Analysis of vegetation from satelite images correlated to the bird species presence and the state of health of the ecosystems of Bucharest during the period from 1991 to 2006

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Abstract

The urban vegetation needs adequate monitoring and conservation, being a critical resource of urban landscape. To its deeply esthetic values, the practical values and, respectively, ecosystem services delivered by the urban biodiversity are added (amelioration of the environment and urban microclimate, flood control, diminishing of the environmental pollution, increasing of biodiversity and habitats etc.). Accurate remote sensing techniques have been used widely in locating and mapping urban vegetation (Light Detection And Ranging-LiDAR, satellite images).

The purpose of this study is to point out the vegetation status in correlation with the number of the bird species (as indicator of the ecosystem's health), using remote sensing techniques (Landsat satellite images), between 1991-2006 in Bucharest, Romania's capital. Rapid urban evolution of Bucharest led to important changes within the structure of the city, underlined by the increasing of the built area to the detriment of the green one. The intensity of the urbanization rate also led to the decreasing of the number of the bird species. The results obtained through analysis of satellite images indicate the necessity to acquire the up-to-date information related to the vegetation status in order to establish in the future, through urban landscape projects, protection measures for the vegetation cover and for the bird habitats in Bucharest Municipality.

Keywords: urbanisation, vegetation monitoring, avian habitat, Landsat, NDVI model, Bucharest Municipality

Introduction

Urban agglomerations modified and modify continuously the environment, mostly generating beneficial effects for inhabitants' life and activities, and, at the same time, negative effects, both on the environment structure and social-economical life.

The results of the studies of the last 20 years support the approach and inclusion of the ecosystemic dimension in the integrated urban regeneration of the cities. Green areas represent an important resource of the urban system and, implicitly, a tool which helps to better manage the urban development (Colusca, Alpopi, 2011; Feltynowski, 2015; Nita, 2016; Antrop, 2004 quoted by Scaunas, Merciu, 2016; Ianos, et al., 2017).

Green infrastructure is a new concept, a net projected within cities, in which there are incorporated

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natural and semi-natural elements as woods, public parks, recreational areas, waste vegetation, resendential gardens, street alignments of trees and bushes, vegetal strips, green belts (Feltynowski, 2015; Nita, 2016; Rouse, Bunster-Ossa, 2013; Ely, Pitman, 2013), and recently, green walls and grassy terraces (Maas, et al. 2006; Hopkins, Goodwin, 2011, Cheng, et al., 2010, Dunnett, Kingsbury, 2004; Rayner, et al., 2010).

Green areas deliver a series of natural functions, often named ecosystemic services, including the air and water purification, healthier soils, improvement of the urban climate and microclimate (Millennium Ecosystem Assessment, 2003; Wolch, et al., 2014; Nita, 2016), playing an important role in water infiltration in the ground and in the restoration of aquifers (Xiao, et al. 2006; Bartens, et al., 2008), water interception at the tree canopy level (Xiao, et al., 2006), as well as the flooding control (Lull, Sopper 1969; Craul, 1992; Chen, et al., 2006 quoted by Wolch, et al., 2014), diminishing the environment pollution by capturing the dust particles (Nowak, et al., 2006; Mitchell, et al., 2010; Dogon-Yaro, et al., 2016), increase of biodiversity and habitats (Lima, et al., 2013; Petrisor, 2015; Hüse, et al., 2016), low noise (Fang, Ling, 2003; Van Renterghem, et al., 2012; Wolch, et al., 2014).

A valuable benefit of the green infrastructure is represented by the diminishing of the heat island effects (Bornstein, 1968; Federer, 1976; Rosenfeld, et al., 1998; Wolch, et al., 2014; Sirodoev, et al., 2015; Davis, et al., 2016; Ongoma, et al., 2016).

Also vegetation provides nesting sites for birds and provides support to a number of insects, which, in their turn, are a food source for birds and other wild species. Trees and shrubs that produce fruits and seeds are a direct food source for many bird species. In urban settings, linear corridors between different types of habitats are among the most important, creating the connection between different isolated areas, and between towns and adjacent rural environment.

The role of the green infrastructure is major in generating social and economical beneficial effects: provision of green spaces and recreational facilities for residents, improving of the population health, pleasant design in residential areas and a better rating of real estate, etc. (Alberti, Marzluff, 2004; Conway, et al., 2010; Colusca, Alpopi, 2011; Cohen, et al., 2012; Wolch, et al., 2014; Feltynowski, 2015; Lee, et al., 2015; Davis, 2016; Li, Liu, 2016).

This study intends to make a prior analysis of the urban green areas from the perspective of their recovery. Within the study, the authors captured the evolution of Bucharest municipality in the terms of built area – green area ratio, between 1991-2006, in correlation with the state of health of vegetation and with the state of environment (the birds being chosen as a quality indicator of the environment).

Bucharest knew an accelerated urban evolution beginning with the second half of the 19th century (Mihailescu, 2003 quoted by Ianos, et al., 2014) which still continues. Along time, as the city enlarged, natural vegetation diminished in some areas as a result of the building and adjacent infrastructure construction, in the detriment of the species unable to adapt to the new type of habitat. Biodiversity loss as a consequence of urbanization is worrying, because the decreasing of the number of species in an ecosystem points to a low ecological health and a poor quality of habitats.

In this respect, it is necessary the correct and rapid acquisition of the information on the state and changes of the structure of the urban vegetation, to subsequently be used as a tool in the decision process related to the improving of the urban ecosystem status. Urban landscape projects involve mostly the knowledge of the components of the urban space and their interconnections.

Methods and data

Accurate remote sensing techniques have been widely used in locating and mapping urban vegetation: Light Detection And Ranging - LiDAR (Holmgren, et al., 2008; Kim, Muller, 2011; Bellakaou, et al, 2016; Dogon-Yaro, et al., 2016; Näsi, et al., 2016; Scaunas, Merciu, 2016), satellite imagery (Bino, et al., 2008; Mcfarland, et al., 2012; Mészáros, et al., 2014; Jovanović, et al., 2015; Agrawal, et al., 2016; Burchfield, et al., 2016; Milanović, et al., 2016).

Remote sensing techniques present several advantages: speed of the measurements, efficiency, high resolution of the recording, acquisition of an important number of data in a digital archive, integration of all information from a certain area, an important tool for monitoring environmental conditions facilitating investigation and intervention, 3D images of a certain area, the support of collecting a set of relevant data and their integration into an easily accessible system for public use, and environmental control and management (Mcfarland, et al., 2012; Jovanović, et al., 2015; Milanović, et al., 2016).

For this study the authors used data obtained from the analysis of satellite images. Therefore, two satellite scenes were used: Landsat Surface Reflectance 4-5 TM at a resolution of 30 m (Table 1), from the 31st of July 1991 and, respectively, the 17th of August 2006.

Vegetation can be detected on the satellite images by its specific appearance and shades.

Vegetation analysis was performed based on cover infrared images that were created in the near and medium infrared spectral zone. Thus, in images acquired near-infrared spectral channel, vegetation appears in shades of bright red, while infrared images obtained in the medium infrared channel, the vegetation is detected by shades of dark red.

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Table 1. Spectral bands Lansat Thematic Mapper (TM)

Landsat	Name	Wavelength (micrometers)	Resolution (meters)
Band 1	Blue	0.45-0.515	30
Band 2	Green	0.525-0.605	30
Band 3	Red	0.63-0.69	30
Band 4	Near Infrared	0.75-0.90	30
Band 5	Shortwave IR-1	1.55-1.75	30
Band 6	Thermal R	10.40-12.50	120* (30)
Band 7	Shortwave IR-2	2.08-2.35	30

Source: Internet 1

The data obtained by satellite images can be processed through especially designed software applications, whose main role is to interpret remote-sensed images photographically. The authors used ENVI 5.1 program in order to analize the satellite images and presumed: creating vector file (polygon for resample) for Bucharest, clipping a raster for 1991 and 2006, creating multispectral images (Layer Stacking) and combinating bands for viewing.

