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GIS TECHOLOGY IN REGIONAL RECOGNITION OF THE DISTRIBUTION PATTERN OF MULTIFLORAL HONEY: THE CHEMICAL TRAITS IN SERBIA

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Abstract - GIS is a computer-based system to input, store, manipulate, analyze and output spatially referenced data. There is a huge range application of GIS that generally sets out to fulfill: mapping, measurement, monitoring, modeling and management. In this study, GIS technology was used for the regional recognition of origin and distribution patterns of multifloral honey chemical traits in Serbia. This included organizing and analyzing the spatial and attributive data of 164 honey samples collected from different regions of Serbia during the harvesting season of 2009. Multifloral honey was characterized in regards to mineral composition, sugar content and basic physicochemical properties. The kriging method of Geostatistical Analyst was used for interpolation to predict values of a sampled variable over the whole territory of Serbia

Keywords: Geographic Information System, Geostatistical Analyst, multifloral honey; geographical origin; distribution pattern; Serbia.

INTRODUCTION

Geographic information systems (GIS), remote sensing, dynamic-simulation modeling and geostatistics, are utilized in a variety of scientific and professional endeavors, ranging from forestry, landscape mapping and watershed ecology to archaeology, pollution detection and geology. Today GIS is also used for wide specter of research dealing with ecotoxicology, recognition of distribution of chemical components in all environmental media – air, water and soil, as well as in biota and their products. For ecologists GIS has opened many new possibilities for research and the application of gathered information. Because the system of environment is highly complex, we most often tend to study them by focusing on small, discrete simplified aspects. However, most of the problems in the environment are multifactorial and demand the analysis of a wide spectrum of information resources, questions and interests. For most ecological studies we need more spatially explicit and quantified information about the factors that might actually explain the observed environmental variables, distributions and patterns of landscape features. We can achieve this by adding information about geology, soil type, climate, hydrology, distribution and the behavior of

wild species (Radović et al., 2005a; Radović et al., 2005b; Radović et al., 2007; Ćirović et al., 2008; Denoel et al., 2009).

The main goal of this work was to identify the geographical origin of multifloral honey and its chemical variables on the territory of Serbia. This was achieved by implementing geographic information systems and geostatistical interpolation methods in interpretation of the results of univariate data analysis (descriptive statistics and analysis of variance), and pattern recognition methods (principal component analysis and cluster analysis) for the 164 investigated multifloral honey samples of different geographical origin from Serbia (Lazarević et al., 2013). Spatial and relational databases are integrated into Geographical Information Systems (GIS) and produce 26 thematic maps representing the spatial distribution of chemical variables of multifloral honey on the territory of Serbia.

