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Scientific paper

The Use of GIS Methodology in Jumping Plant Lice (Hemiptera: Psylloidae) Studies in Serbia

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SUMMARY

Entomofaunistic studies contain a large number of data regarding the number of collected species, the number of individuals within species, time of collection, localities, species biology and morphology natural enemies and hosts. Besides thematic and temporal components this kind of studies include spatial component which is crucial for the use of GIS methodology and advanced possibilities of geospatial analysis. During our studies on jumping plant lice (Psylloidea) fauna and their natural enemies on the territory of Serbia which lasted for several years, a large number of spatially referenced data related to this group of insects were collected. The process of collecting, archiving and classifying the data on each species was improved by applying the GIS methodological approach after which the data were entered into database. The analysis of data using thematic and spatial queries, as well as graphic, numeric and textual display of the results from studies enabled simpler and more complete survey of horizontal and vertical distribution of jumping plant lice, their biology and relationship with plants, predators and parasitoids.

Keywords: GIS; Jumping plant lice; Psylloidea; Natural enemies; Database; Geospatial analysis; Serbia

INTRODUCTION

Processes in the environment are complex and take place under the influence of different factors therefore, it is important to use different sources of information when they are studied. Radović et al. (2007) point out that most of ecological studies demand explicit and qualitative terrain information and that spatial reference represents a main condition for the application of geographical information systems (GIS) in order to improve researches regarding faunistic and floristic diversity.

It is known that GIS consists of computer hardware and software, data and users. It can be designed as a part of a wider system or as a separate system which enables efficient collecting, storing, analysing and displaying of spatially referenced data. Implementation of the GIS project at any level and with any content includes defining the objectives of a designed system, designing and creating the computer hardware, software and database, performing necessary analysis and displaying the obtained results (Miloradov et. al., 1996). There are many definitions of GIS but all imply that GIS system enables work with spatial (georeferenced) data connected to some specific place on the Earth's surface (Marphy, 1995). In GIS, geographic entity on physical level is described with raster and vector model using geometric primitives in the form of points, lines, polygons and a corresponding spatial database model (Kukrika, 2000). At the beginning, GIS technologies were mainly used for presentational mapping, while contemporary users from different fields exploit advanced possibilities of spatial analysis with assistance of logical and mathematical models to manage, plan and make decisions (Vukanović and Reljić, 1996). In contemporary circumstances GIS represents technology necessary for management of spatial data, which is especially visible in domain of natural resources and environmental protection and to a smaller extent in social and economical sector (Muškatirović and Jovanović, 1996).

There are many examples of advanced information technologies usage in agriculture and forestry. Instruments of remote sensing detection and spatial geoinformation technology, such as geoinformation systems and global positioning systems, enable detection of damages caused by insects and provide necessary information for efficient plant protection management (Chenghai, 2005). The use of GIS technology helps in selection of timely and spatially limited treatments; therefore, by applying pesticides only on infected surfaces their amount is reduced, which directly affects costs and ecological aspects of plant protection. (Daya et al., 2002). Answers to many questions related to insect ecology and plant protection contain spatial components, which lead to greater interest of entomologists in GIS methods for the purposes of archiving, classifying, analysing and displaying of georeferenced data. By applying GIS methodological approach, it is possible to study distribution, migration, biology, population dynamics and other ecological aspects of insects (Johnson, 1989). GIS is also a great tool for analysing the impact of climate changes on assessment of harmfulness and vector potential of insects (Aurambout et al., 2009).

During our study on jumping plant lice and their natural enemies in Serbia, a great number of qualitative and quantitative spatially referenced data were collected. The use of GIS methodology in this research enabled simpler and more efficient archiving, classifying, analysing and displaying of the results in order to carry out further studies on horizontal and vertical distribution, biology of certain species, migrations and relationship with some plant species and natural enemies.

MATERIAL AND METHODS

The database of jumping plant lice and their natural enemies on the territory of Serbia was created in a software tool Microsoft Office Access 2003. The data from study as well as the data from literature (Hodkinson and White, 1979; Ossiannilsson, 1992) represented a basis for the database set up. The creation of database with the data obtained in this study was based on temporal, spatial and thematic characteristics of sampled material which included date, locality, registered species of jumping plant lice, developmental stage, host plants and natural enemies. The data on systematic affiliation, species synonyms, zoogeographical distribution, host plants, biology and general data on natural enemies which were used for the database creation were obtained from literature. Database consists of 31 relational table which are named "Parent" or "Child" tables (Figure 1). Database was updated using created insert forms and subforms. The data on jumping plant lice, their natural enemies and host plants collected during the study or obtained from literature was entered into database.

