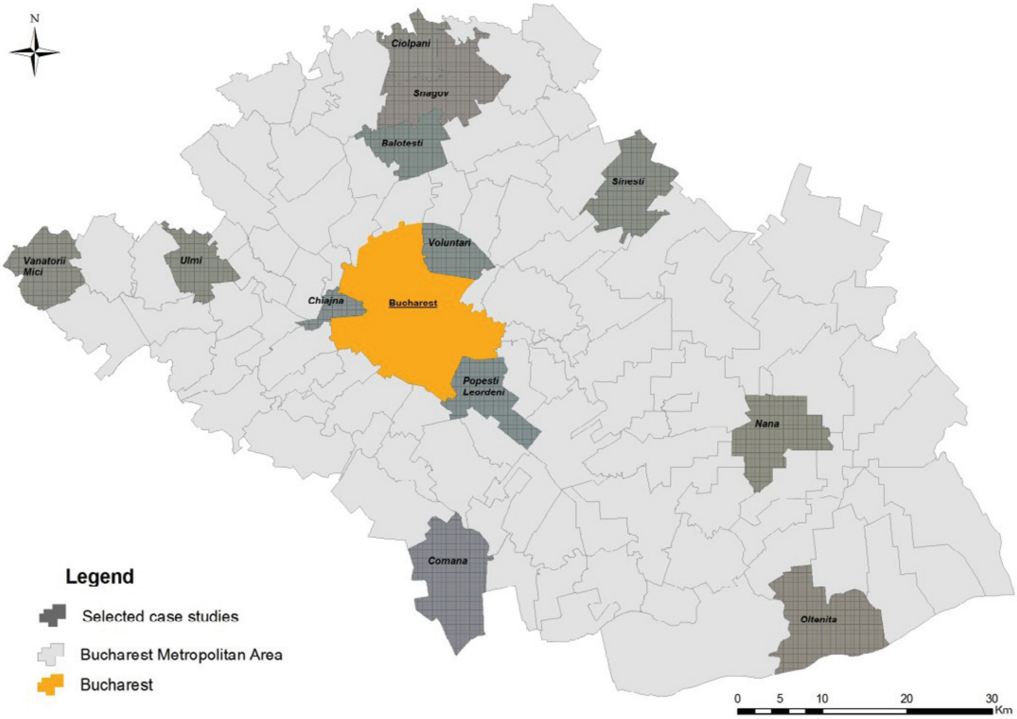


Fig. 1. Case studies in the Bucharest Metropolitan Area

The analyses were developed at two levels: the Bucharest Metropolitan Area and on 12 case studies, selected based on their geographical position and on the dynamic of residential areas so that all available scenarios are taken into consideration.

Where the entire cell was occupied by any other attribute except the existent residential we assigned a null value - which meant no favorability for the development of residential surfaces in that cell.

Table 1. Scoring mechanism from the economic and environmental criteria

	Economic					*Environment*	
X_1	X_2	X_3	X_4		X_5	X_6	X_7
Services	Incompatible functions	Roads	Residential	*Cell*	Forests	Water bodies	Soils
3	1	3	3	*presence*	3	3	5
5	2	5	5	*proximity*	5	5	4
4	3	4	4	*1*	4	4	3
2	4	2	2	*2*	2	2	2
1	5	1	1	*>2*	1	1	1

After applying the scores in the grids, we realized favorability maps for the 7 attributes that have been divided in two main categories: economical attributes (services, incompatible functions, roads, residential) and natural attributes (forests, water and soils) and we realized the total integration of the attributes according to the formula:

$$N\_economy = (X_1 * X_2 * X_3 * X_4) / 4 \quad (1)$$
$$N\_environment = (X_5 * X_6 * X_7) / 3 \quad (2)$$
$$N\_total = N\_economy + N\_environment \quad (3)$$

Once the database achieved with the seven analyzed indicators, we integrated them on the basis of the formulas presented before and we realized synthetically maps concerning the favorability in the developing of residential surfaces with a synthetic color scale (from red for a maximum favorability to green for a minimum favorability).

In the delimitation of the favorability areas we started with the elements considered to have a maximum attractiveness, mainly in the development of new residential surfaces, namely oxygen generating surfaces.

