8th International Conference

MINING AND ENVIRONMENTAL PROTECTION

22 – 25th September 2021, SERBIA

MINING AND ENVIRONMENTAL PROTECTION

PROCEEDINGS

Editor
Prof. dr Ivica Ristović

Sokobanja
22 – 25th September 2021

FOREWORD

After the consultations with business entities in the field of mining and environmental protection, faculties and scientific institutes, an initiative for organizing a scientific meeting on mining and environmental protection was taken in 1996. The Faculty of Mining and Geology in Belgrade, CENTER FOR ENVIRONMENTAL ENGINEERING, have organized the First Yugoslav Conference with International participants held from 25th to 27th April 1996 in Belgrade, Serbia. 2nd International Symposium was held in Belgrade from 25th to 27th 1998. 3th Symposium was held in Vrdnik from 21st to 23rd May 2001, 4th International Symposium was held in Vrdnik from 23rd to 25th June 2003, 5th International Symposium was held in Vrdnik from 10 to 13 June 2015, 6th International Symposium was held in Vrdnik from 21st to 24th June 2017, and 7th International Symposium was held in Vrdnik from 25th to 28th September 2019.

Due to the large number of subjective and objective reasons organization of the symposium was discontinued in 2003. On the basis of the conclusions made at the 7th Symposium MEP 2019 and great interest of domestic and foreign scientific and professional public, the Faculty of Mining and Geology in Belgrade, in cooperation with co-organizers (National University of Science and Technology "MISIS", Moscow, Russia Berg Faculty TU Košice, Slovakia, University of Ljubljana, Faculty of Natural Sciences and Engineering, Slovenia, Goce Delčev University in Štip, N. Macedonia and University in Banja Luka, Faculty of Mining, Prijedor, Republic of Srpska, Bosnia & Herzegovina, Association of Mining and Geology Engineers), shall organize the 8th International Conference Mining and Environmental Protection – MEP 2021.

Considering the overall work of the conference from 1996 until today, we are proud to celebrate this year the 25 years of work and existence of the International Conference on Mining and Environmental Protection - MEP For all these years, about 700 scientific and professional papers in this field have been published in the Proceedings of the International MEP Conference, and about 1500 participants from the country and abroad have attended the conferences.

Unfortunately, the situation with the Covid 19 pandemic has changed a lot, including the number of participants who will be present at the Symposium. On the other hand, this year a large number of participants from the country and abroad are expected to attend the conference online.

The previous Symposium, were very successful and scientist and companies from many countries gathered to exchange information and research results. The objective of this Conference is to bring together engineers, scientists and managers working in mining industry, research organizations and government organizations, on development and application of best practice in mining industry in the respect of environment protection.

At the Book of Proceedings of 8th International Conference on Mining and Environmental Protection are 38 Papers. Almost half is from abroad, or their authors is from different countries. At least 100 authors and co-authors took part in the preparation of these papers. The papers were reviewed by Reviewers and Scientific Committee. Only high-quality papers were selected, from two side, one from the scientific basis and the second from point of view of applicability in resolving problems at the development of mining.

We are very grateful to the authors of the papers, who contributed to a great extent to the success of this meeting by having sent enough number of high quality papers, and thereby made the work of the reviewers a pleasant one in respect of selecting the best quality papers. Also, we would like to thank all of the participants in the Conference, as well as the sponsors who helped and enabled us to hold such a great meeting.

The Organizing Committee of the Conference made the decision to dedicate this Conference and this Proceedings to prof. dr Milivoje Vulić from the Faculty of Natural Sciences and Engineering, University of Ljubljana, longtime Vice President of the International Conference Mining and Environmental Protection, a great professor and scientist, a good man, who passed away between the last and this Symposium.

Editor

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THE ASSESSMENT OF SPATIAL DISTRIBUTION OF TRACE ELEMENTS IN SOIL AND MOSS USING ARTIFICIAL INTELLIGENCE IN THE BREGALNICA RIVER BASIN, NORTH MACEDONIA

Robert Šajn[1], Trajče Stafilov[2], Bilijana Balabanova[3], Jasminka Alijagić[4]

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Abstract: *The main objectives of this paper are to improve spatial distribution maps using an artificial neural network - multilayer perceptron (ANN-MLP) at macroregional scale and to compare the two methods, the universal kriging method and ANN-MLP for representing the spatial distribution of selected anthropogenic and geogenic elements in North Macedonia. The Bregalnica River Catchment Area (5400 km^2) is heavily contaminated due to long-lasting mining activities (Figure 1). There are many agricultural lands in the region that are irrigated with the contaminated Bregalnica River that flows past the mines. The level of contamination in two different sampling media, soil and moss samples have been measured by using ICP-MS and ICP-ES. The soil and moss measurements together with geospatial data obtained from the digital elevation model (DEM), land use data, and remote sensing are incorporated into the spatial distribution mapping using the advanced prediction modelling technique ANN-MLP. Both methods have been further compared and evaluated, which lead to the general conclusion that ANN-MLP gives more realistic and detailed results than the universal kriging method used for the reconstruction of main distribution pathways.*

Keywords: *universal kriging method, ANN-MLP, copper, lead, pollution*

1. INTRODUCTION

Information on the amount and distribution of heavy metals in the environment is of great importance since their toxicity makes them hazardous to living organisms [1]. Several factors must be considered in presenting these data, including the distinction between the natural and anthropogenic sources of the element, the chemical and physical conditions under which a particular element occurs, the topography of surfaces, and meteorological factors [2–4].