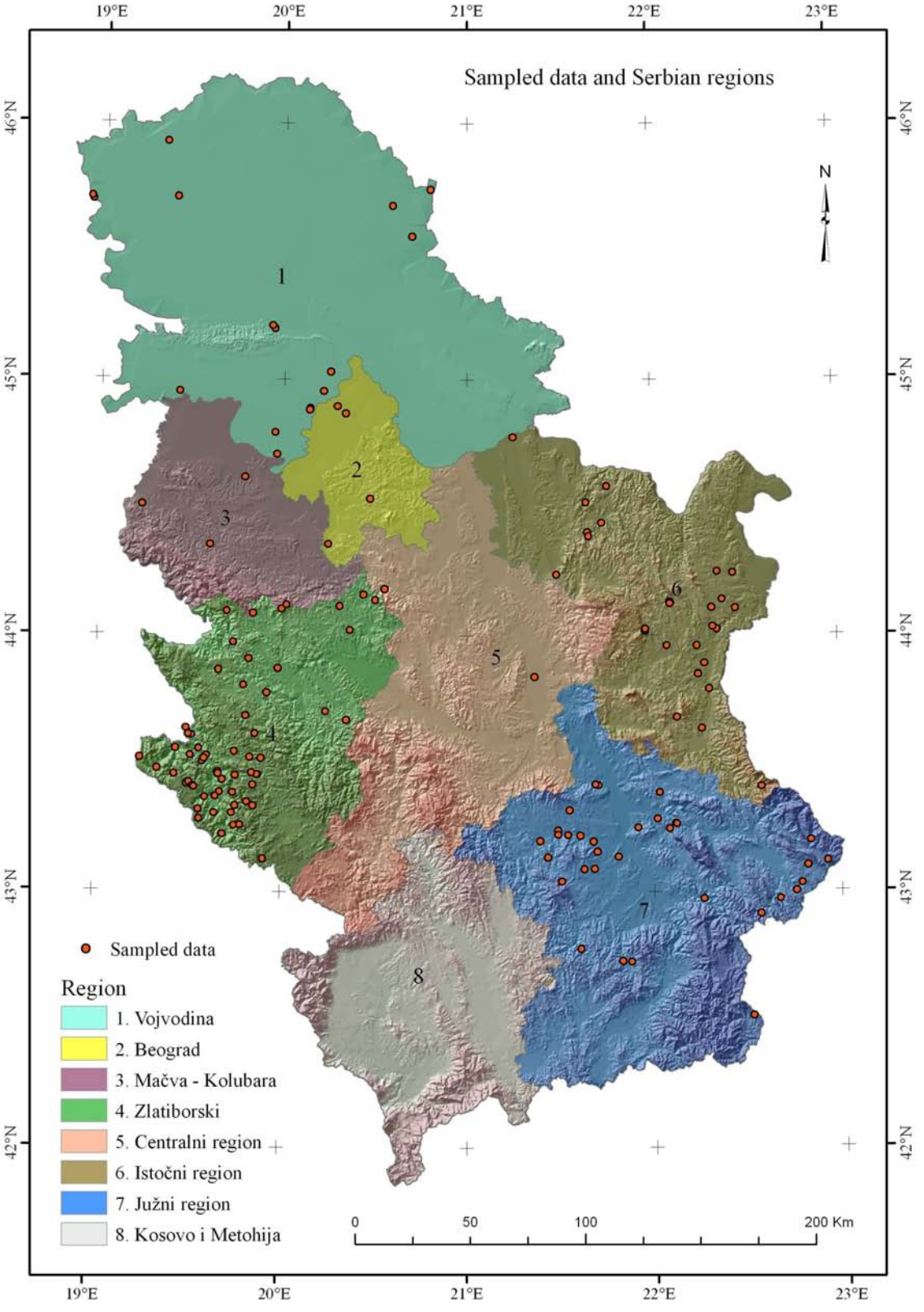
Honey is a complex mixture because its composition and properties depend not only on the nectar-providing plant species, but also on other factors such as bee species, geographic area, season, mode of storage, and even harvest technology and conditions. The European Council directive 2001/110/EC concerning honey allows specific denominations of honey, where the name "honey" can be supplemented by information about the floral, vegetable, regional, territorial or topographical origin. The term "unifloral honey" is used to describe honey in which most of the nectar or honeydew is derived from a single plant species. The overwhelming majority of honeys on the market contain nectar or honeydew from several plant species in the foraging area of the beehive and are, therefore, called multifloral or polyfloral honey. Honey composition is tightly associated to its botanical origin, which is closely related to the geographical area from which the honey originated (Kropf et al., 2009; Kaškoniene and Veskutionis 2010; Lazarević et al., 2013). Honey composition is very dependent on geographical location, even for the same plant species, as the accumulation of phytochemicals depends on climatic conditions (sunlight, temperature, precipitation and moisture), soil characteristics, and the presence of different minerals arising from soil (Bogdanov et al., 2007; Pellerano et al., 2012). This suggests that the chemical composition of honeys, even of the same floral origin but from different geographical origin, may be quite different (Castro-Varquez, 2010; Ruoff et al., 2006). Over the last few decades, there have been several reports on the use of multivariate chemometric analysis of the general physicochemical parameters, minerals, sugars, and other constituents in order to differentiate types of unifloral honeys, honeydew and blossom honeys (Arvanitoyannis et al., 2005; Nalda et al., 2005; Šarić et al., 2008; Baroni et al., 2009; Lazarević et al., 2013).