3. Results

3.1. Metropolitan level

The real important weight of the residential surfaces situated at less than 50 meters from the forestry surfaces and also next to the aquatic ones (even if we enter in their protection area) stands for an eloquent indicator of their attractiveness (Table 2) as more than 162 ha of residential surfaces are situated at less than 50 m from forest and 287 ha at less than 50 m of water bodies.

The distribution of residential surfaces based on the transport infrastructure (Table 3) indicates the good distribution of residential surfaces from an accessibility point of view, in terms of the road network, although over 2250 ha of residential surfaces are situated at more than 1 km. At this is added the precarious state of numerous local and county roads.

Favorability maps for the development of residential areas were obtained, differentiated for the 7 indicators, on the two large categories (economical and environmental), and the total favorability. Local level results are more expressive than those at the Metropolitan level where the large surface requires a rethinking of the analysis scale.

Table 2. Distribution of residential surfaces in the proximity of oxygen generating surfaces

Type*	Distance (m)	Forests (ha)	Water bodies (ha)
1	50	1.29	0.10
2	50	59.36	102.24
3	50	94.28	184.19
4	50	8.22	2.97
1	250	5.59	10.28
2	250	561.81	1721.63
3	250	436.20	1477.52
4	250	38.58	26.76

* According to the typology presented in the methodology section

Table 3. Distribution of residential surfaces in the proximity of major road infrastructure

Distance (m)	1*	2	3	4
50	39.87	2464.83	1209.22	8.59
250	126.46	4864.24	4864.24	34.52
500	44.72	2150.57	2005.66	27.10
1000	15.22	1006.73	1232.39	22.93

* according to the typology presented in the methodology section. Ha of residential surfaces situated at the corresponding distance from national and county roads

Suitability of development according to the existing residential areas indicates a maximum development within the localities, where open spaces still exist, or at the outskirts. The favorability from this perspective decreases proportionally to the distance. Suitability of residential development areas in connection with incompatible functions follows a quite opposite model. It refers to a minimum value next to the industrial or agricultural units, cemeteries, etc., considered as restrictive factors (due to noise, pollution, etc.) in the development of residential space, and increases as the distance from it increases.

Road network represents as an essential component of residential accessibility focuses upon an important element in the decision-making process. In our analysis, the maximum favorability is located in proximity to roads, decreasing with increasing distance from them. The method should be improved by introducing information and technical state of transport infrastructure, and scroll certain distance.

In our analysis the natural elements are represented by the bodies of water, forest areas and soil type. For water (Fig. 2) and forest bodies, the maximum suitability is determined by their presence in proximity and then decreased with increasing distance, thus the favorability follows closely the main valleys in the metropolitan area. This approach is validated and the situation on the ground, most new residential projects appearing between 1970 and 2007 in the proximity of forest or aquatic surfaces.