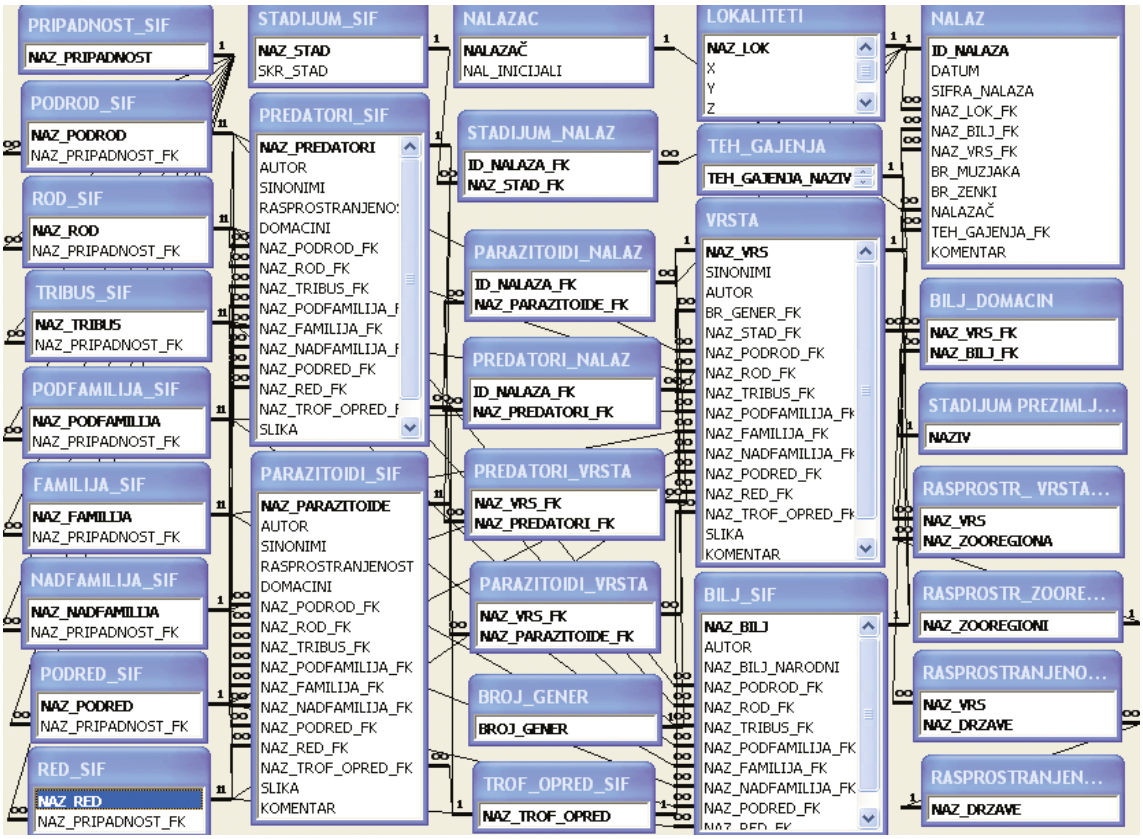

Figure 1. Database with relationships

GIS methodological approach for studying jumping plant lice and their natural enemies in Serbia was carried out in ESRI software ArcGIS 9.2. Integration of the database in ArcGIS 9.2 software was carried out using georational data model. For this purpose, query tables containing the data on jumping plant lice and their natural enemies were set. The tables contain spatial, temporal and thematic data from the database. The query tables were entered into software and the referent data were presented in adopted coordinate system. For displaying the results of the study in a referent frame, we used UTM zone 34N coordinate system.

