The ecological footprint – indicator for analyzing the environmental impact of residential surfaces in metropolitan area. Case study: Bucharest Metropolitan Area

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1 ABSTRACT

The ecological footprint represents an efficient assessment model that estimates the space consumption for natural resources use and conditioning of wastes resulted from the human activities, and thus is an efficient model for analysing the environmental impact of residential surfaces. In the Bucharest Metropolitan Area residential spaces have been constantly expanding in the past 20 years, determining an increasing pressure on environmental components. The ecological footprint becomes useful because it can allow us to integrate residential spaces structure, size, emplacement, capacity and infrastructure connectivity in an determining more and more pressure on different components of the environment. For analyzing and evaluating the ecological footprint of residential spaces were analyzed their structure, size, emplacement, capacity and infrastructure demands, all being compared with the environment's support capacity.

2 GENERAL DATA

2.1 Introduction

Lately, due to the increase of factors to be considered in environmental impact analyses, scientific researchers have been looking for more efficient methods of expressing and quantifying that impact. One of these methods, developed by professors Mathis Wackernagel and William Rees from University of British Columbia, was the ecological footprint, as a standard methodology in environmental impact assessments for different development models. The authors considered that "the ecological footprint quantifies the total surface of land necessary for sustaining a locality or a human activity" (Wackernagel and Rees, 1995). According to Lenzen and Murray (2003) the ecological footprint represents the biological productive land that can generate the resources consumed or can assimilate wastes produced by the human society.

The method has been developed for accounting the environmental impact of numerous human activities, using standard land-use types (cropland, grazing area, fishing grounds, forest, carbon and built-up areas) (Wackernagel, 2004), and constantly comparing the results, with the biocapacity of the analysed territory. The method is more useful in the Bucharest Metropolitan Area, were in the last 20 years, due to a lack of authority and economical dysfunctions, residential development was spectacular, but in the same time chaotic and irregular, as it is characteristic to un-institutionalised metropolitan areas (Ioja, 2008).

2.2 Study area

Although numerous propositions and legislation projects exists, concerning the Bucharest Metropolitan Area, its status is still a theoretical one, as none of the administrative actors are interested in actively involving in this form of territorial organization. In the proposed project of the Bucharest Metropolitan Area, it contains 95 administrative territorial units, from 5 counties (Ilfov, Calarasi, Ialomita, Giurgiu, Dambovita) and Bucharest – the capital city of Romania (figure 1). The Bucharest Metropolitan Area has a total population of over **2,5** million inhabitants, but this number could be higher if we would take into consideration the large numbers of illegal migrants, whom aren't comprises in censuses. The enormous economical potential of Bucharest determines an active mobility of the population; in the same time a system of social rules, determined people's movement from the capital city to the surrounding Metropolitan Area.

The natural resources of the Bucharest Metropolitan Area are mainly determined by the plain relief (including different sectors of the Romanian Plain) and the floodplains of the main rivers. It is located in a temperate climate, with annual average temperatures of 10-110C and precipitations of 600-700 mm. Danube's tributaries (Arges, Dambovita, Colentina, Mostistea),were transformed in a series of lakes, initially for agricultural and fisheries purposes, and subsequently for leisure. Another element of significant importance for residential spaces is the presence, especially in the northern part, of numerous forest surfaces (mainly species of oak). This, together with the lakes, represents elements of attractiveness in the development of residential spaces.