The subsequent step was the extraction of the spectral signature from definite regions of interest (ROI), in ENVI program.
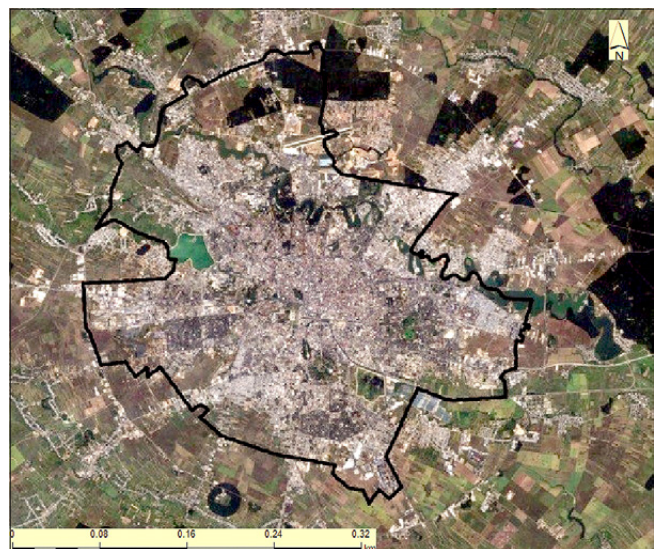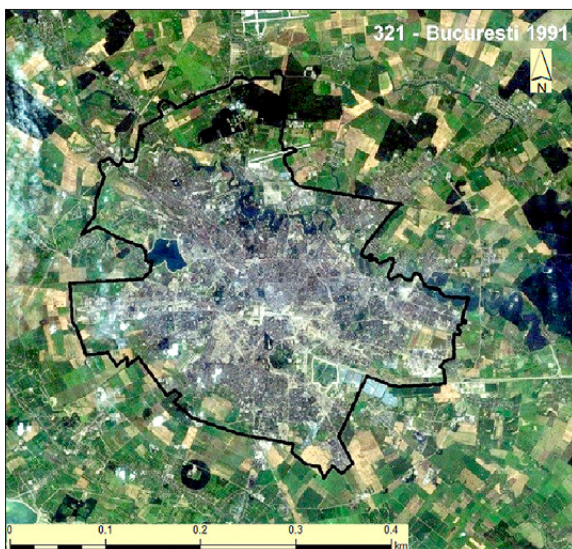
Also, the Normalized Difference Vegetation Index (NDVI) was calculated as a ratio between the difference and the sum between the infrared and red reflectance areas of the electromagnetic radiation (Mcfarland et al., 2012; Jovanović et al., 2015; Burchfield et al., 2016):

$$NDVI = (NIR-R)/(NIR+R)$$

where:
NIR – near infrared spectral band;
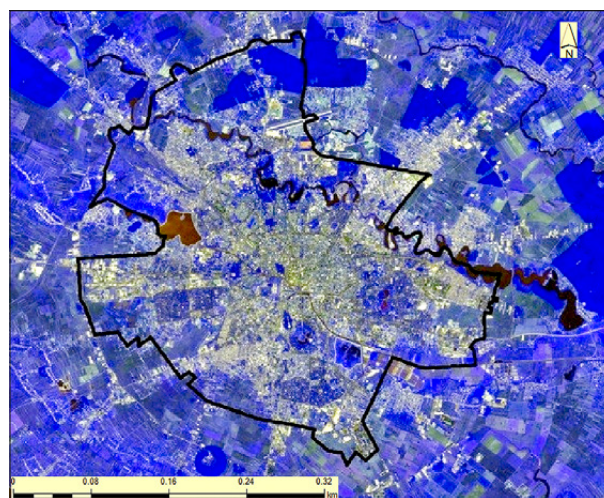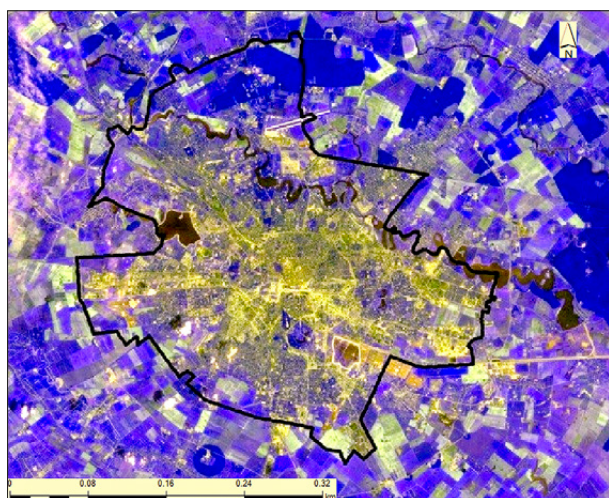R – red spectral band.

Also, NDVI is an indicator that describes the greenness, relative density and health of vegetation for each pixel in a digital image (Dogon-Yaro, et al., 2016).

Data on the spatial distribution of the vegetation were correlated later with the number of the bird species. In the specialized studies, it was demonstrated that the birds represent a quality indicator of the environment (Bino, et al., 2008; Coops, et al., 2009; Lima, et al., 2013; Mohamad, et al., 2013; Idilfitri, et al., 2014; Morante-Filho, et al., 2015), because a high ecological diversity is necessary for supporting several species. Several resons for which birds are considered as quality indicator of the environment can be mentioned: they are easily observed and identified, they live in almost all types of habitats and occupy different ecological niches, they are most often at the top of the food chain and therefore they are very exposed to the accumulation of chemical polluters; their diet includes a wide range of species, from plants to animals.

Results and Discussions

Rapid urban evolution of Bucharest, Romania's capital, led in time to important changes on the city structure, marked by the increasing of the built space in the detriment of the green surfaces. As a result, we used satellite images in order to observe the recent evolution of the capital city (respectively between 1991-2006), when significant changes were recorded in its urban structure.

The analysis of the combination of 321 spectral bands (red, green, blue) allowed by band 2 (green) to differentiate the main types of vegetation: suburban forest, parks, street alignments (Figures 1 and 2). A comparative analysis points out that, if in 1991 the suburban area of the capital city was better covered by different vegetation types, to which a great-

Figures 1 and 2. Combination of 321 of spectral bands for Bucharest (1991 and 2006)

Figures 3 and 4. Combinations of 234 spectral bands for Bucharest (1991 and 2006)

er share of the agricultural lands was added, later, in 2006, it was observed the increasing of the building covered surfaces (with a higher dynamics in the suburban area of Bucharest, but also inside the city, especially in north-west and north-east areas), this fact leading directly to a diminishing of the green areas (Figures 1 and 2).

The image analysis related to the combination 234 was facilitated by the fact that it is the first to include an infrared band, thus permitting a clearer differentiation between building covered areas (built surfaces) and those covered by vegetation (Figures 3 and 4).

Combination 432 highlights the vegetation in red, lighter spots representing a stronger spectral response. Band 4 (NIR – near infrared) allows the differentiation between the vegetation types: forests are dark red, deciduous trees are represented by a lighter red, the agricultural areas and the grassy ones are very light red coloured (Figures 5 and 6).

An attentive analysis of the shades of red underlines better the changes of the city structure, i. e. the

diminishing of the afforested surface beginning with 2006, in comparison with 1991, especially in the north of Bucharest.

From the interpretation of the satellite images related to combination 453 it can be observed that it is optimal for vegetation differentiation, due to the presence of two bands of the infrared (4 and 5) (Figures 7 and 8). The bands cause more pronounced shades of vegetation. Band 5 (shortwave infrared) is sensitive to changes of water content of the leaves or soil. Vegetation is represented in shades of orange and brown, lighter tints showing a stronger spectral response of the vegetation and the darker ones, a weaker response. The areas without vegetation and the built-up spaces, typical to urban areas, appear in shades of blue and gray (Figures 7 and 8).