The determination of locality coordinates was carried out using a method of visual reading from digital topographic maps in ESRI ArcGIS 9.2 software and Global Position System (GPS) instruments. For this purpose, we used 1: 25000 (TK25) and 1:50000 (TK50) scale maps published by Military Geographic Institute in Belgrade. The procedure for determination included marking the localities on a digital map and exporting the coordinates in UTM (MGRS) coordinate system. Locality coordinates determination with GPS equipment were carried out using autonomous method with precision of 3-5 meters with Geoexplorer 3 (Trimble) and E-trex Vista Hcx (Garmin) instruments. The working procedure consisted of instrument initialization with necessary number of satellites, naming and recording the position of locality.

In order to visually present global spatial reference of localities for the presence of jumping plant lice and their natural enemies, raster and vector data related to studied surfaces were implemented in GIS. Raster data comprised georeferent maps of Tara, Fruška Gora and Kopaonik national parks. Vector data included MGRS (UTM) zone 34T grid (polygon and lines), borders of the Republic of Serbia and borders of Fruška Gora, Kopaonik and Tara national parks (polygon).

RESULTS

Database

The data from jumping plant lice study contain spatial, temporal and thematic components (attributes). Spatial and temporal components comprise information about the date of specimen collection and the names of localities with their coordinates and altitudes. Thematic

component of specimen comprises the data on jumping plant lice development stages, the number of males and females, host plants, and technology for plant cultivation, registered species and number of predators and parasitoids and the data about collector of the specimen.

General data obtained from the literature contain information about jumping plant lice species (Latin name, the name of the author, year of species description and synonyms, taxonomic rank, number of generations per year and overwintering stage, nutrition, host plants, zoogeographic distribution); and also, the data on their natural enemies (Latin name of the species, the name of the author, year of species description and synonyms, taxonomic rank, zoogeographic distribution, types of plant lice and their hosts). Research also includes the data about host plants (Latin and popular name, name of the author of species, taxonomic rank).

Currently, the database of jumping plant lice and their natural enemies contains:

– About 33.200 data collected during the study (Jerinić-Prodanović, 2010) and about 1.200 literary data regarding 63 registered species of jumping plant lice with 2.306 specimen units,

– About 1.500 data collected during the study (unpublished data) and about 400 literary data regarding 44 registered species of jumping plant lice predators,

– About 6.000 data collected during the study (unpublished data) and about 200 literary data regarding 20 registered species of jumping plant lice parasitoids,

– About 2.400 data collected during the study and literary data about 75 plant species from 49 genera belonging to 25 families and

– Names of 419 studied localities (Figure 2) including their coordinates and altitudes.