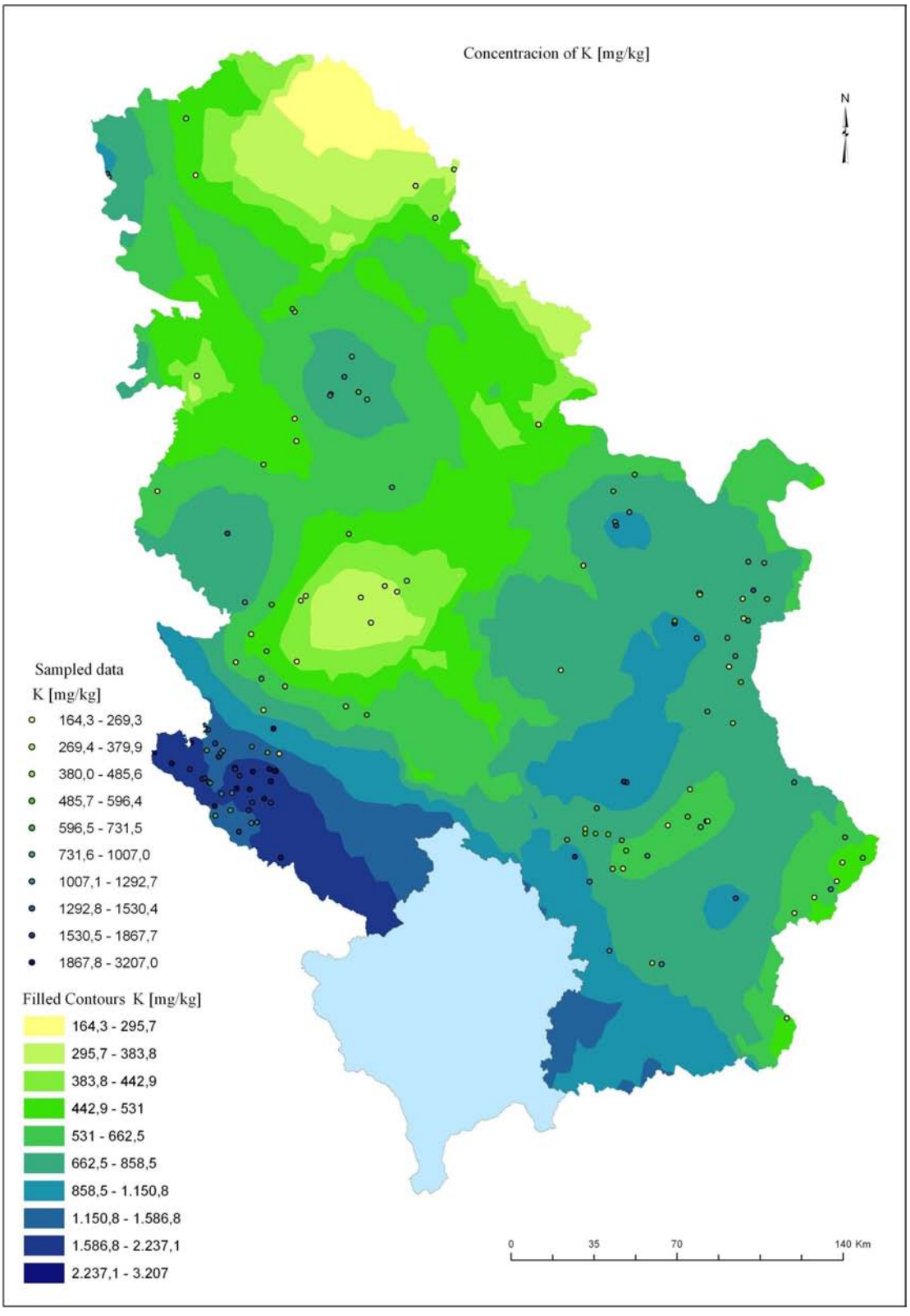
Serbia has very good prerequisites for the development of beekeeping (apiculture), distinguished by the heterogeneous relief and climatic conditions and by the existence of various honeybee pastures. Considering the area of wild flora, it would be possible to breed up to 800 000 bee colonies (Lazarević et al., 2012). However, despite this possibility, the current utilization of potential is only 33.4%, resulting in an annual production of 4 000-5 000 tons of honey (Marinković and Nedić, 2010), (www.webrazs.stat.gov.rs 2013) According to the annual honey production, Serbia is in the middle of the list of EU member states (www.eurostat.ec.europa.eu 2013).