Further, regions of interest (ROI) for water, constructions, grass, forest, park-deciduous, crops were defined, and later, the pixels were classified using Maximum Likelihood algorithm, with ENVI program (Figures 9 and 10).
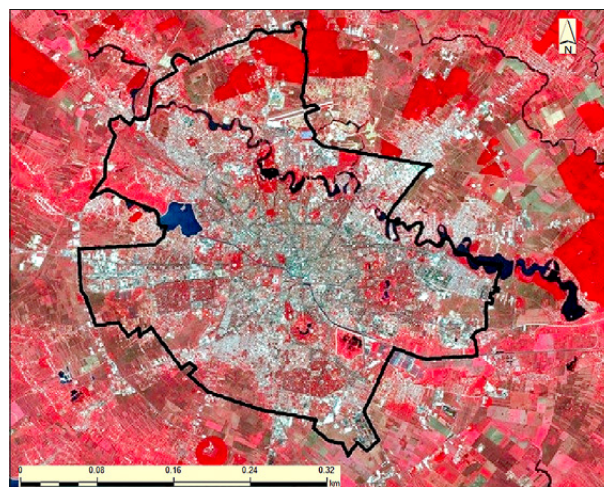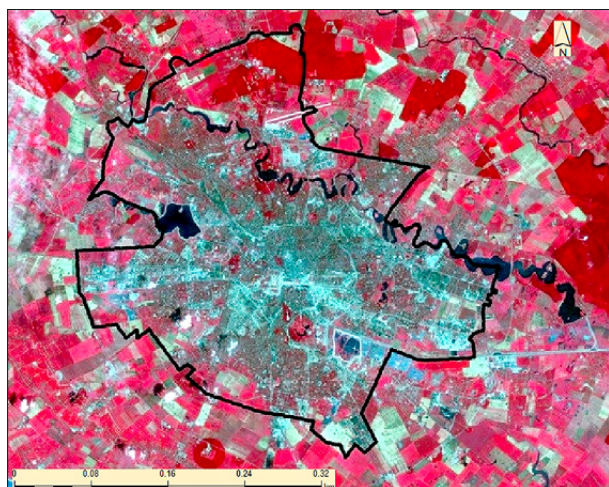
Figures 5 and 6. Combinations of 432 spectral bands for Bucharest (1991 and 2006)
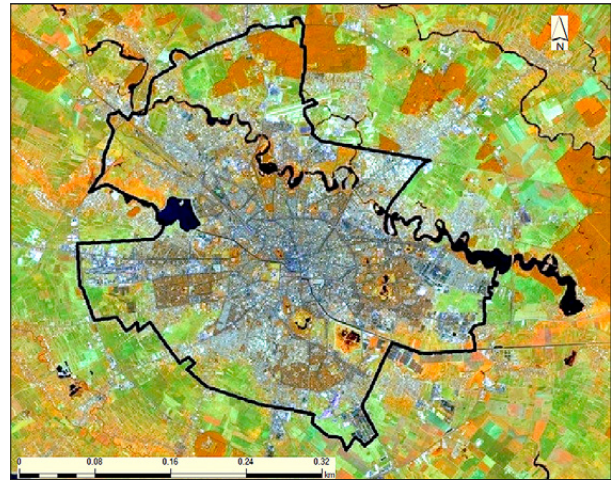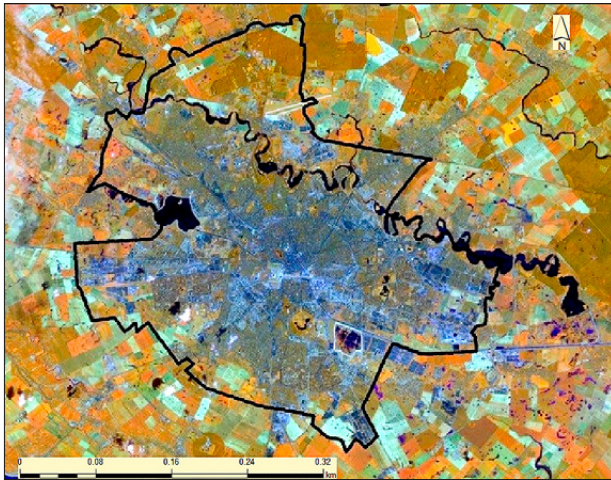
Figures 7 and 8. Combinations of spectral bands 453 for Bucharest (1991 and 2006)
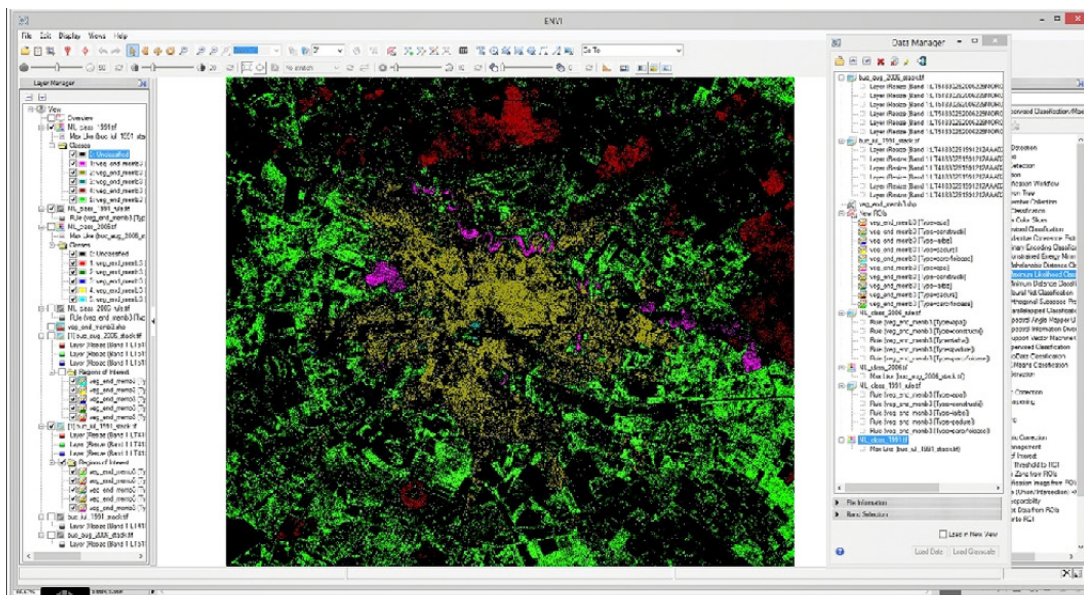

Figure 9. Screenshot of ENVI program during Maximum Likelihood Classification analyses for Bucharest, in 1991
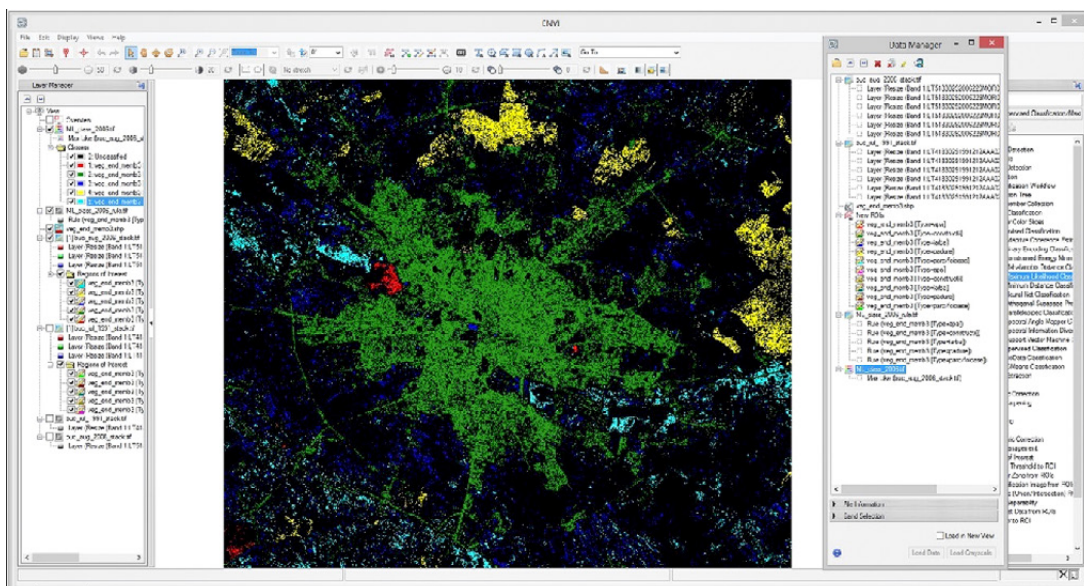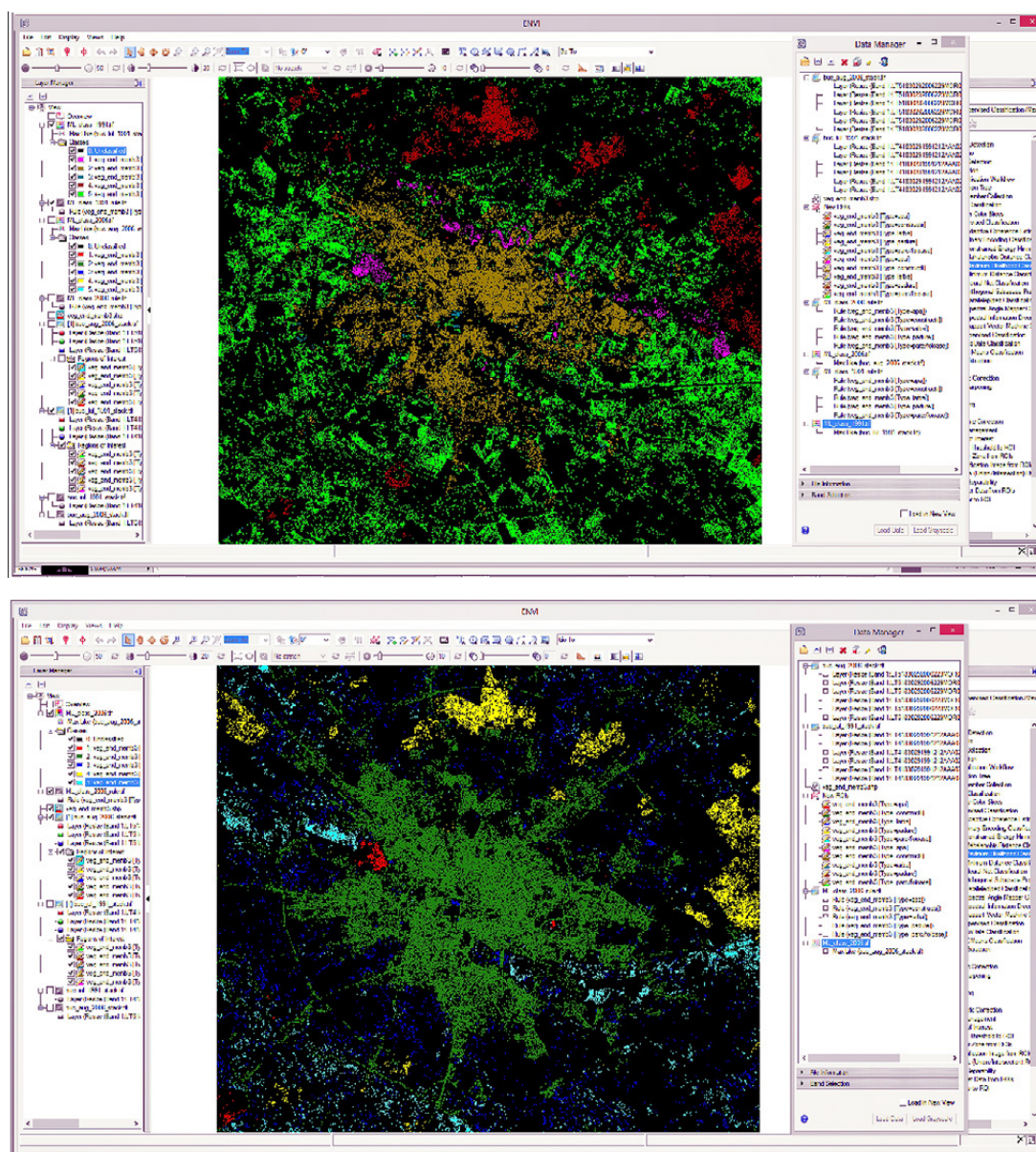