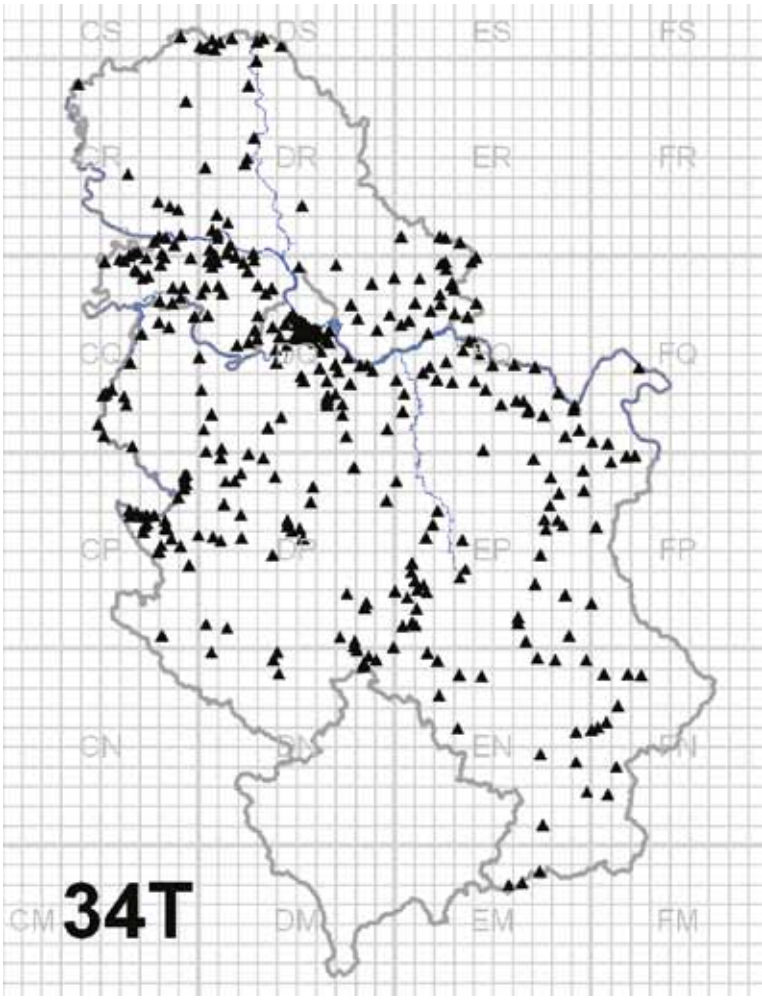

Figure 2. Map of studied localities in UTM projection

Analysis of the research data in GIS software

Besides regular feature of information systems that enable analysis of the data related to thematic queries; GIS methodological approach expands and improves analysis of data by using geospatial queries and mapping of results in adequate referent frame. Implementation of jumping plant lice and their natural enemies database i.e. corresponding tables of the query into GIS software, enables analysis of data according to thematic and spatial conditions.

Thematic queries were adjusted for the data from the database which helped to gather details regarding biology of certain jumping plant lice species, horizontal and vertical distribution and relationship with plants, predators and parasitoids. By applying a thematic query with condition about "systematic affiliation" to family, subfamily, genus, species, we gained a survey of hierarchically organized thematic layers in accordance with their systematic position in super family of jumping plant lice as well as a map of horizontal dispersion of each species on the territory of Serbia (Figure 3).