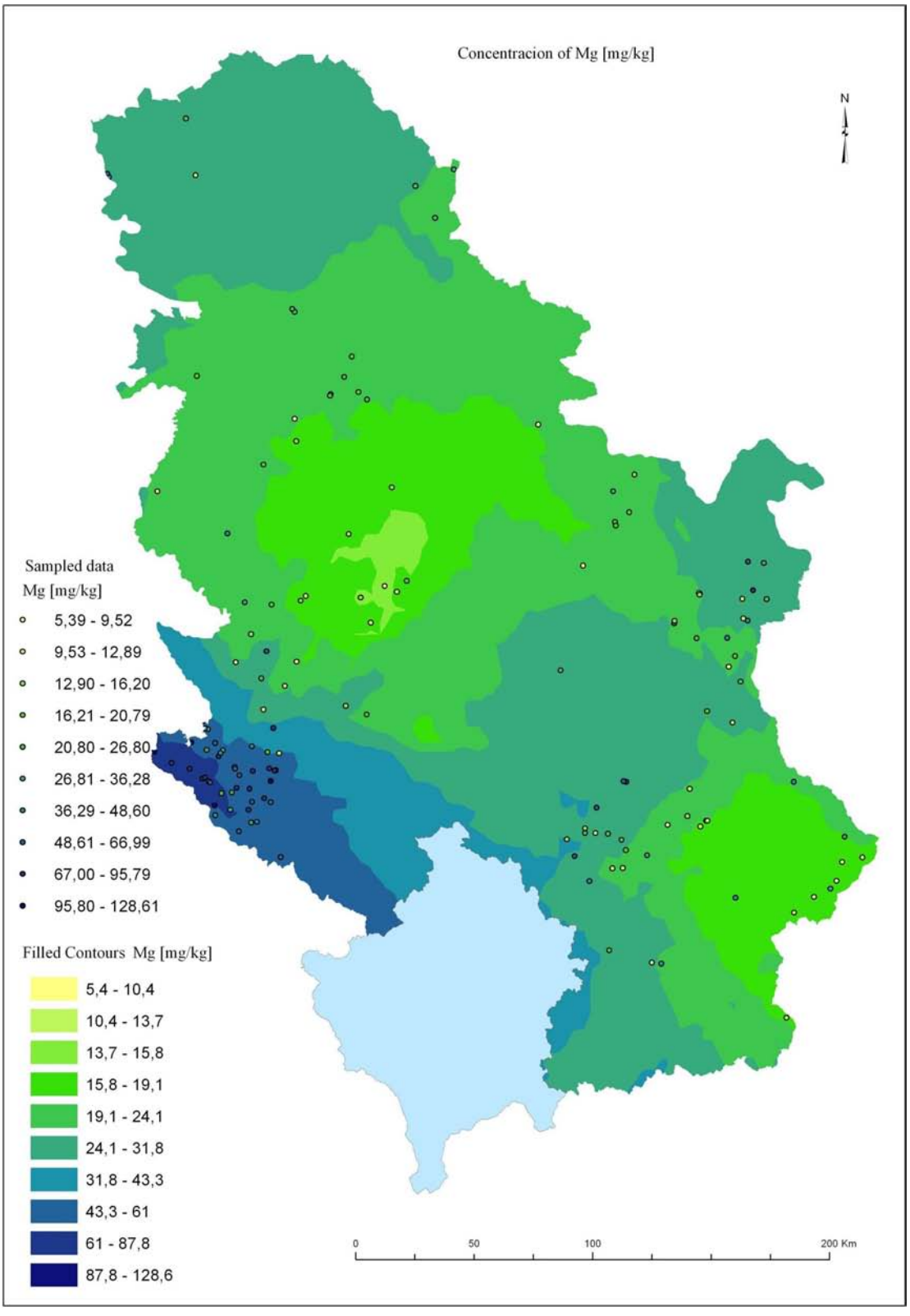
MATERIALS AND METHODS

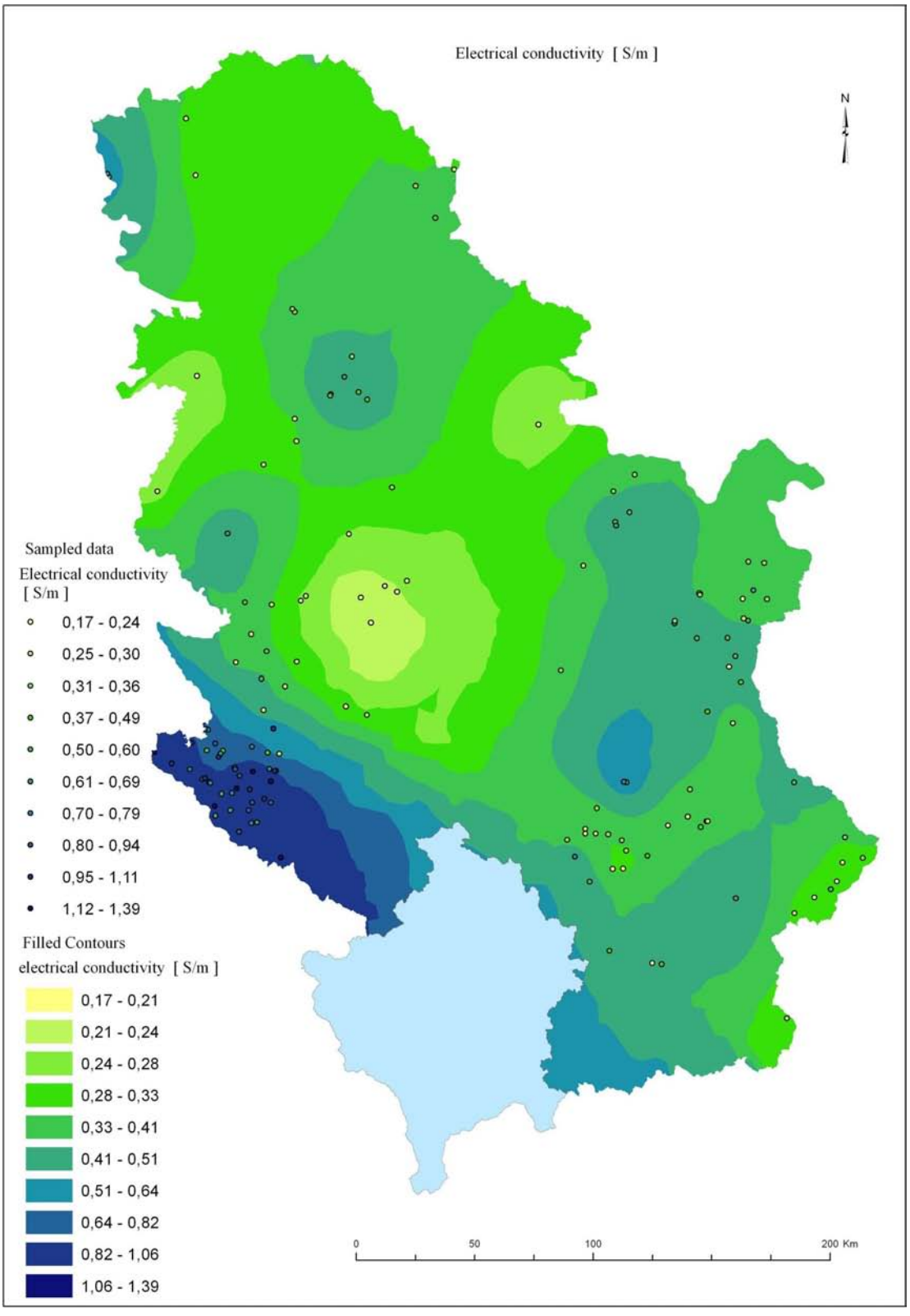
Sample collection

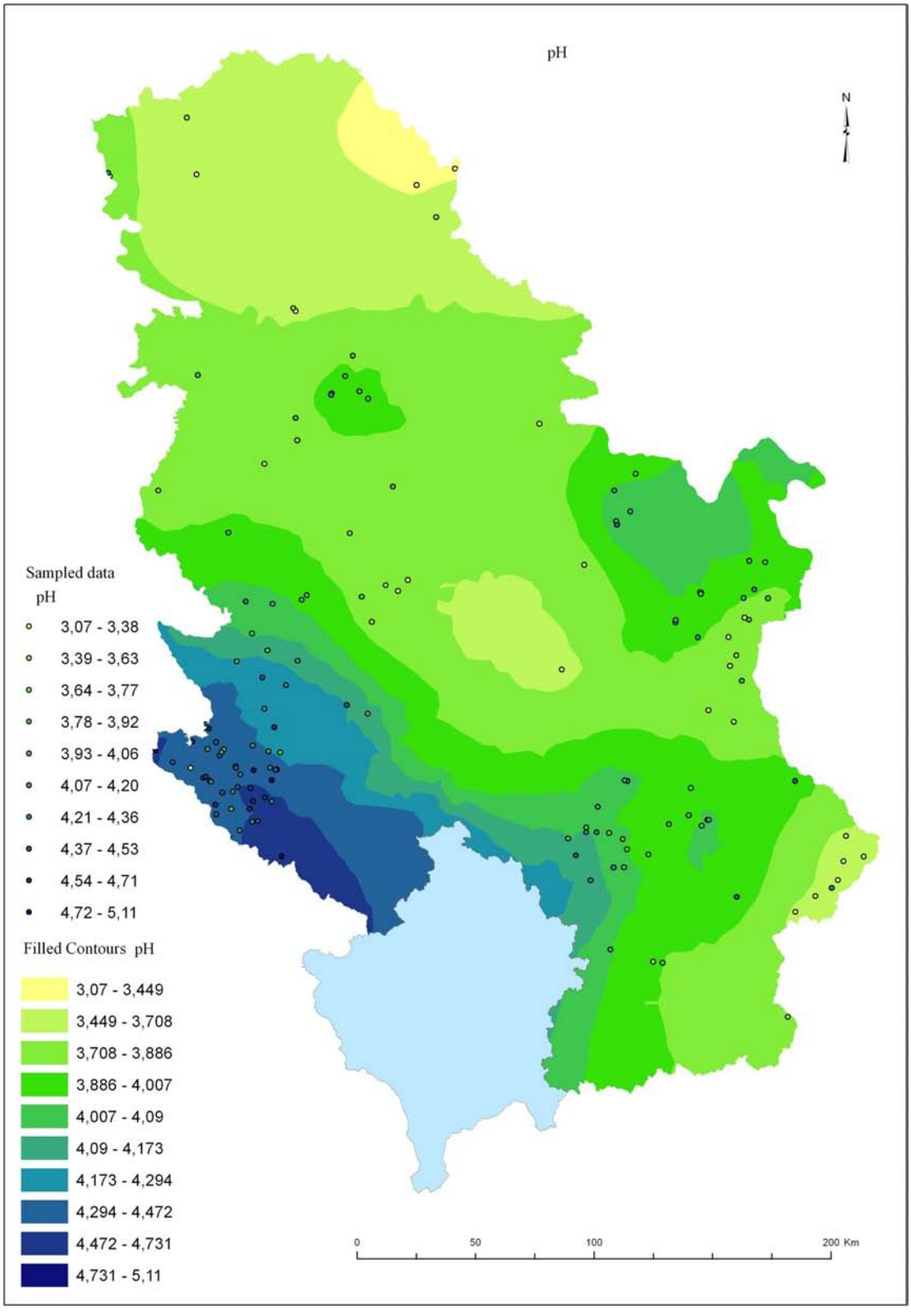
The total numbers of 164 multifloral honey samples collected from different parts of Serbia (Fig 1) during the harvesting season of 2009 were provided by the "The Association of the Beekeeping Organizations of Serbia" (SPOS) (www.spos.info 2013). The botanical origin of the samples was established by the SPOS based on information provided by the beekeepers and some sensory characteristics of the collected honeys. All samples were in their original packages and were transferred to the laboratory of Faculty of Chemistry, University of Belgrade, and kept in a refrigerator until analysis (Lazarević et al., 2013).