Figure 10. Screenshot of ENVI program during Maximum Likelihood Classification analyses for Bucharest, in 2006

Figures 11 and 12. Maps exported from ArcMap on the classification of pixels in Maximum Likelihood Classification for Bucharest, in 1991 and 2006

Results were imported in ArcMap, with which the maps of the pixels classified for 1991 and 2006 were made (Figures 11 and 12).

Between 1991 and 2006 the built surface of the city considerably increased, emphasizing at the same time a drastic reduction of the green surfaces, and, as we shall see later, a decrease in the health of vegetation, correlated with urban biodiversity loss, especially of birds.

The two maps of the analysis of the vegetation health state were made in ArcMap, by the calculation of the Normalized Differentiation Vegetation Index (NDVI).

Sanogena vegetation, with a greater amount of chlorophyll, absorbs most of the amount of red light it receives, and instead reflects a large part of the near

infrared radiation. Dry or rarefied vegetation reflects more of the received red light and less of the infrared radiation.

NDVI values vary depending on the absorption of the radiation by chlorophyll in red spectral area and its reflectance in the near infrared spectrum, and range between -1 and 1, expressing the green vegetation consistency (Mihai, 2007, 2009, 2013).

The NDVI, which is an index of plant greenness or photosynthetic activity, has been used to distinguished pixels which belong to vegetation features on the digital image from those of other features. The output of this work is a new image file with NDVI values ranging from -0.3 to 0.9 (Figures 13 and 14). Values close to +1 (light tones) represent a thick consistency of vegetation and are specific to the dense deciduous forests. Values
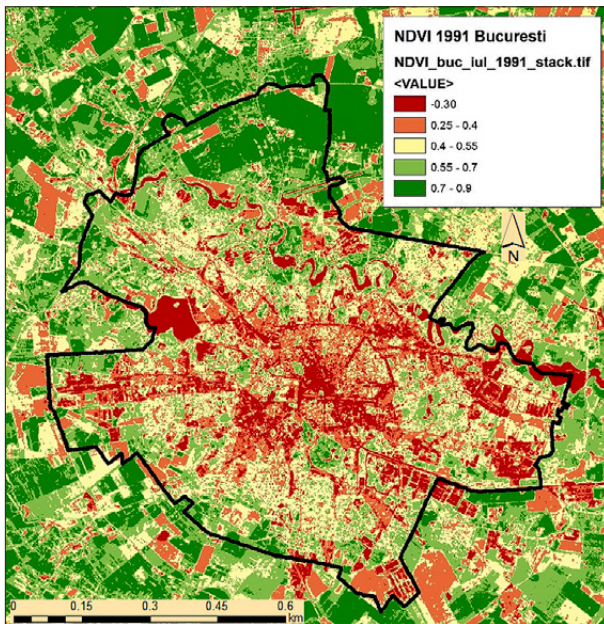
Figure 13. Map exported from ArcMAp as a result of the calculation of the Normalized Differentiation Vegetation Index – NDVI, in 1991

Figure 14. Map exported from ArcMAp as a result of the calculation of the Normalized Differentiation Vegetation Index – NDVI, in 2006

close to -1 (dark tones) represent the land devoid of vegetation. Values close to 0 (intermediate tones) are associated to the land with grass or crops.

As it can be observed in the analysis of the Figures 13 and 14, in 2006, compared to 1991, green areas decreased considerably, both the public use and private, being replaced by buildings (NDVI values of -30).

Street plantations of the urban green area category of general use, which normally contribute by their presence to "the binding" of the green area system of a city, were broken and diminished, many of them disappearing. Small sized green areas were replaced by buildings, and the new residential complexes were built without green areas. Perimeter plantations of the public institutions (hospitals, schools, kindergartens, factories, etc.), which protected them from neighborhoods and traffic arteries, diminished or disappeared. In addition, the existing plant vigor, as we see in Figure 14, linked to the quality of chlorophyll spectral response is greatly diminished, degraded because of maintenance deficiency, water stress, acid rain and various diseases affecting the quality of vegetation (NDVI values ranging between 0.25 and 0.55).

As we will see further, these radical transformation of the urban structure, within a period of only 15 years, had also major consequences at the level of the city biocenoses.

Data from the analysis of satellite images were correlated with the presence of bird species on the territory of Bucharest, in 1991 and 2006 (Papadopol, Petrescu, 1991, 2006).

Bucharest is the host of an impressive number of birds observed along a year. Avian community of the
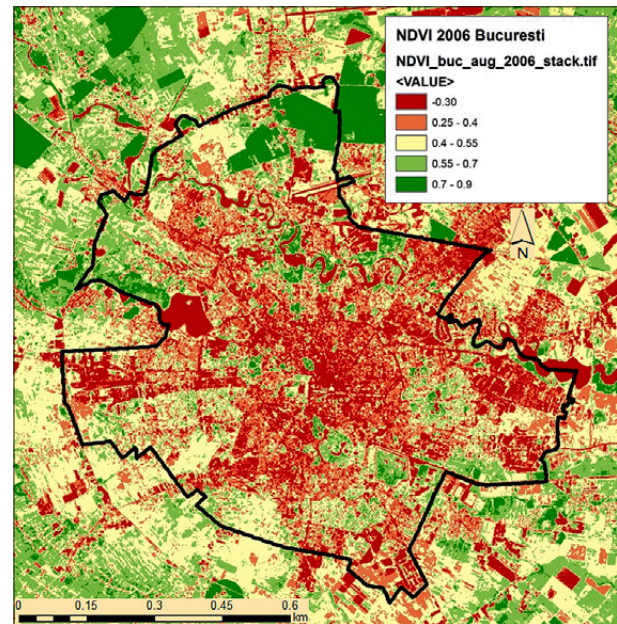
Bucharest city is made taxonomically of 135 bird species belonging to 19 orders, 44 families, 90 genera. The most numerous are Paseriformes, with 68 species (Table 2).

In the biocenoses where birds are included, and such kind of biocenoses are the most numerous, birds belong to different degrees of consumers, most of them having an important part in the general dynamics of the ecosystems, in the relationships and interactions between the biocenotic factors (Papadopol, Petrescu, 2006). Trophic relationships are the most important link between the species of a biocoenosis; every species becomes a link in the transfer and transformation of the substances and energy into biocenoses and ecosystem (Botnariuc, Vădineanu, 1982).