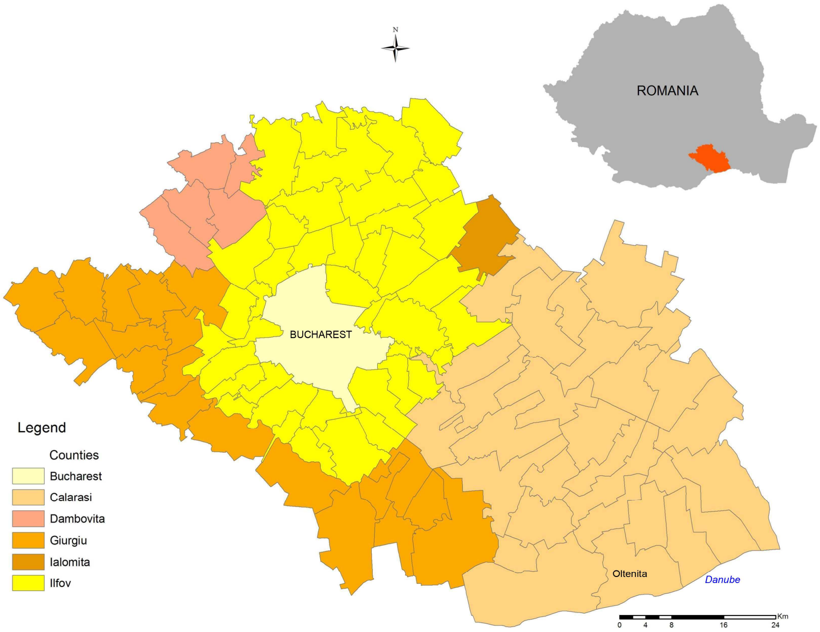

Fig. 1 : Territorial administrative units of the Bucharest Metropolitan Area

2.3 Methodology

At its original sense, the ecological footprint was developed as a useful method for comparing the sustainability of resource use among different populations (Rees, 1992). The ecological footprint is defined later on as the land area needed to ensure the consumption of the population and absorb all their wastes (Wackernagel and Rees, 1995). Starting from this definition, human consumption was divided into five categories: food, housing, transportation, consumer goods and services.

In all studies, the ecological footprint is continually compared with the biocapacity of the analysed territory, representing the bio-productive supply, i.e. the biological production in an area. The biocapacity represents an aggregate of the production of various ecosystems within that area e.g. arable, pasture, forest, productive sea. Biocapacity is dependent not only of natural conditions but also on prevailing farming / forestry practices. Several estimates have shown that currently, the humanity has an ecological footprint that is exceeding the Earth's biocapacity (Kitzes, 2007).

The ecological footprint can be separated into the Spatial footprint (and this is divided into the main land-use categories: cropland, grazing land, fishing grounds, forests and built-up land) and the Energy footprint (known also as "carbon land"). It has been observed that problems appear due to the fact that these different types of land-uses have different biocapacity values. Furthermore, for a better understanding appeared the need of expressing the ecological footprint of human activities in a unitary value, and therefore were established equivalence factors, used for transforming a specific land type (i.e. cropland, pasture, forest) into a universal unit of biologically productive area, a global hectare.

Among the five land-use typed the ecological footprint operates with, built-up area, and subsequently residential surfaces, represent the most difficult one to determine, as the low resolution satellite images that are available for most areas aren't able to capture dispersed households, roads and other adjacent infrastructure. That is why some researches confronted with such lack of data, have found an method for estimating residential footprints, as this type of land is assumed to have replaced a natural land-use type, specific to that area. We consider this approach to be wrong, because residential surfaces generally have a mixture of houses, gardens and other green surfaces. For residential areas, as for all built-up land, the equivalence factor is of 2,2 (gHa / Ha), the greatest value of all land-use types (Monfreda, 2004).

The spatial footprint of residential spaces is easy to determine, as it can be determined by the surface of the houses, or by that surface multiplied by a factor determined by the number of floors. On the either side, the energetic footprint is more difficult to determine as residential spaces add Carbon to the atmosphere in numerous ways, therefore it must consider a number of different elements: the model of the basic housing construction type (individual- collective); energy modelling of housing types; lot sizes and housing mixtures; lighting layout (public illumination) and anticipated energy use; water and wastewater infrastructure and operation; transportation infrastructure, costs and accessibility (Brueckner, 2000; Burge, 2006).

In our research, we developed a model (table 1) that considers both the spatial footprint (represented by the surface parameter) and the energy footprint (expressed through construction materials, energy consumption, water consumption, transportation accessibility and waste production).

Ecological footprint	Analysed parameters	Observations
Spatial footprint	Surface	The surface of the building (expressed as an average square meters value between the plan footprint of the building and the living surface of housing) multiplied by the difference between the equivalence factor of residential spaces and the equivalence factor of the natural ecosystem developed in the area.
Energy footprint	Construction materials	Total sum of the surfaces needed to obtain all the construction materials.
	Energy consumption	Depending on energy consumption, and the modality in which this is obtained.
	Water consumption	Differences between those based on own supplies (springs, wells) and those from the public system
	Transportation accessibility	Expresed through the surface needed to obtaine the fuel and adsorbe the emissions
	Waste production	Total surface needed to adsorbe the wastes, including waste-water
	Total	Sum of the total obtained values
Total ecological footprint	Sum of the spatial and the energy footprints	

Table 1 Analyse model for the ecological footprint of residential areas

3 CASE STUDY

3.1 Residential development in the Bucharest Metropolitan Area

After 1989, residential development recorded a real "explosion" in the Bucharest Metropolitan Area, per example, only in the Bucharest-Ilfov development region increasing from a total of 30 million m2 in 1990, to almost 36,5 million in 2007. This phenomenon was favoured by several factors, such as the re-emergence, after 1990, of numerous private properties. Most of these were small properties, which caused them to be agriculturally unproductive, so the population abandoned this type of land use in favour of the constructed surfaces. Also, the disappearance of severe regulations, both regarding human migrations and construction regulations, determined many inhabitants of Bucharest to move permanently or temporarily in the Bucharest Metropolitan Area. All these factors determined the appearance of functioning disorders, increasing the ecological footprints of these residential surfaces.