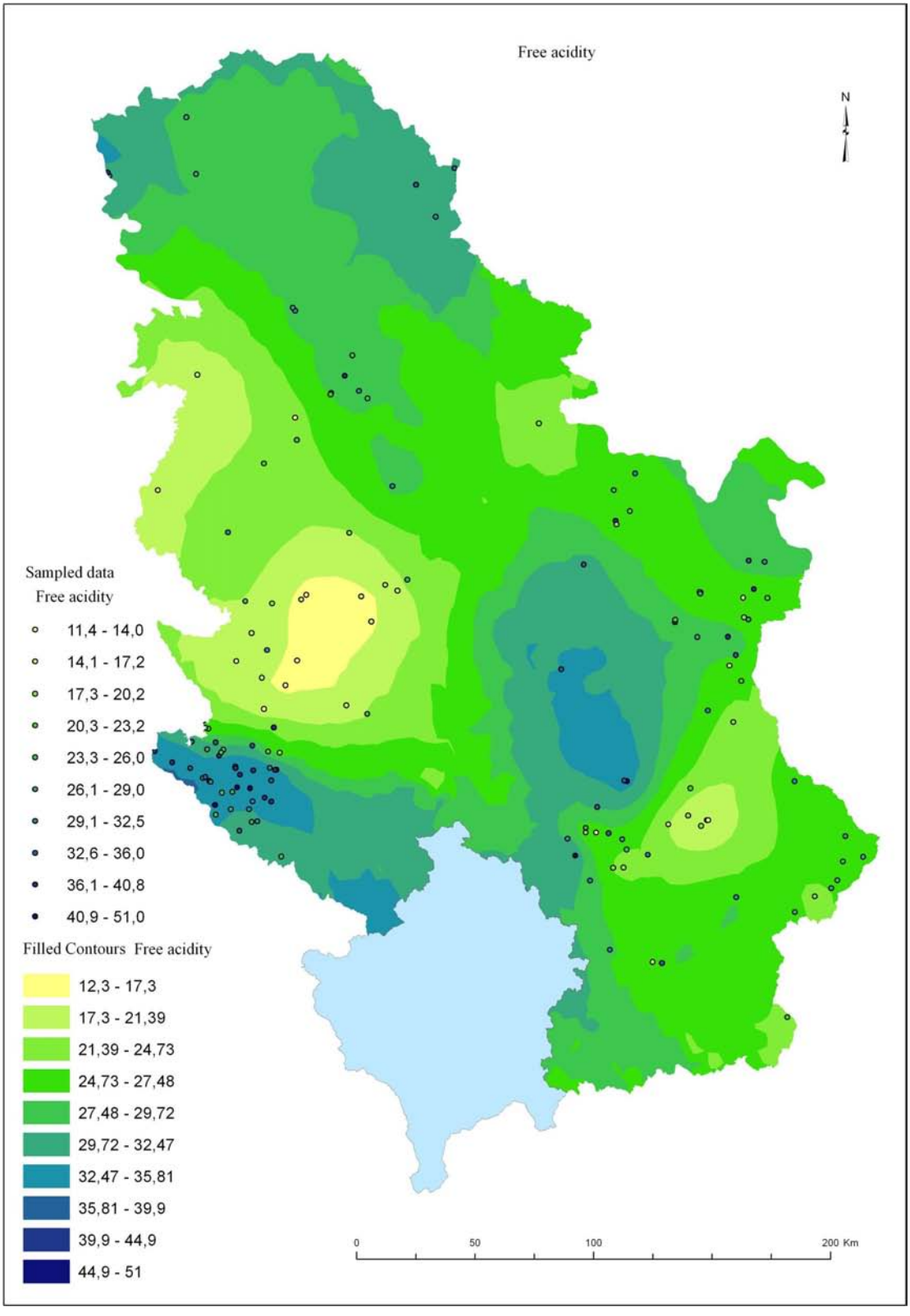

Sampled data and Serbian regions
19°E
20°E
21°E
22°E
23°E
46°N
45°N
44°N
43°N
42°N
N
1
2
3
4
5
6
7
8
Sampled data
Region
1. Vojvodina
2. Beograd
3. Mačva - Kolubara
4. Zlatiborski
5. Centralni region
6. Istočni region
7. Južni region
8. Kosovo i Metohija
0
50
100
200 Km


Concentracion of K [mg/kg]
N
Sampled data
K [mg/kg]
164,3 - 269,3
269,4 - 379,9
380,0 - 485,6
485,7 - 596,4
596,5 - 731,5
731,6 - 1007,0
1007,1 - 1292,7
1292,8 - 1530,4
1530,5 - 1867,7
1867,8 - 3207,0
Filled Contours K [mg/kg]
164,3 - 295,7
295,7 - 383,8
383,8 - 442,9
442,9 - 531
531 - 662,5
662,5 - 858,5
858,5 - 1.150,8
1.150,8 - 1.586,8
1.586,8 - 2.237,1
2.237,1 - 3.207
0
35
70
140 Km