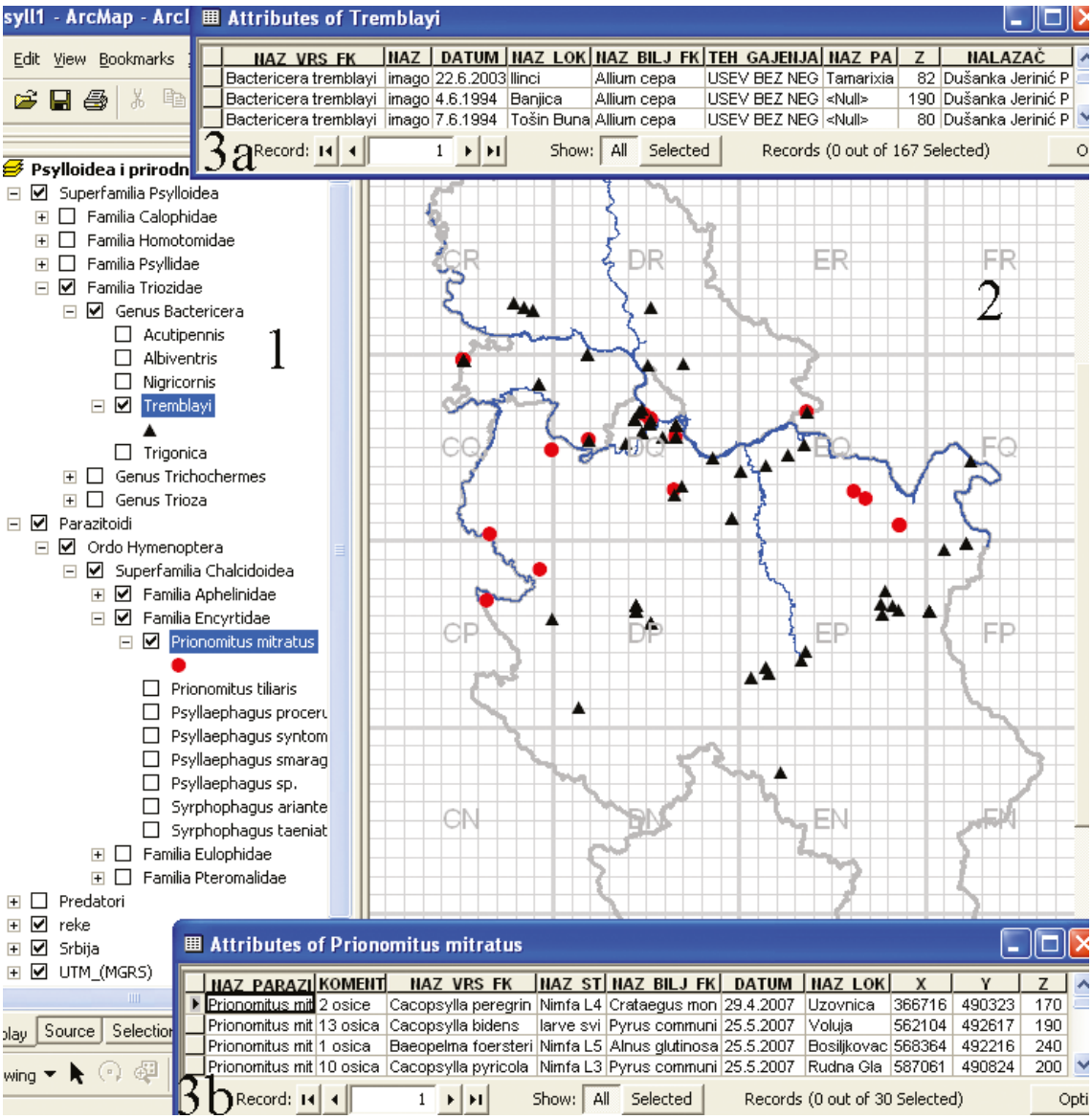

Figure 3. Hierarchical layers of jumping plant lice and their natural enemies (1), map of horizontal distribution (2), tabled with research data (3a i 3b)

The formed layers, together with species levels are followed by corresponding tables which contain data about jumping plant lice species, development stage, date and the name of locality where the research was carried out, plant species (rearing measures are mentioned for cultivated plants), parasitoids and predators, 3D coordinates and the data on collector of the specimen. The organized tables enable further analysis of each species independently.

According to tabular presentation of the data for 33 species of jumping plant lice, based on date and development stage, the results indicate that 20 species have 1 generation, 5 species have 2 generations, and 8 species have a number of generations per year. According to nutrition, 65 species were determined as follows: 8 monophagous, 41 close oligophagous, 14 wide oligophagous, as well as 2 polyphagous species. It was found that 20 species of jumping plant lice overwinter as imago and 11 as eggs, while 5 species overwinter as larvae. By analysing distribution of jumping plant lice on cultivated plants, we determined the percentage of their presence on plants under extensive and intensive cultivation measures. The duration of certain development stages of further studied species of jumping plant lice was assessed using thematic query with condition "name of the stage". By analysing the data on natural enemies of jumping plant lice we determined faunistic composition of predators and parasitoid species, time of their occurrence and order of dominance. By analysing vertical proportion and using altitude "<500 meters and >500 meters", as a condition, we discovered that presence of jumping plant lice on host plants was altitude-dependant. The results demonstrate that 18 species of jumping plant lice occur only in lowlands (altitude under 500 meters), 19 species only in highlands (altitude above 500 meters), while 26 species occur on host plants in both types of regions.

By using thematic queries where a condition was „plant species Conifers", we determined the abundance of migrant jumping plant lice on conifers, depending on altitude. According to the results, they are present in studied localities of mountain regions (Goč, Tara, Kopaonik, Golija, Divčibare, Ozren), but were not registered in lowland regions (Ilinci, Beograd, Irig, Vršac).