For Europeans, wild birds, most of them migratory, represent an extraordinary natural and cultural inheritance. Our continent is the home of over 530 species which can be observed along the year, with a total estimated population for over two billion pairs. Millions of them migrate to Africa, and others reach here, from the Arctic region or from Russia, during winter.

EU Biodiversity Strategy aims to achieve the objective of halting the loss of biodiversity, of the degradation of the ecosystem services and restoring them as quickly as possible by 2020, and as a major objective, increasing of flocks (BirdLife International, 2015). Therefore, the Birds Directive was a major part of the EU legislative framework on Biodiversity Conservation.

In Romania, the status of protection of the bird species of community interest (SOR, 2015) under the aegis of: Directive 2009/147/EC, Emergency Ordinance no. 57 of 20 June 2007, the Red Book of verte-

brates in Romania, Law 407/2006, Red List of Threatened Species IUCN 2012 - LR IUCN cat. 2012, Berne Convention 1979, Bonn Convention 1979, Agreement AEWA, Convention CITES (SOR, 2015).

According to specialized studies, the birds were classified in two large groups, one on species fenology and the other one related to the habitats where they were observed (Papadopol, Petrescu, 1991, 2006; Mohamad et al., 2013; Idilfitri et al., 2014; Morante-Filho et al., 2015) (Table 2, Figures 15 and 16).
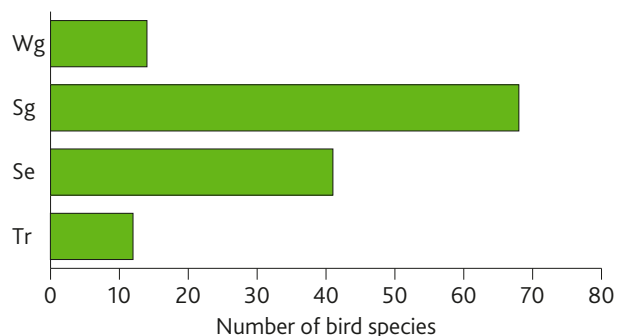

Figure 15. Species classification of the avian community after fenology (Wg=winter guest, Sg=summer guest, Tr=transit bird, Se=sedentary bird)
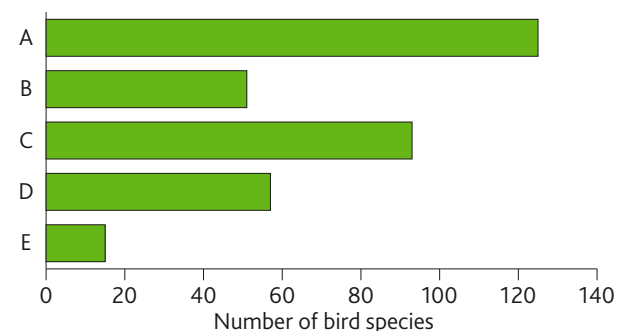

Figure 16. Classification of species of the avian community after the habitats they populate (A=large forests/parks which include (or not) large water surfaces; B=open lands, with a low vegetation; C=small parks, narrow green areas, private gardens; D=areas with water (rivers, lakes) with low or average high vegetation; E=prevalent built areas, with a scarce vegetation

The phenological division of the avian community of Bucharest was made: sedentary birds (those which stay in these ecosystems all along the year), summer guests (migratory birds which remain and nestle in Bucharest), winter guests (birds which visit the city only in winter) and transit birds (migratory birds which stop in the city for resting and foraging while crossing in spring and in autumn (Figure 15, Table 2).

Analyzing the avifauna (1991-2006), the authors took into account several habitats characteristic of the city, not including surrounding areas, which we have classified into five major categories (Figure 16, Table 2): A=large forests/parks, which include (or not) large

water surfaces; B=open lands, with low vegetation; C=small parks, narrow green areas, private gardens with low grassy vegetation and old trees; D=areas with water (rivers, lakes) with a low or average high vegetaion; E=prevalent built areas, with scarce vegetation.

Tree and shrub vegetation, of different age, provides nesting and resting places, but also various foraging sources for the four bird categories: Sedentary, Summer guest, Winter guest, migratory birds (long distance migrating species of birds).

Vast forests and parks, which include large areas of water, are populated with over 120 species of birds. This category includes large parks of the city aged over 100 years as Cismigiu, Kiseleff and Herastrau, or parks under 40-70 years as Youth Park, Polytechnic Park, Izvor Park or Alexandru Ioan Cuza Park (Titan Park or IOR Park), plus other midsized parks of different ages.

Till 1991, these areas were unaltered, in which there were also some day raptor birds as *Milvus milvus, Pernis apivorus, Buteo buteo* of night raptor birds as *Strix aluco, Otus scops* were present, either in transit or nesting, all of them species places at the top of the food chain. The presence of the prey birds is an indicator of some stable biocenoses, with a large biodiversity, which provides the source of food and nesting. Along the time, their surface was slightly diminished by construction of buildings, but generally, the changes made by the maintenance works, tree cuts or maintaining the grassy vegetation, did not alter at a large scale the components of avifauna. As a matter of fact, in this kind of habitat, similar to a forest, are living 68 species of insectivorous birds, as well as some species of baccivore-granivorous and/or omnivorous birds.

In terms of quality, summer guest birds are prevalent within avifauna, as nesting ones, most of them insectivores, being the proof of the high biodiversity which still exists here, both flora and fauna.

The absence of the large day and night birds of prey, after 2006, can be explained by the fact that these large green areas were, in time, surrounded by the residential areas, which isolate them from the forest and land net which around Bucharest. Before 1990, among them there were free lanes so that a natural flow of immigration and emigration fauna existed between the city and the natural green areas around Bucharest, without obstacles, allowing biocoenoses to remain stable through this natural flow of wildlife. Birds of prey need large territories for foraging, sometimes of tens of km², with low vegetation. Large park areas, almost entirely covered with trees and shrubs, do not always provide an optimum habitat for foraging, so the birds must seek new hunting territories outside the city. Daily crossings between the places of resting

Table 2. The birds present in the city of Bucharest in 1991 and 2006 (Papadopol, Petrescu, 1991; Papadopol, Petrescu, 2006). Legend: ▲=species presence; △=species absence.