Concentracion of Mg [mg/kg]
N
Sampled data
Mg [mg/kg]
5,39 - 9,52
9,53 - 12,89
12,90 - 16,20
16,21 - 20,79
20,80 - 26,80
26,81 - 36,28
36,29 - 48,60
48,61 - 66,99
67,00 - 95,79
95,80 - 128,61
Filled Contours Mg [mg/kg]
5,4 - 10,4
10,4 - 13,7
13,7 - 15,8
15,8 - 19,1
19,1 - 24,1
24,1 - 31,8
31,8 - 43,3
43,3 - 61
61 - 87,8
87,8 - 128,6
0
50
100
200 Km


Electrical conductivity [S/m]
N
Sampled data
Electrical conductivity
[S/m]
0,17 - 0,24
0,25 - 0,30
0,31 - 0,36
0,37 - 0,49
0,50 - 0,60
0,61 - 0,69
0,70 - 0,79
0,80 - 0,94
0,95 - 1,11
1,12 - 1,39
Filled Contours
electrical conductivity [S/m]
0,17 - 0,21
0,21 - 0,24
0,24 - 0,28
0,28 - 0,33
0,33 - 0,41
0,41 - 0,51
0,51 - 0,64
0,64 - 0,82
0,82 - 1,06
1,06 - 1,39
0
50
100
200 Km


pH
N
Sampled data
pH
3,07 - 3,38
3,39 - 3,63
3,64 - 3,77
3,78 - 3,92
3,93 - 4,06
4,07 - 4,20
4,21 - 4,36
4,37 - 4,53
4,54 - 4,71
4,72 - 5,11
Filled Contours pH
3,07 - 3,449
3,449 - 3,708
3,708 - 3,886
3,886 - 4,007
4,007 - 4,09
4,09 - 4,173
4,173 - 4,294
4,294 - 4,472
4,472 - 4,731
4,731 - 5,11
0
50
100
200 Km


Free acidity
N
Sampled data
Free acidity
11,4 - 14,0
14,1 - 17,2
17,3 - 20,2
20,3 - 23,2
23,3 - 26,0
26,1 - 29,0
29,1 - 32,5
32,6 - 36,0
36,1 - 40,8
40,9 - 51,0
Filled Contours Free acidity
12,3 - 17,3
17,3 - 21,39
21,39 - 24,73
24,73 - 27,48
27,48 - 29,72
29,72 - 32,47
32,47 - 35,81
35,81 - 39,9
39,9 - 44,9
44,9 - 51
0
50
100
200 Km

GIS procedures

Microsoft Office Excel and Access were used to organize the Geographic Information System (GIS) database. Locations of data sampling are vector (point) data. Vector data and the database were integrated, analyzed and printed with GIS software (ArcGIS 9). Geostatistical Analyst was used to create a predicted distribution of the attributive data. Geostatistics is a set of models and tools developed for the statistical analysis of continuous data. These data can be measured at any location in space, but they are available in a limited number of sampled points. Input data are available at measured points and models are an approximation of the reality. The precision of predictions made by Geostatistical Analyst are correlated with the density of input data (Longley et al., 2005). In this study, the kriging method of Geostatistical Analyst was used for interpolation to predict values of a sampled variable over the whole territory of Serbia. The method was an ordinary kriging prediction type with the following properties: trend type third, global polynomial interpolation, semivariogram, number of lags = 12, spherical model type, no anisotropy.

Chemical analysis

Multivariate chemometric analysis (Lazarević et al., 2013) included physicochemical parameters: pH, electrical conductivity (*EC*), free acidity (*FA*), optical rotation (*OR*) and moisture. The mineral composition of honey was analyzed by inductively coupled plasma – optical emission spectrometry (ICP-OES). The results are expressed as mg metal per kg honey (ppm) for the macro elements (K, Mg, Na and Ca) and the micro-elements (Fe, Zn, Cu and Co), or as μg metal per kg honey (ppb) for the trace elements (Cd, Cr and Ni). The sugar content, i.e., glucose, fructose, sucrose, trehalose, maltose, isomaltose, isomaltotriose, melezitose and turanose with gentiobiose (Gen + Tur), was determined by the means of ion chromatography with amperometric detection. Results are expressed as percentage of sugar content.

RESULTS AND DISCUSSION

The GIS of multifloral honey was organized for the territory of Republic of Serbia and was divided (by type and format) into various data forms:

Vector data:

State border of Republic of Serbia, borders of regions (type line), 164 honey samples data (type point).

***Database*:**

For 164 honey sample locations: x,y coordinates, name of apiary owner, name of the region and place of apiary location, numerical value of physicochemical parameters (pH, electrical conductivity (*EC*), free acidity (*FA*), optical rotation (*OR*) and moisture), content of sugar, i.e., glucose, fructose, sucrose, trehalose, maltose, isomaltose, isomaltotriose, melezitose and turanose with gentiobiose (Gen + Tur), concentration of metal, mg per kg honey (ppm) for the macro elements (K, Mg, Na and Ca) and the micro-elements (Fe, Zn, Cu and Co), or as μg metal per kg honey (ppb) for the trace elements (Cd, Cr and Ni).