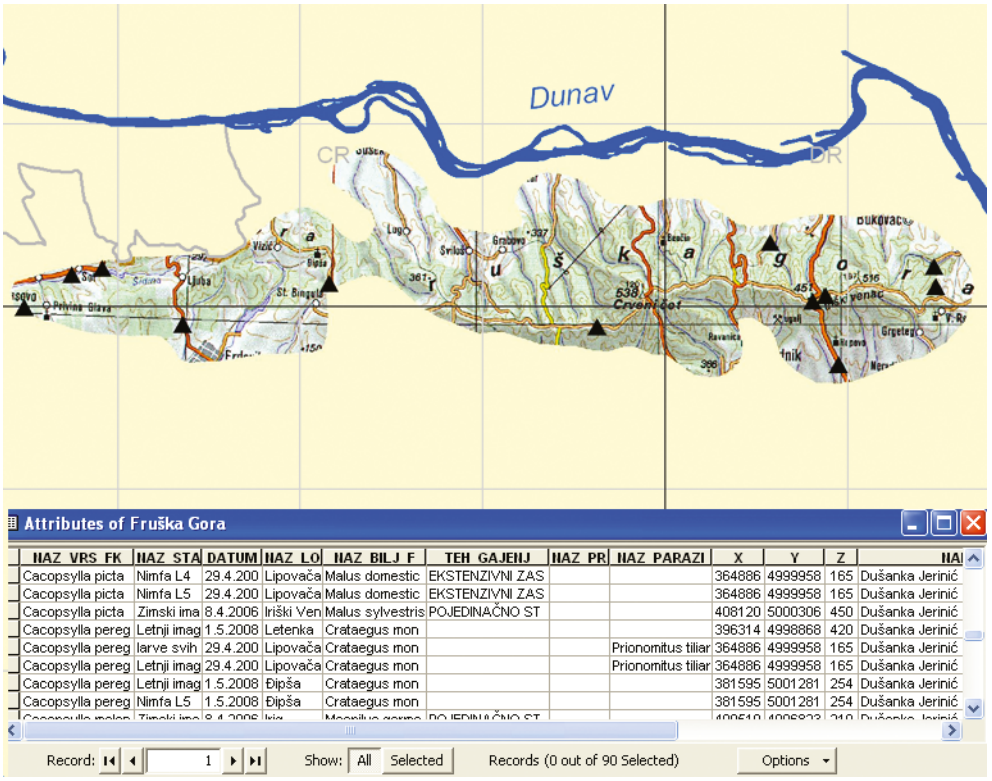

Figure 4. Studied localities in the national park Fruška Gora

By applying queries concerning the data on natural enemies of jumping plant lice with condition "taxonomic rank", we created a survey of hierarchically organized thematic layers for natural enemies in accordance with their systematic position and maps of localities on the territory of Serbia where presence on jumping plant lice was registered (Figure 3).

For each hierarchical layer which represented a natural enemy species, we created a table that enables further analysis of thematic data about host of jumping plant louse, jumping plant louse stage, number of developed imagoes, locality, and 3D coordinates of the studied locality.

Geospatial queries are qualitative characteristic of GIS and enable spatial analysis within localities represented by corresponding geometric figures, in a form of polygon. In this study, geospatial analyses were used to determine the presence of jumping plant lice and their natural enemies in national parks Fruška Gora, Kopaonik and Tara. Geospatial queries were set for geometrical primitives in a form of points which represent localities where the research was carried out and polygons which represent administratively defined surface of the national park. The results from geospatial queries regarding the position of localities where jumping plant lice and their natural enemies were studied, in the polygons which represent national parks, are presented in tables with thematic data.

According to the data, in the national park Fruška Gora (Figure 4) 17 species of jumping plant lice on 13 host plant species were registered at 12 localities, along with 15 predator species and 5 parasitoids of jumping plant lice. Research was carried out at localities at the altitude of 123-520 meters.

In the national park Kopaonik 17 species of jumping plant lice were registered on 11 plant species at 5 localities. Research was carried out at localities at the 560-1740 meters altitude.

In the national park Tara 27 species were registered on 20 plant species at 10 localities. Research was carried out at localities at the 230-1205 meters altitude.

The results of geospatial queries can be further analysed using corresponding queries with a thematic condition in order to continue the study on biology and migration of jumping plant lice.

When a new data is entered in the database of jumping plant lice and their natural enemies in Serbia, query tables implemented in GIS are automatically updated, hierarchical layers of species and thematic data on layers are placed in a corresponding table, which provides preciseness of data for new thematic and spatial queries.

DISCUSSION

Entomofaunistic researches contain a large number of data that have to be efficiently stored and classified in order to be further studied. By processing the data, we obtained the information on biology and morphology of the studied species, natural enemies, hosts and relationships between them. Considering the possibility of applying GIS methodology in entomology Liebhold et. al. (1993) stated that this form of research contained spatial component which enabled the use of GIS in studying of insect ecology and plant protection management.

About 43.000 spatially referenced data were collected during our study of jumping plant lice and their natural enemies. In order to apply advanced possibilities of GIS methodology on this group of insects, computer software, hardware and database were created. There are different versions of commercial (ArcGIS, Geomedia, MapInfo, etc.) and non commercial software (Quantum GIS, OziExplorer, etc.) on the market, but, as a part of our GIS methodological approach in studying jumping plant lice and their natural enemies in Serbia, ESRI software ArcGIS 9.2. was chosen since it has a wide range of GIS tools for analysing and displaying the results. Every computer that can support possibilities of chosen software is an adequate solution.