	BIRD SPECIES		ORDER	FENOLOGY	HABITAT	1991	2006
1	*Accipiter nisus* (Eurasian sparrowhawk)		Accipitriformes	Wg	A, B, C, E	▲	▲
2	*Acrocephalus scirpaceus* (Eurasian reed-warbler)		Passeriformes	Sg	A, D	▲	▲
3	*Acrocephalus arundinaceus* (Great reed warbler)		Passeriformes	Sg	A,C,D	▲	▲
4	*Aegithalos caudatus* (Long-tailed tit)		Passeriformes	Se	A, B, C, D,	▲	▲
5	*Alcedo atthis* (Common kingfisher)		Coraciiformes	Se	A, D	▲	△
6	*Anas crecca* (Common teal)		Anseriformes	Wg	A, D	△	▲
7	*Anas acuta* (Northern pintail)		Anseriformes	Tr	A, D	△	▲
8	*Anas platyrhynchos* (Mallard)		Anseriformes	Se	A, D	▲	▲
9	*Anthus trivialis* (Tree pipit)		Passeriformes	Sg , Tr	A, B, C	▲	▲
10	*Anthus spinoletta* (Water pipit)		Passeriformes	Sg , Tr	A, B, C	△	▲
11	*Apus apus* (Common swift)		Caprimulgiformes	Sg	A, C, D, E	▲	▲
12	*Ardeola ralloides* (Squacco heron)		Pelecaniformes	Sg	A, D	▲	▲
13	*Ardea cinerea* (Grey heron)		Pelecaniformes	Sg	A, D	▲	▲
14	*Asio otus* (Long-eared owl)		Strigiformes	Se	A, D	▲	▲
15	*Athene noctua* (Little owl)		Strigiformes	Se	A, C, E	▲	▲
16	*Aythya nyroca* (Ferruginous duck)		Anseriformes	Sg	A, D	△	▲
17	*Aythya ferina* (Common pochard)		Anseriformes	Sg	A, D	△	▲
18	*Bombycilla garrulus* (Bohemian waxwing)		Passeriformes	Wg	A, B, C, E	▲	▲
19	*Buteo buteo* (Common buzzard)		Accipitriformes	Se , Tr	A, B, C	▲	△
20	*Charadrius dubius* (Little ringed plove)		Charadriiformes	Sg	A, D	▲	△
21	*Caprimulgus europaeus* (European nightjar)		Caprimulgiformes	Sg , Tr	A, B, C	▲	△
22	*Carduelis carduelis* (European goldfinch)		Passeriformes	Se , Tr	A, B, C	▲	▲
23	*Carduelis cannabina* (Eurasian linnet)		Passeriformes	Se , Tr	A, B, C	▲	▲
24	*Carduelis chloris* (European greenfinch)		Passeriformes	Se	A, B, C	▲	▲
25	*Carduelis spinus* (Eurasian siskin)		Passeriformes	Sg	A, B, C	▲	▲
26	*Certhia familiaris* (Eurasian treecreeper)		Passeriformes	Se	A, B, C	▲	▲
27	*Ciconia ciconia* (White stork)		Ciconiiformes	Sg , Tr	B, D	▲	△
28	*Circus aeruginosus* (Western marsh-harrier)		Accipitriformes	Sg	B, D	△	▲
29	*Chlidonias hybrida*	(Whiskered tern)	Charadriiformes	Sg	A, D	△	▲
30	*Coccothraustes coccothraustes* (Hawfinch)		Passeriforme	Se	A, B, C	▲	▲
31	*Columba palumbus* (Common woodpigeon)		Columbiformes	Sg	A, B, C	▲	△
32	*Columba livia domestica* (Rock dove)		Columbiformes	Se	C, E	▲	▲
33	*Coracias garrulus* (European roller)		Coraciiformes	Sg	A, B, C, D	▲	△
34	*Corvus corone sardonius* (Carrion crow)		Passeriformes	Se	A, B, C, E	▲	▲
35	*Corvus frugilegus* (Rook)		Passeriformes	Se	A, B, C	▲	▲
36	*Corvus monedula* (Eurasian jackdaw)		Passeriformes	Se	A, B, C, D, E	▲	▲
37	*Cuculus canorus* (Common cuckoo)		Cuculiformes	Sg	A, B, C	▲	▲
38	*Crex crex* (Corncrake)		Gruiformes	Sg	A, B, C	▲	△
39	*Cygnus olor* (Mute swam)		Anseriformes	Sg	A, D	△	▲
40	*Delichon urbicum* (Northern house-martin)		Passeriformes	Sg	C, E	▲	▲
41	*Dendrocopos major* (Greater spotted woodpecker)		Piciformes	Se	A, C	▲	▲
42	*Dendrocopos syriacus* (Syrian woodpecker)		Piciformes	Se	A, C	▲	▲
43	*Dryobates minor* (Greater spotted woodpecker)		Piciformes	Se	A, C	▲	△
44	*Egretta alba* (Great white egret)		Pelecaniformes	Tr	A, D	△	▲

Analysis of vegetation from satelite images correlated to the bird species presence and the state of health of the ecosystems of Bucharest during the period from 1991 to 2006

	BIRD SPECIES	ORDER	FENOLOGY	HABITAT	1991	2006
45	*Egretta garzetta* (Little egret)	Pelecaniformes	Tr / Sg	A, D	△	▲
46	*Emberiza citrinella* (Yellowhammer)	Passeriformes	Se , Wg	A, B, C	▲	▲
47	*Emberiza hortulana* (Ortolan bunting)	Passeriformes	Sg	A, B, C	▲	▲
48	*Emberiza schoeniclus* (Reed bunting)	Passeriformes	Wg	A, D	▲	△
49	*Erithacus rubecula* (European robin)	Passeriformes	Sg , Wg	A, B, C	▲	▲
50	*Falco tinnunculus* (Common kestrel)	Falconiformes	Se	A, C	▲	▲
51	*Falco vespertinus* (Red footed falcon)	Falconiformes	Sg Tr	A, C	△	▲
52	*Falco subbuteo* (Eurasian hobby)	Falconiformes	Sg Tr	A, C	△	▲
53	*Ficedula albicollis* (Collared flycatcher)	Passeriformes	Tr	A, B, C	▲	△
54	*Ficedula hypoleuca* (European pied flycatcher)	Passeriformes	Sg , Tr	A, B, C	▲	△
55	*Fringilla coelebs* (Eurasian chaffinch)	Passeriformes	Se	A, C	▲	▲
56	*Fringilla montifringilla* (Brambling)	Passeriformes	Wg	A, C	▲	▲
57	*Fulica atra* (Common coot)	Gruiformes	Sg	A, D	▲	▲
58	*Gallinago gallinago* (Common snipe)	Charadriiformes	Sg	A, D	▲	△
59	*Gallinula chloropus* (Common moorhen)	Gruiformes	Se	A, D	▲	▲
60	*Galerida cristata* (Crested lark)	Passeriformes	Se	A, D	▲	▲
61	*Garrulus glandarius* (Eurasian jay)	Passeriformes	Se	A, C	▲	▲
62	*Gavia arctica* (Arctic loon)	Gaviiformes	Wg, Tr	A, D	▲	△
63	*Ixobrychus minutus* (Little bittern)	Pelecaniformes	Sg	A, D	▲	△
64	*Jynx torquilla* (Eurasian wryneck)	Piciformes	Sg	A, D	▲	▲
65	*Hippolais icterina* (Icterine warbler)	Passeriformes	Sg	A, B, C, D	▲	▲
66	*Hippolais pallida* (Eastern olivaceous warbler)	Passeriformes	Sg	A, C	▲	▲
67	*Hirundo rustica* (Barn swallow)	Passeriformes	Sg	A, B, C, E	▲	▲
68	*Lanius collurio* (Red-backed shrike)	Passeriformes	Sg	A, C	▲	△
69	*Lanius minor* (Lesser grey shrike)	Passeriformes	Sg	B, D	▲	△
70	*Larus cachinnans* (Caspian gull)	Charadriiformes	Se	A, C, D	▲	▲
71	*Larus canus* (Mew gull)	Charadriiformes	Wg	A, C, D	▲	▲
72	*Larus marinus* (Great Black-backed Gull)	Charadriiformes	Wg	A, C, D	△	▲
73	*Larus ridibundus* (Black-headed gull)	Charadriiformes	Se	A, C, D	▲	▲
74	*Leiopicus medius* (Middle spotted woodpecker)	Piciformes	Se	A, C	▲	▲
75	*Loxia curvirostra* (Red crossbill)	Passeriformes	Wg	A	▲	▲
76	*Lullula arborea* (Wood Lark)	Passeriformes	Wg	A, C	▲	△
77	*Luscinia luscinia* (Trush nightingale)	Passeriformes	Sg	A, C	▲	▲
78	*Luscinia megarhynchos* (Common nightingale)	Passeriformes	Sg	A, C	▲	▲
79	*Mareca penelope* (Eurasian wigeon)	Anseriformes	Wg-Tr	A, D	▲	▲
80	*Mareca strepera* (Gadwall)	Anseriformes	Sg	A, D	▲	△
81	*Miliaria calandra* (Corn bunting)	Passeriformes	Sg	A, B	▲	△
82	*Milvus milvus* (Red kite)	Accipitriformes	Tr	A, C	▲	△
83	*Motacilla alba* (White wagtail)	Passeriformes	Sg , Tr	A, B, C	▲	▲
84	*Motacilla cinerea* (Grey wagtail)	Passeriformes	Tr, Sg	A, B, C	▲	△
85	*Motacilla flava* (Yellow wagtail)	Passeriformes	Sg , Tr	A, B, C	▲	▲
86	*Muscicapa striata* (Spotted flycatcher)	Passeriformes	Sg	A, C	▲	▲
87	*Nycticorax nycticorax* (Black-crowned night heron)	Pelecaniformes	Sg	A, D	▲	▲
88	*Oriolus oriolus* (Eurasian golden oriole)	Passeriformes	Sg	A, C, E	▲	▲
89	*Otus scops* (Eurasian scops owl)	Strigiformes	Sg	A, C	▲	△
90	*Parus caeruleus* (Blue tit)	Passeriformes	Se	A, C	▲	▲