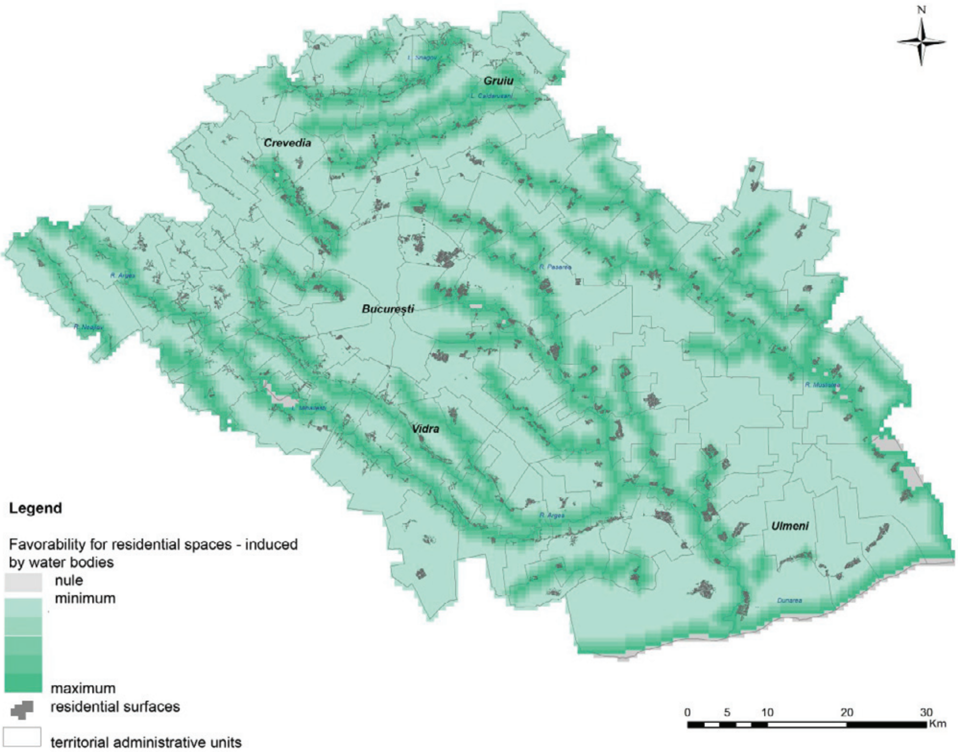


Fig. 2. Favorability for the development of residential areas according to water bodies in the Bucharest Metropolitan Area

Regarding soils (Fig. 3), in the absence of information concerning the stability degree, the main attribute considered was humidity present in the soil profile, which can cause problems for units built without proper insulation. For a judicious analysis there should be integrated also information regarding the genetic type of soil, as well as its fertility, erosion and degree of compaction, etc. Minimum favorability is recorded in the south western part of the metropolitan area (due to the Arges valley) but also in the central area, where loess geomorphologic processes have a high incidence.

The three indicators of the environmental conditions (water bodies, forests and soils) have been integrated in a synthetic map (Fig. 4), presenting the concentration of maximum favorability in the northwestern and eastern parts of the metropolitan area.

3.2. Local level

At local level, analyze regarded twelve case studies (Balotesti, Chiajna, Comana, Ciolpani, Nana, Oltenita, Popesti-Leordeni, Sinesti, Snagov, Ulmi, Vanatorii Mici, Voluntari), developed on grids with a cell size of 100 x 100 meters. The analysis had a higher degree of detail to the spatial scale, and presented a noticeable fact, especially for the economical attributes (such as incompatible functions). The total aggregation of attributes (Fig. 5) indicates a clear delimitation inside the locality of areas with maximum favorability and areas with restrictiveness in the development of residential areas.

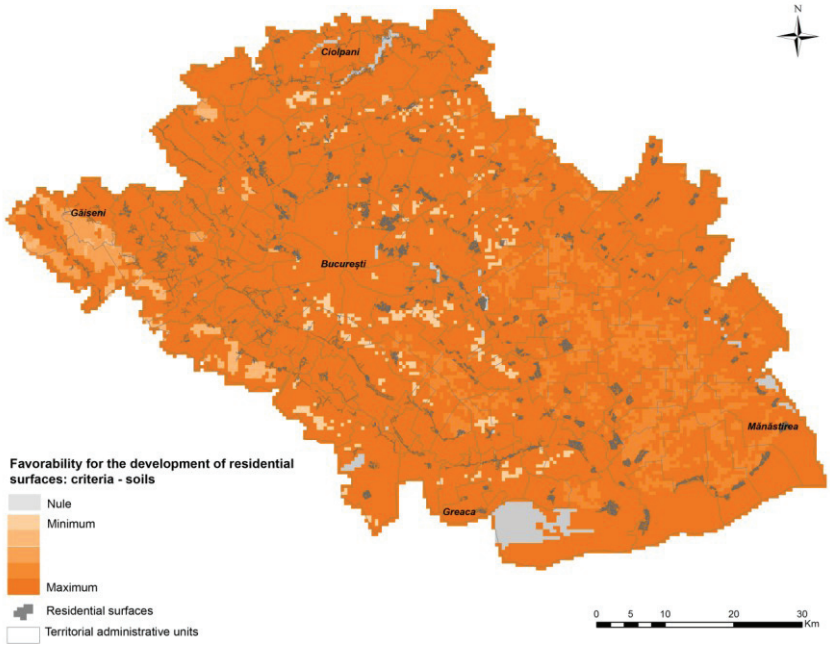


Fig. 3. Favorability for the development of residential areas according to soils in the Bucharest Metropolitan Area