***Raster data*:** Georeferenced raster topographic maps R= 1: 300000.

Digital elevation model (DEM) – resolution 100m.

***Digital spatial models interpolated with kriging*:** (26 thematic maps)

1. Digital models of the physicochemical parameters (pH, electrical conductivity (*EC*), free acidity (*FA*), optical rotation (*OR*) and moisture)

2. Digital models of the content of sugar, i.e., glucose, fructose, sucrose, trehalose, maltose, isomaltose, isomaltotriose, melezitose and turanose with gentiobiose (Gen + Tur)

3. Digital models of the concentration of metal, mg per kg honey (ppm) for the macro elements (K,

Mg, Na and Ca) and the micro-elements (Fe, Zn, Cu and Co), or as μg metal per kg honey (ppb) for the trace elements (Cd, Cr and Ni).

Based on these data, 26 thematic maps representing the spatial distribution of chemical variables of multifloral honey were created. The results of this comprehensive study, based on a vast number of genuine honey samples, represent the first attempt to classify multifloral honey chemical variables over the whole territory of Serbia. Characterization of the studied samples was performed regarding the basic physicochemical properties, mineral composition and sugar content. GIS geostatistical analyses of chemical variables enabled the identification of the geographical origin of the honeys on the territory of Serbia.

Samples of honey originating from the Zlatibor region were clearly distinct from the rest of Serbia, showing higher values of potassium and magnesium contents, as well as higher values of electrical conductivity, pH and free acidity (Fig 2-6).

GIS and Geostatistical Analyst was also used to create a predicted distribution of the incidence, symptoms and consequences of *Nosema ceranae* infection monitored in 200 honey bee colonies in Serbia over 5 years (2008-2012), (Stevanović et al., 2013), and in the study of 55 honey bee colonies from different regions in Serbia that were monitored for the presence of deformed wing virus (DWV) and acute bee paralysis virus (ABPV), (Simeunović et al., 2014). Implementation of GIS could certainly contribute to the control of *Varroa destructor* mite and *Nosema ceranae* disease in Carniolan honey bee (*Apis mellifera carnica*) colonies in an environment-friendly way (Tlak-Gajger et al., 2013).

The results of honey chemical composition and their spatial distribution on the territory of Serbia have significance in opening possibilities to compare them with research into heavy metal accumulation in the tissues of plants and lichens (Stamenković, S.M. et al., 2013; Stamenković, S.S. et al., 2013; Miljković et al, 2014), and accumulation of heavy metals in industry centers from which metals are continuously emitted into the terrestrial environment and pose a great threat on human health. (Lorestani et al., 2011). This GIS complements the investigation of the ecophysiological and biochemical traits of three herbaceous plants growing on disposed coal combustion fly ash of different weathering stage (Gajić et al., 2013). Implementing GIS technologies in this research could improve overall chemical management policy – adequate identifying ecotoxicological risks and their relation to local condition and characteristics of the system.

Spatially organized data of honey chemical content may be used as a health management bioindicator and as one of the parameters for monitoring the antimicrobial activity of honey and other bee products – pollen loads and beeswax (Barliba and Tita, 2014), (Kacaniova et al., 2012).

GIS also enables the comparison of changes in the chemical content of honey with climate (temperature and precipitations) changes in Serbia and their impacts and adaptation measures (Spasova et al., 2010).

CONCLUSIONS

The present work is a contribution to GIS application in the areas of aphidology, chemical characteristics of regional honey production and quality and ecotoxicology. The results of this comprehensive study, based on a vast number of genuine honey samples, is the first attempt to implement GIS technology for the presentation of chemical variables of multifloral honey over a whole territory of Serbia. Visualization of the sampled data with chemical variables distribution on the territory of Serbia is achieved along with identifying the geographical origin of multifloral honey. GIS geostatistical analyses of chemical variables enable identifying the geographical origin of the honeys on the territory of Serbia.

Samples of honey originating from the Zlatibor region are clearly distinct from the rest of Serbia, showing higher values of potassium and magnesium

contents, as well as higher values of electrical conductivity, pH and free acidity.

The advantages of the this GIS multifloral honey study on the territory of Serbia are: highly sophisticated computer solutions (hardware and software); production process standardization (data input and storage); data standardization (they may be used with any other GIS software currently and in the future); system openness (the system is open to input of new themes and modification of existing ones); clear visualization; analyses thoroughness (interactive, with more systematic, thematic, and topographic parameters); and system decision support in many areas of ecotoxicology, agriculture and food safety.

The future benefit of this GIS should be to quantify and correlate present multifloral honey chemical variables with abiotic and biotic environment data. A whole new set of environmental indicators (type of vegetation, climate, geological and soil type, hydrological and topographical characteristics, environmental pollution) that influence honey characteristics and production should appear. GIS can then be used to explore the correlation between all these data sets. This will be helpful to a wide circle of users in the areas of environmental sciences, agriculture and biotechnology.

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