	BIRD SPECIES	ORDER	FENOLOGY	HABITAT	1991	2006
91	*Parus lugubris* (Sombre tit)	Passeriformes	Se	A, C	▲	△
92	*Parus major* (Great tit)	Passeriformes	Se	A, C	▲	▲
93	*Passer domesticus* (House sparrow)	Passeriformes	Se	C, E	▲	▲
94	*Passer montanus* (Eurasian tree sparrow)	Passeriformes	Se	A, C	▲	▲
95	*Perdix perdix* (Grey partridge)	Galiiformes	Se	A, B, C	▲	△
96	*Pernis apivorus* (European honey-buzzard)	Accipitriformes	Tr	A	▲	△
97	*Phalacrocorax carbo* (Great cormorant)	Suliformes	Sg	A, D	△	▲
98	*Phylloscopus sibilatrix* (Wood warbler)	Passeriformes	Sg Tr	A	▲	▲
99	*Phoenicurus ochruros* (Black redstart)	Passeriformes	Sg	A, C	▲	▲
100	*Phoenicurus phoenicurus* (Common redstart)	Passeriformes	Sg	A, B, C, D, E	▲	▲
101	*Pica pica* (Black-billed magpie)	Passeriformes	Se	A, C, E	▲	▲
102	*Picus canus* (Grey-headed woodpecker)	Piciformes	Se	A, C	▲	▲
103	*Picus viridis* (Eurasian green woodpecker)	Piciformes	Se	A, C	▲	▲
104	*Podiceps cristatus* (Great crested grebe)	Podicipediformes	Sg	A, D	▲	△
105	*Porzana porzana* (Spoted crake)	Gruiformes	Sg	A, D	▲	△
106	*Phylloscopus collybita* (Common chiffchaff)	Passeriformes	Sg , Tr	A, C	▲	▲
107	*Phylloscopus trochilus* (Willow warbler)	Passeriformes	Tr	A, C	▲	▲
108	*Prunella modularis* (Hedge accentor)	Passeriformes	Wg	A, B, C, D	▲	△
109	*Pyrrhula pyrrhula* (Eurasian bullfinch)	Passeriformes	Wg	A, B, C	▲	▲
110	*Rallus aquaticus* (Western water rail)	Gruiformes	Sg	D	▲	△
111	*Remiz pendulinus* (Eurasian penduline-tit)	Passeriformes	Sg / Se	A, B, C, D	▲	△
112	*Riparia riparia* (Sand Martin)	Passeriformes	Sg	C	▲	△
113	*Scolopax rusticola* (Eurasian woodcock)	Charadriiformes	Tr	A, C, D	▲	▲
114	*Sitta europaea caesia* (Wood nuthatch)	Passeriformes	Se	A, B, C	▲	▲
115	*Spatula clypeata* (Northern shoveler)	Anseriformes	Sg	A, D	▲	△
116	*Spatula querquedula* (Garganey)	Anseriformes	Sg	A, D	▲	△
117	*Streptopelia decaocto* (Eurasian collared-dove)	Columbiformes	Se	C, D, E	▲	▲
118	*Streptopelia turtur* (European turtle-dove)	Columbiformes	Sg	C, D, E	▲	△
119	*Strix aluco* (Tawny owl)	Strigiformes	Se	A, C	▲	△
120	*Sturnus vulgaris* (Common starling)	Passeriformes	Sg , Se	A, B, C	▲	▲
121	*Sylvia atricapilla* (Blackcap)	Passeriformes	Sg	A, B, C	▲	▲
122	*Sylvia borin* (Garden warbler)	Passeriformes	Sg Tr	A, B, C	▲	▲
123	*Sylvia communis* (Common whitethroat)	Passeriformes	Sg Tr	A, B, C, D	▲	▲
124	*Sylvia curruca* (Lesser whitethroat)	Passeriformes	Sg Tr	A, B, C	▲	▲
125	*Sylvia nisoria* (Barred warbler)	Passeriformes	Sg Tr	A, B, C	▲	▲
126	*Tachybaptus ruficollis* (Little grebe)	Podicipediformes	Se	A, D	△	▲
127	*Tringa ochropus* (Green sandpiper)	Charadriiformes	Tr	A, D	▲	△
128	*Troglodytes troglodytes* (Winter wren)	Passeriformes	Sg , Tr	A, B, C	▲	▲
129	*Turdus iliacus* (Redwing)	Passeriformes	Wg, Tr	A, B, C	▲	▲
130	*Turdus merula* (Eurasian blackbird)	Passeriformes	Se , Sg , Tr	A, B, C, D, E	▲	▲
131	*Turdus philomelos* (Song trush)	Passeriformes	Sg	A, B, C	▲	▲
132	*Turdus pilaris* (Fieldfare)	Passeriformes	Tr, Se	A, C	▲	▲
133	*Turdus viscivorus* (Mistle thrush)	Passeriformes	Tr	A, C	▲	▲
134	*Upupa epops* (Common hoopoe)	Bucerotiformes	Sg	A, B, C, D	▲	△
135	*Vanellus vanellus* (Northern lapwing)	Charadriiformes	Sg	A, D	▲	△

Source: *Data collected by authors*

or nesting and the foraging territory are blocked by numerous tall buildings, brightly lit, or by high traffic associated with high noise (ring road), which represent limiting factors for birds. The response to the high stress of these limiting factors is that birds leave these habitats that no longer provide optimal environmental conditions.

Small parks, narrow green spaces, private gardens with low herbaceous vegetation and old trees form a class of preferred habitat for over 75 bird species which have found shelter, food or nesting spot. As it can be seen on satellite maps of vegetation areas of 1991, the largest area of vegetation in Bucharest is occupied by a mosaic of green islands, isolated by buildings and streets, that are scattered randomly over the entire city. This mosaic was represented by houses with private gardens, small parks, squares, or by the street lining which separate and protect, from neighborhoods or heavy traffic arteries, the residential areas built until 1991.

Between 1970-1990, Bucharest underwent an extensive modernization action, which involved an unprecedented aggression on small buildings and green spaces. Central part of the city was demolished and hundreds of old houses with greenery around them but also with private backyards, where they were stable biocenosed for hundreds of years, were destroyed. In their place appeared a mosaic of bare land, which, in a few years, began to be colonized by pioneer herbaceous vegetation and several species of shrubs. All these vacant lands, left in ruins, were occupied successively by species of insects and other anthropophilous invertebrates, mammals, reptiles and birds. Simultaneously with the demolition of old buildings, on the outskirts residential areas begin to be build, designed without green areas, only with tree curtains that separate the buildings from each other or from the streets. Untill 1990, the construction of these residential areas on the outskirts produced a strong fragmentation of natural ecosystems that surrounded the city and who had a stable biocenosis. In 1991-2006 period, all vacant terraines appeared after demolition, associated with other uncovered lands, with low vegetation, became the target of real estate investments, and many of them disappeared, being covered with parking lots, buildings and large residential areas, which explains

the absence of over 17 species of insectivorous or carnivorous birds whose life was linked to trees and shrubs, insects and other species of fauna (Figure 17).

Water areas (rivers, lakes) with low or average high vegetation, associated with large areas of water from parks, are a category of habitat preferred by 87 bird species in Bucharest.

Bucharest hydrographic network includes large water reservoirs on both Colentina, decorated with many ponds, and Dambovita River that crosses Bucharest. In 1980, Dambovita underwent a radical change, the banks were embanked and concreted, and all the terrestrial and aquatic biocoenoses developed on the left and right banks of this river were destroyed. After 1990, the recovering of the aquatic biocenosis have began; the river flow within the city was populated with fauna naturally brought by the upstream water flow, and also the first vertrebate colonizer of the river appear, *Anas platyrhynchos* (Mallard), as anthropophilous species, nesting on Dambovita. Also during the summer, this river flow is the foraging area for *Larus cachinnans*, nesting species on the buildings of Bucharest since 1974. In the cold season, there is wintering place, inside the city, for *Larus ridibundus, Fulica atra, Anas platyrhynchos* and *Larus cachinnans.*

In the hydrographic management plan of Dambovita River of the '80s, it was also included the arranging of the Vacaresti Lake, a large stretch of water, which was to be supplied from Dambovita. After 1990, the work was abandoned, part of the lake basin bordered by concrete embankments is covered by water provided by its own springs and rain. In time, vacant nude land, was covered by vegetation and partially by water and colonized by a rich fauna. Today, it is a well stable biocenosis, where more than 115 bird species live, along with many other species of invertebrates and vertebrates. The appearance of this surface of about 170 ha of water and vegetation encouraged the Anseriformes species to seek new places for nesting and foraging in Bucharest (Figure 18).

Since 1990, there were remarked species as: *Aythya nyroca, Aythya ferina, Cygnus olor,* not reported in Bucharest till then. Also here, species which prefer aquatic environment were also observed: *Fulica atra, Chlydonias hybridus, Podiceps cristatus, Egretta garzetta, Egretta alba, Phalacrocorax carbo, Ardea cinerea, Ardea purpurea*, etc. The emergence and development of the wetlands with a large surface, similar to a natural wetland, made it possible to live within the city or to nest more than 15 species of waterfowl, unreported until 2006. Subsequently, Vacaresti Lake was proposed for the creation of an Urban Natural Park, as a protected area, recognized today.