Fig. 4. Total favorability for the development of residential areas in the Bucharest Metropolitan Area

The residential areas didn't modify only their surface in the analyzed period of time, but also the density in terms of residential buildings and of the dwellings. For the analysis, we chose 12 case studies where we mapped housing density in the 70's and those existing after 2005. For the localities in the north of Bucharest Metropolitan Area there is a wide range of locations– where the maximum density increased from 13 dwellings / ha to 20 dwellings per hectare (Fig. 6), and their remarkable development towards elements of attraction, development that has been achieved mainly on agricultural lands.

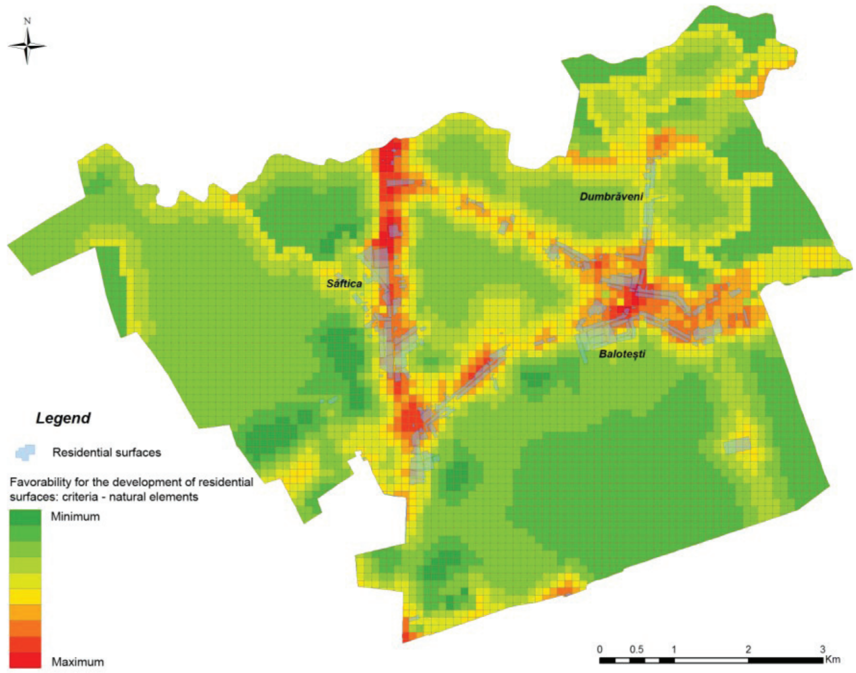
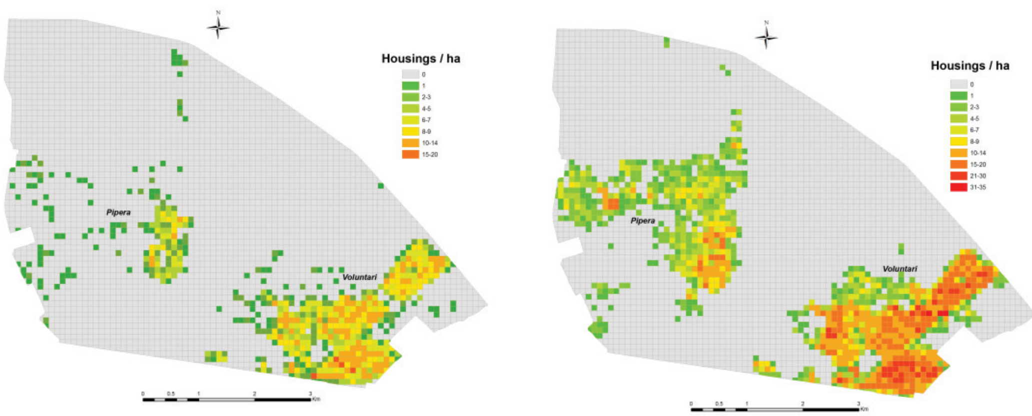


Fig. 5. Total favorability for the development of residential areas in Ciolpani - Bucharest Metropolitan Area



a b

Fig. 6. Residential changes between 1977 (a) and 2005 (b) in Voluntari - the Bucharest Metropolitan Area

Areas where decreases were registered (generally low, 1-2 unit cell size reported) are to be found mainly at the outskirts of the towns. Note that the range decrease - increase [-1, +1] may occur because of the spatial inconsistencies between the two sources for obtaining the data (topographic maps and satellite images). The situation is different when they point new residential surfaces, where it is noticeable a clear differentiation of the residential areas during the last thirty years (an increase with 105.5 % of their surface).