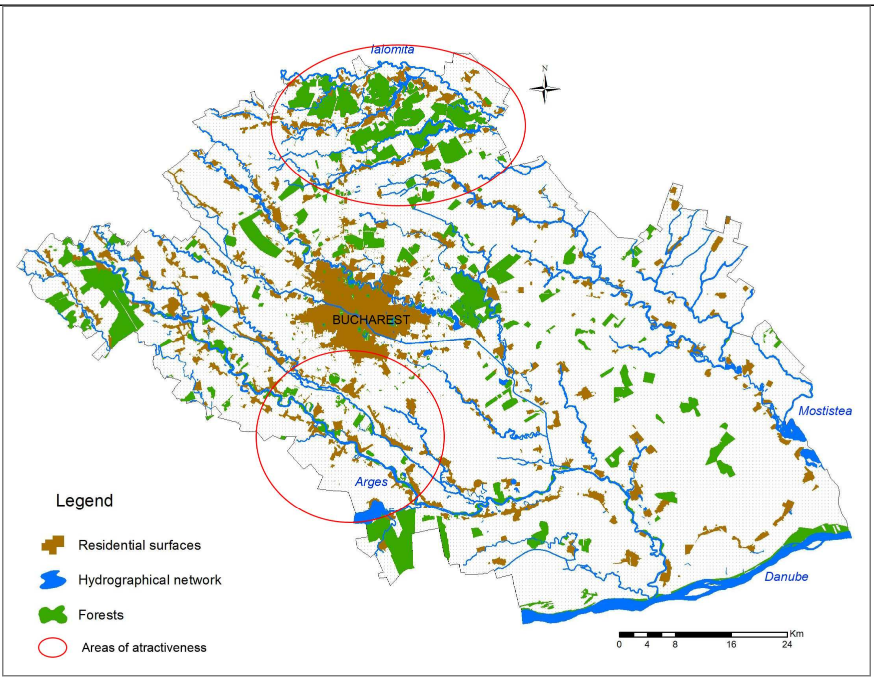

Fig 2: The relationship between localities and valuable elements of the natural capital (rivers and forests)

As a consequence many localities increased their constructible surfaces in order to satisfy the need of newcomers, but in the same time under the pressure of landowners for increasing the price of their lands; and this increases were directed towards areas with natural attractiveness factors, such as forest and lakes, without considering in the development the lack of infrastructure present in these directions (Patroescu, 1999). Two types of development are mostly encountered: single owners' households, generally with small surfaces surrounding them, and constructed by their inhabitants using day-labourers; rand esidential projects of developers, generally on bigger surfaces, with single or multiple users' housings, but with a personal infrastructure, poorly connected to the network existent in the metropolitan area.

3.2 Results

In the Bucharest Metropolitan Area, it is hard to calculate a precise value for the ecological footprint of residential areas, as the region is confronted with a deficit of reliable data, even the data existent at the National Institute for Statistics being deficient when they are compared to the reality of the field. Difficulties are primary due to the fragmentation and heterogeneity of residential areas, but also due to the large number of residential surfaces that aren't enlisted in the official documents at local or regional levels (Thorsnes, 2000). We have excluded from our calculus Bucharest, as it high values would have made it imposible to observe the situation existent in its metropolitan area.

For the case study, we have chose for comparing two individual residential spaces, situated in similar environments, but with different consume models of the inhabitants with the average existant at the metropolitan level (Table 2). For the missing data, we have used estimates, based on existant literature (Sharing Nature's interest, 2000) and personal observations, but these should be regarded with caution, as their accuracy isn't proved yet.