Predominantly built areas, with little vegetation, are represented by the old buildings and the build-
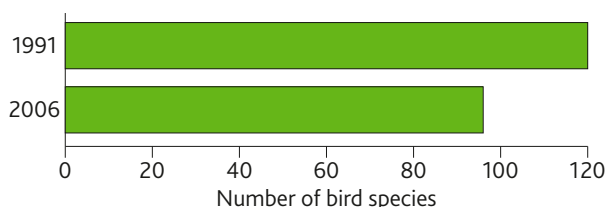

Figure 17. Comparative diagram of the number of bird species, for 1991 and 2006

Mirela Dragoș, Angela Petrescu,
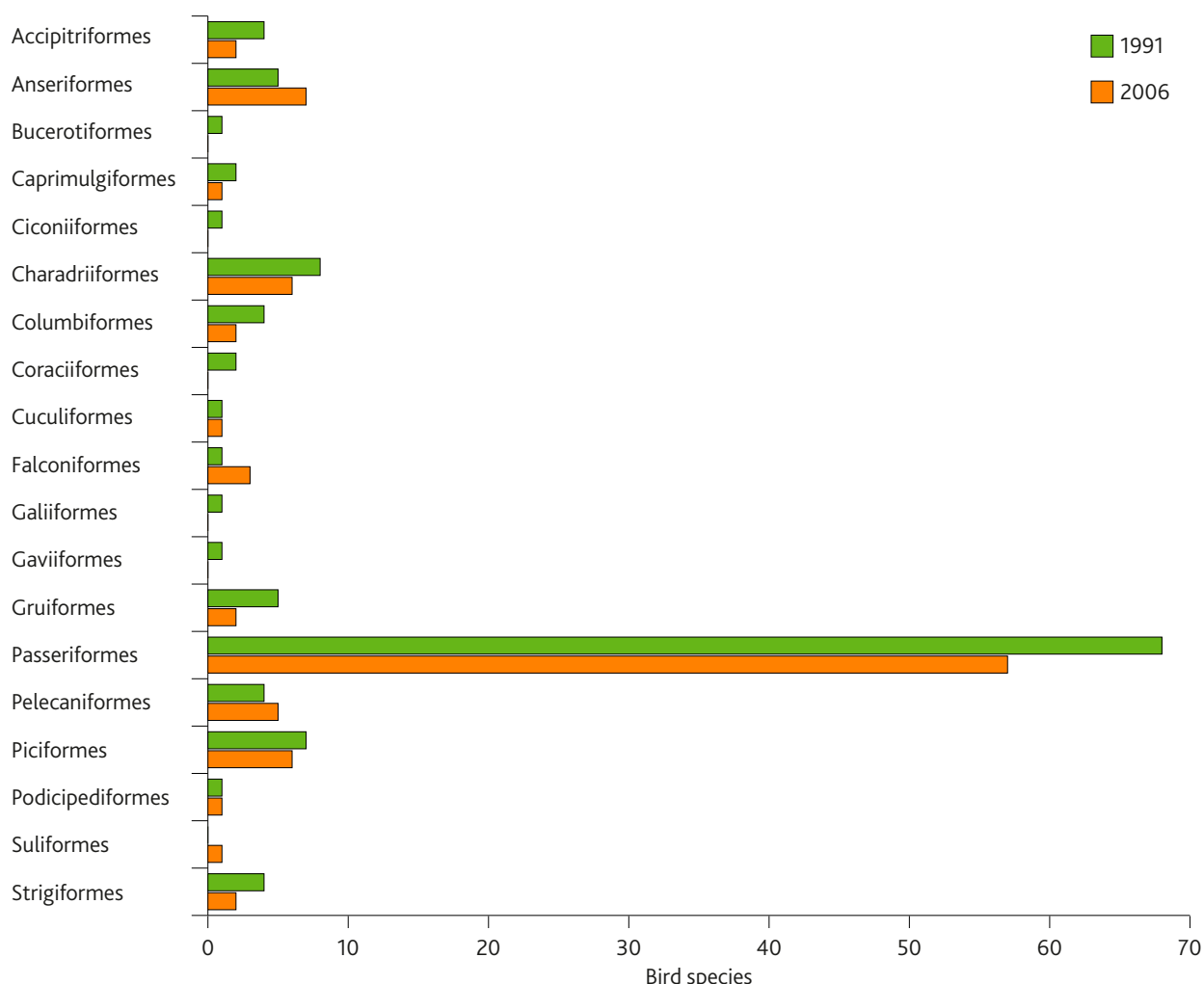George-Laurențiu Merciu

Figure 18. The number of birds per order, present in Bucharest in 1991 and 2006

ings of the residential areas. These habitats are preferred by some bird species adapted to rest or nest using these resources. *Passer domesticus, Hirundo rustica, Delichon urbica, Apus apus, Phoenicurus ochruros gibraltariensis, Athene noctua, Coloeus monedula, Falco tinnunculus* and *Larus cachinnans* are the species which prefer to nest in/on the buildings of Bucharest. Between 1991-2006 the number of nesting places of *Delichon urbica* and *Hirundo rustica* drastically decreased, on one hand, because of the lack of the optimum nesting places, by the demolition of the old buildings with roof and eaves, because of the lack of the material necessary for the nest building (water, mud, vegetal fibers), and, on the other hand, the lack of food, represented exclusively by insects. At first, *Larus cachinnans* nested on the roof of the high buildings of Bucharest, and now it nests on the blocks of flats around Dambovita River or in the parks with large water surfaces. *Coloeus monedula*, nesting species, was frequent till 1990, today it is quite rare, because the lack of the nesting places, because it prefers the roofs with chimnies. Because of

the modern type of domestic heating, new buildings do not have chimnies, or those already built of metal, covered, and do not allow the nest construction. *Falco tinnunculus* is a cosmopolitan bird that nests here since 1990 on the highest building in Bucharest, Palace of Parliament (House of the People).

It is known that, ecologically, each species of the ecosystem provides services directly or indirectly, bringing benefits to both the environment and people. Functions of birds in urban environment can be grouped into three categories: ecological, psychological and social (Idilfitri et al., 2014). Insectivorous birds help plants by the control and the quantity of insects they eat from tree bark, leaves and branches, while the omnivorous birds control the populations of vertebrates (micromammals, reptiles, etc) penetrating the residential areas. Psychologically, chirping birds and their game on twigs and soil, improve the viewers' state of relaxation. And socially, the abundance of the bird species in green areas increase the value of the area both by aesthetic appearance and by economic/estate aspect.

Conclusion

The urban vegetation adequate monitoring and conservation are great current ecological challenges due to the fact that it is an important key to understand and manage urban development. In the field of environmental protection and vegetation conservation, contemporary trends are related to the use of recent remote sensing technologies applied in order to realize scientific and research aims and tasks.

The modern technologies provide many useful data to the urban planners and to other decision makers on the urban green spaces' dynamics and on the decisions to be made (areas that require replanting, new planting locations etc.).

This paper studied the efficacity of satellite imagery for extracting urban trees, a necessary action in the context of an accelerate rate of urbanisation of the capital town. The paper proved that the satellite images represent a suitable technology and a viable source of information for urban planners and other decision makers to evaluate, enhance urban landscape patterns and facilitate a better understanding of the current spatial distribution and typology of trees in Bucharest Municipality.

In this study, the results of satellite images have demonstrated the present state of the environment and the effects upon it (fragmentation, state of health) in the Bucharest Municipality. Therefore, based on these results, control and protection measures for the vegetation cover of the municipality of Bucharest will be proposed. Furthermore, these proposals will be an important element in the process of decision making for the conservation of urban vegetation.

Another object of interest in this study was the correlation between habitats and bird species (those being chosen as a quality indicator of the environment).

Within the period 1991-2006, from the ecosystems of Bucharest, 38 bird species, most of them Passeriformes, alongside Strigiformes, Falconiformes and Piciformes, have disappeared; they were characteristic to tree and shrub vegetation formed in large and groups, of various ages, fructifications and rich canopy. Controversely, the emergence and development of the wetland Vacaresti Delta, with a large-area, similar to a natural wetland, led to the emergence within the city of more than 15 species of waterfowl unreported until 2006.

Birds have a significant biological and economic value through the benefits they bring, having a major role in controlling insect species and pollination. Protecting and preserving the habitats they live in, it also increases the biological value of the ecosystems and ecosystem services, and social values of urban communities. One of eight bird species is threatened with extinction and their number continues to grow because of the habitat destruction, climate change and invasive species (BirdLife International, 2015).

Therefore, future work should concentrate on developing an approach by which to identify a solution to make more accessible the urban habitats for several species.

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