4. Discussion

At metropolitan level, the favorability synthetically maps have been realized at a pixel resolution of 500 meters. Depending on the analyzed criteria we underlined various areas with a maximum favorability, as it is the example of the north part of the Metropolitan Area for the forestry surfaces criteria or the Arges watershed, Mostistea watershed or the lakes from Ialomita, for the water table criteria. In the case of the soils the areas with a low favorability are more obvious in the development of residential surfaces situated along the Neajlov, near the marshes from Comana or in the rivers Pasarea and Colentina watersheds.

Regarding the incompatible functions however, at a closer look in the present development of residential areas, they are not a limiting factor, a little lower price for the land in the proximity of compensating their decision-making process of their possible negative effects. The aggregation of the four economical indicators at metropolitan level lead to the elaboration of a favorability map which unfortunately at this scale doesn't present the significant improvements of the method.

Instead the aggregation of the three indicators grouped in the landscape class show the stroke of some coherent areas of great favorability, such as Snagov Plain, the Inferior Arges Basin (from the confluence with the Dambovita river until its confluence), the superior Pasarea Valley and the Arges-Sabar lowland in some sectors. Aggregate economic attributes indicate a maximum favorability in the development of residential surfaces inside or in the close proximity of the already existing residential.

Aggregate natural attributes indicate different regions in the development of residential surfaces, but also the fact that sometimes the existing residential is developed in adverse areas from the point of view of the landscape attributes. The total aggregation of the attributes discovers new spaces where residential development would benefit by conditions if not at their maximum, at least at an optimal level.

In the same time, with the overlaying of the already existing residential surfaces on the favorability map, we can observe that not in all the cases these are developed in areas with a maximum favorability (as it is the case of Cupele and Vanatorii Mari villages from the Vanatorii Mici township) and also the presence of areas with a high favorability where residential development hasn't been exploited yet.

While realizing the favorability map for the development of the residential spaces, the information and the precise data are rarely available and they determine a certain degree of uncertainty in creating the model [33]. To avoid this demerit, the input data should present a certain resolution and admit the integration of the data that concern different environmental, social and economic parameters [25].

Moreover it should be considered that in most cell spaces there are a large number of quiescent cells. The cell model could have many layers to deal with different information needed for each cell [34]. In simple models, one value per cell could be sufficient. It is clear that the sprawl of the residential areas cannot be limited to an ecological model of dispersion of the species, but may be viewed as a process of colonization at multiple scales and density dependent [35] and the model can be improved by adding additional factors and by regulating of spatial resolution analysis.

Environmental conflicts between residential and other types of land uses can have as a main determinant the identity and values of various users [36] as a direct consequence of their aspirations and expected outcomes [19]. This type of analysis based on GIS techniques can lead to the identification of optimal areas for the development of the residential surfaces [37], and to the avoidance of sensitive or risk areas from an environmental point of view [38]. It can offer useful information to the decisional factors and determine the general tendencies in the spatial distribution of the favorability classes.

A few potential limitations of this study warrant discussion. One is concerned with the method of data gathering [38], as bias in published news may exist. Another possible limitation of this study is its narrow geographical focus, especially in the case studies.

5. Conclusion

The establishment of a research method, generating maps indicating the favorability of development for residential areas according to economical and environmental attributes should represent especially at a metropolitan level a useful tool for land planners, real estate developers and local population, as well as help prevent the emergence of land-use conflicts. It could present arguments for the development of sustainable residential surfaces, ensuring a superior quality of living, without significantly influencing the quality, productivity and regeneration capacity of the environment.

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