Ecological footprint	Analysed parameters	Model A	Model B	AVERAGE
General description of the residential space		House of small surface, constructed of wood, un-connected to the public infrastructure, with people working in agriculture and with small connection to the	Large house of concrete and glass, with all infrastructure endowments, situated at 30 km from Bucharest – where the people work.	An average of all residential surfaces, expressed through housing data obtained from censuses.

		city.		
Spatial footprint	Surface	30 m^2	300 m^2	100 m^2
Energy footprint	Construction materials	Wood = 75 m^2	Concrete, glass, plastic, iron = 3000 m^2	1000 m^2
	Energy consumption	0	150 kW obtained from fossil fuel = 4500 m^2	2000 m^2
	Water consumption	25 litres / day, obtained from own well = 25 m^2	200 litres / day, from the public system = 1000 m^2	500 m^2
	Transportation accessibility	100 km / month, on public transportation = 50 m^2	3000 km / month, on two private cars = 6000 m^2	1500 m^2
	Waste production	Self absorbed	500 kg / month of domestic wastes = 2000 m^2	750 m^2
	Total	150 m^2	17500 m^2	5750 m^2
Total ecological footprint		0,018 Ha	1,785 Ha	0,058 Ha

Table 2: Comparison between the ecological footprints of residential spaces

Model A is a model which considers minimum consumption, as it is rarely encountered in the Bucharest Metropolitan Area, mainly in poor rural communities from the periphery, but even those have begun increasing their consumption. *Model B* considers maximum consumption, and it's also rarely encountered. The *average model* is obtained from census data, and it expresses that the energy footprint of residential spaces in the Bucharest Metropolitan Area, is almost 50 times greater than the spatial one.

From the total area of the metropolitan area, of over 538.000 hectares, if we subtract Bucharest's surface of 23 000, are left about 515 000 for the surrounding localities. The spatial footprint of residential surfaces from these localities is of only 22 000 hectares (figure 3), as expected with higher values in the proximity of Bucharest, and in the northern part. If we would to use the "50 times greater" ratio, extracted from the model, we would observe that the energetic footprint would become of about 1 000 000 hectares, and that is twice more than the current surface of the metropolitan area (Bucharest included).

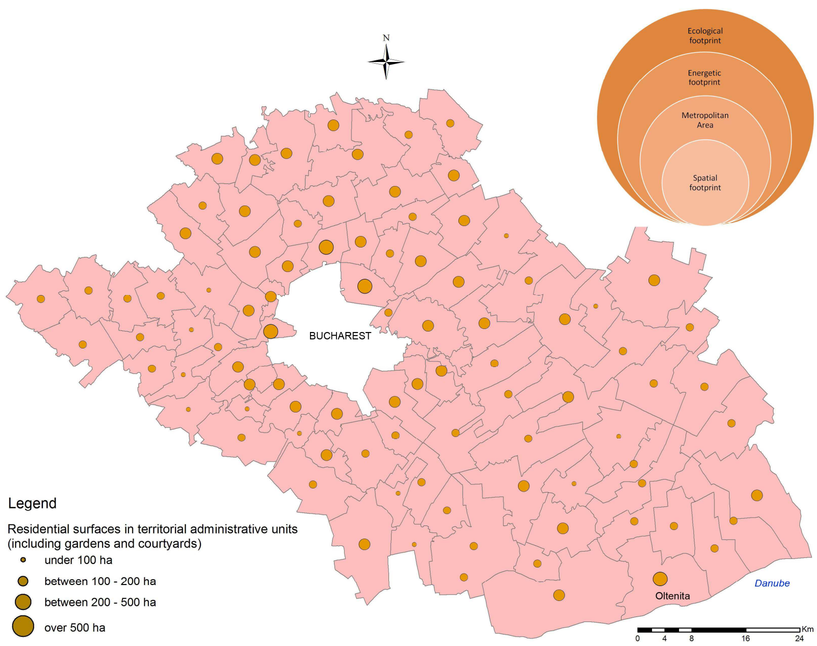

Fig 3: Residential surfaces and their footprints in the Bucharest Metropolitan Area

4 CONCLUSION

The ecological footprint assessment is becoming more and more an efficient method for the environmental impact assessment of human activities. That is why it had been integrated in the past years, especially in Europe, North America and Australia, in environmental analyses, and even in European development and conservation programes. Ecological footprint studies must be realized in all phases of the residential surfaces lifetime: design, construction and use, taking into consideration the amount of renewable and non-renewable resources used (gas, electricity or solar energy).

In the Bucharest Metropolitan Area, although residential development is a known fact, ecological footprint analyses are difficult due to the lack of data. That is why was developed a model that started from the existent statistical data, combined it with existent literature and personal observation. Preliminary results shown that the spatial footprint represents about 4% of the total surface, but the energetic footprint is almost double than the total surface, expressing the high environmental impact of residential surfaces in the Bucharest Metropolitan Area.

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