The most critical moment in applying GIS methodology is a creation of an adequate database where the data are stored and classified using appropriate insert forms. Since this study includes only one superfamily, Microsoft Office Access 2003 personal base was an adequate solution for the database creation. The data from the study as well as the literary data were entered in the database so they could be analysed and, also compared to the results of jumping plant lice and their natural enemies researches in the world. Queries regarding jumping plant lice, parasitoids, predators were created as a part of this database and represent a link between the database and the software. Implementation of queries into GIS software and display in a referent frame enabled analysis of the data using thematic and geospatial queries. Referent mapping data in vector and raster forms which are used in displaying the results from this study were entered into software as separate thematic layers.

Using thematic queries concerning the data on jumping plant lice and their natural enemies where a condition was a taxonomic rank enabled obtaining a survey of hierarchically referenced layers with a display of horizontal proportion of each species separately. Every hierarchical layer is followed by a corresponding table

with a different query condition, which enables analysis of jumping plant lice biology, their relationship with plants, vertical proportions, and relationship with predators and parasitoids.

Geospatial analysis is qualitative characteristic of GIS methods. In entomofaunistic studies, geospatial analysis can be used for studying the influence of geographical, climate and topographic parameters on distribution and biology of species from certain area. The distribution of jumping plant lice and their natural enemies in important geographical areas Fruška Gora, Kopaonik and Tara was determined using geospatial queries with condition "place of locality" in a certain polygon.

In grasshoppers migration studies Johnson (1989) used advantages of GIS methodological approach. By setting spatial queries, he noticed that the population abundance depended on pedological composition of soil and precipitation levels. By applying GIS methodology, Beckler et al. (2005), came to a conclusion that distribution and abundance of Western corn rootworm were in correlation with soil type and altitude and demonstrated that a model for prediction of population abundance and efficient protection management could be developed using GIS technology. When talking about necessity and possibilities of GIS application in forest protection from gypsy moth caterpillars Mihajlović et al. (2005) stated that the advantage of this approach was in a graphic display and possibilities of automatic modeling of thematic maps related to any feature in a database. Possibilities of setting queries using different conditions or their combination, enables a survey of areas with different infestation intensity which helps planning preventive actions. Wichmann and Ravn (2001) used GIS technology and spatial analysis technique to study thoroughly distribution and infestation intensity of *Ips typographus* in Danish woods, in order to provide preventive protection to healthy trees. Vozikis et al. (2005) created a pilot project that included modern GIS technology in protection of olive trees so as to be able to react timely and reduce protection costs.

Economic factor and advantages of GIS methodology and technology in analysis and display of spatially referenced data led to its wide application in the environmental protection with an accent on forecast, preventive actions, efficient and rational protection. However, in bioecological studies GIS technologies have mostly been used for map presentation. The use of advanced possibilities of thematic and geospatial analysis is preconditioned by the existence of numerous qualitative and quantitative research data. It was due to the large number of data collected in researches on jumping plant lice and their natural enemies in Serbia that enabled us to apply GIS methodology in order to improve collecting, storing, classification and the analysis of data by using thematic and geospatial queries as well as display in corresponding referent frame, which gives a new dimension and a quality to the study.

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REFERENCES

Aurambout, J.P., Finlay, K.J., Luck, J. and Beattie, G.A.C.: A concept model to estimate the potential distribution of the Asiatic citrus psyllid (*Diaphorina citri* Kuwayama) in Australia under climate change - a means for assessing biosecurity risk. Ecological Modelling, 220(19): 2512-2524, 2009.

Chenghai, Y.: Remote sensing, GPS and GIS technologies for Agricultural insect pest detection. Science Press, Beijing, 2005, pp. 402-432.

Kukrika, M.: Geografski informacioni sistemi. Univerzitet u Beogradu, Geografski fakultet, Beograd, 2000, str. 1-247.

Daya, N.P., Parth, S.R. and Bouakeo. P.: Monitoring and assessment of sal forest infected by the insect: *Hoplocerambyx spinicorwis*, using remote sensing and GIS. Indian Forester, 128: 955-965, 2002.

Beckler, A.A., French, B.W. and Chandler, L.D.: Using GIS in areawide pest management: a case study in South Dakota. Transactions in Geographic Information Systems, 9(2): 109-127, 2005.

Jerinić-Prodanović, D.: Checklist of plant lice (Hemiptera: Psylloidea) in Serbia. Acta entomologica Serbica, 15(1): 29-59, 2010.

Johnson, D.L.: Spatial autocorrelation, spatial modeling, and improvements in grasshopper survey methodology. Canadian Entomologist, 121: 579-588, 1989.

Liebhold, A.M., Rossi, R.E. and Kemp, W.P.: Geostatistics and geographic information systems in applied insect ecology. Annual Review of Entomology, 38: 303-327, 1993.

Marphy, L.D.: Geografic information sistem: Are they decision support system? Proceeding of the 28th Annual Hawaii International Conference on System Sciences, Hawaii, pp. 131-140, 1995.

Mihajlović, Lj., Marković, N. i Milanović, S.: Potrebe i mogućnosti primene Geografskog informacionog sistema u zastiti šuma od gubara. Biljni lekar, 23(6): 626-631, 2005.

Miloradov, M., Jačanin, I. i Marjanović, P.: Metodološke osnove razvoja GIS tehnologija i projektovanje geografskih informacionih sistema. Zbornik radova GIS stanje i perspektive, Geografski institut „Jovan Cvijić" SANU, Beograd, 1996, str.1-8.

Muškatirović, J. i Jovanović, V.: Obrazovanje u oblasti GIS u svetu i kod nas. Zbornik radova GIS stanje i perspektive, Geografski institut „Jovan Cvijić" SANU, Beograd, 1996, str. 77-84.

Ossiannilsson, F.: The Psylloidea (Homoptera) of Fennoscandia and Denmark. Fauna Entomologica Scandinavica, 26: 346, 1992.

Radović, D., Stevanović, V., Marković, D., Jovanović, S., Dzukić, G. and Radović, I.: Implementation of GIS technologies in assessment and protection of natural values of Tara national park. Archives of Biological Sciences, 57(3): 193-204, 2005.

Vukanović, S. i Reljić, S.: Stanje i perspektive u rešavanju problema saobraćaja i transporta. Zbornik radova GIS stanje i perspektive, Geografski institut „Jovan Cvijić" SANU, Beograd, 1996, str. 89-96.

Vozikis, E., Sidiropoulos, N. and Vozikis, G.: The Use of Modern Technologies (GPS, GIS and Geodata) for Controlling Olive Tree Pests. From Pharaohs to Geoinformatics. FIG Working Week 2005 and GSDI-8 FIG 2005, Cairo, 2005, pp. 16-21.

Wichmann, L. and Ravn, H.P.: The spread of *Ips typographus* (L.) (Coleoptera, Scolytidae) attacks following heavy windthrow in Denmark. Forest Ecology and Management, 148: 31-39, 2001.

Primena GIS metodologije u istraživanjima lisnih buva (Hemiptera: Psylloidea) u Srbiji

REZIME

Istraživanja entomofaune sadrže veliki broj podataka koji se odnose na broj sakupljenih vrsta, broj jedinki u okviru vrste, vreme sakupljanja, istraživane lokalitete, biologiju i morfologiju istraživanih vrsta, prirodne neprijatelje i domaćine. Pored tematske i vremenske komponente, ova istraživanja sadrže i prostornu komponentu, koja je ključna u primeni GIS metodologije i naprednih mogućnosti geoprostornih analiza. Tokom višegodišnjih sopstvenih istraživanja faune lisnih buva (Psylloidea) i njihovih prirodnih neprijatelja na prostoru Srbije, prikupljen je veliki broj prostorno određenih podataka o njima. Proces prikupljanja, arhiviranja i klasifikovanja podataka o ovoj vrsti unapređen je primenom GIS metodološkog pristupa pri čemu su ti podaci smešteni u projektovanu bazu podataka. Analizom podataka putem tematskih i prostornih upita, zatim grafičkim, numeričkim i tekstualnim prikazivanjem rezultata istraživanja, omogućeno je jednostavnije i celovitije sagledavanje horizontalne i vertikalne rasprostranjenosti lisnih buva, njihove biologije i odnosa prema biljkama, predatorima i parazitoidima.

Ključne reči: GIS; lisne buve; Psylloidea; prirodni neprijatelji; baza podataka; geoprostorne analize; Srbija