Many tools have been developed and tested to help researchers analyse processes of contaminated particles distribution and the level of contamination, including statistical techniques such as multiple linear regression [5], kriging [6] and regression kriging [7]. In the last few years, a few studies also applied new methods from the machine learning field such as artificial neural networks [8], boosted regression trees [9] and random forests [10]. Those machine learning methods overcome the imperfections of parametric and non-parametric statistical methods, including overfitting, autocorrelation, non-linearity [11] and in that way giving more accurate spatial models.

The applicability of two machine learning methods – artificial neural networks and universal kriging –has already been shown as a useful method for the spatial distribution of elements in the case of Zenica, Bosnia and Herzegovina [12]. In the presented study, a much larger area was taken into account – Bregalnica River Basin – thus, the number of variables that influence the accuracy of the methods is much bigger. The main objective of this paper is to present the results of a systematic study of the spatial distribution of contamination of different elements in topsoils and mosses using linear and nonlinear mathematical methods and to present the applicability of the two modelling techniques – artificial neural networks and universal kriging more precisely

2. MATERIALS AND METHODS

2.1 Study area

The catchment area of the Bregalnica river covers an area of about 5400 km^2 and it is characterized by two valleys - the Maleshevska and the Kočani valleys (Fig.1,2). In general, the region is characterized by a moderate continental climate. The average annual temperature is around 13 °C. The most frequent winds are from the west with a frequency of 199 ‰ and a speed of 2.7 m/s, and the east wind with a speed of 2.0 m/s, with a frequency of 124 ‰ [13]. Winds have an important influence on the distribution of atmospheric dust with the content of heavy metals [14]. The average annual precipitation is about 500 mm adjusted by Mediterranean cyclones [13].

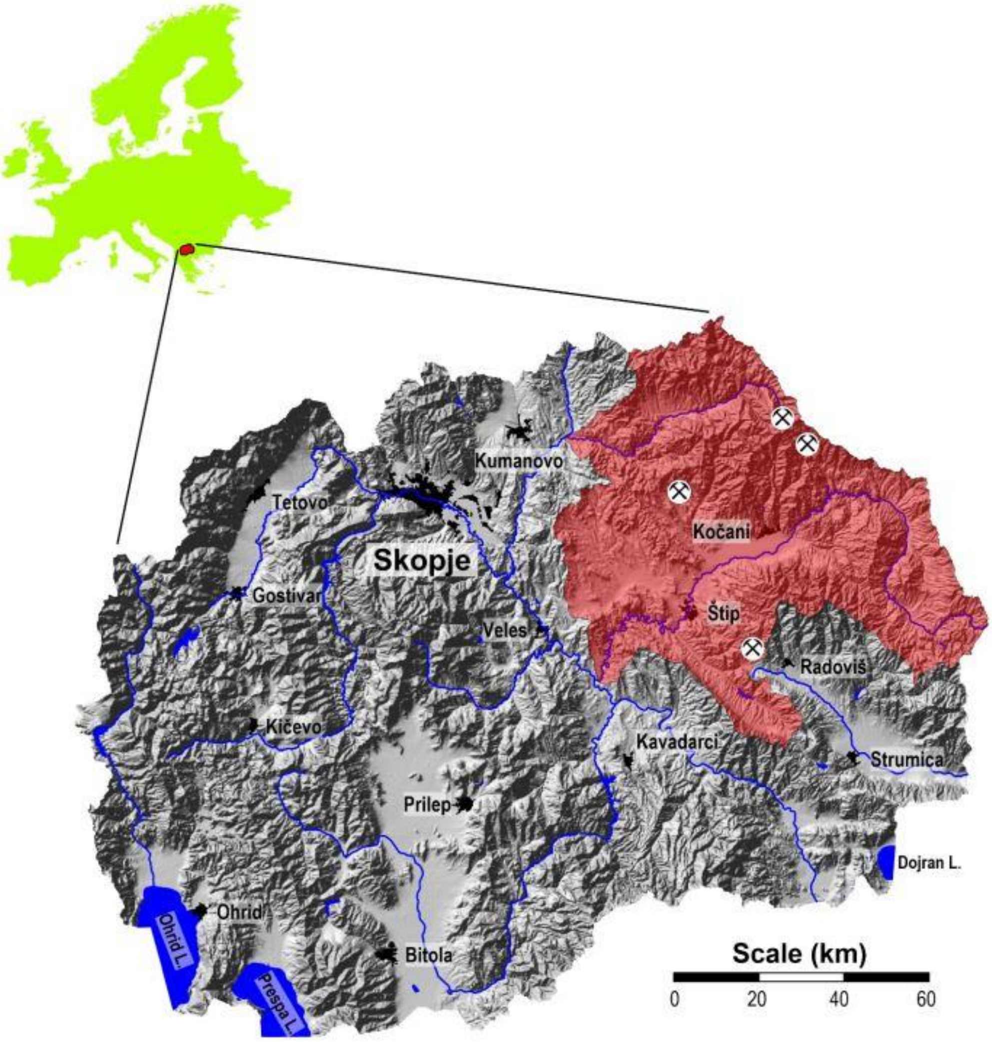

__Figure 1.__ Study area

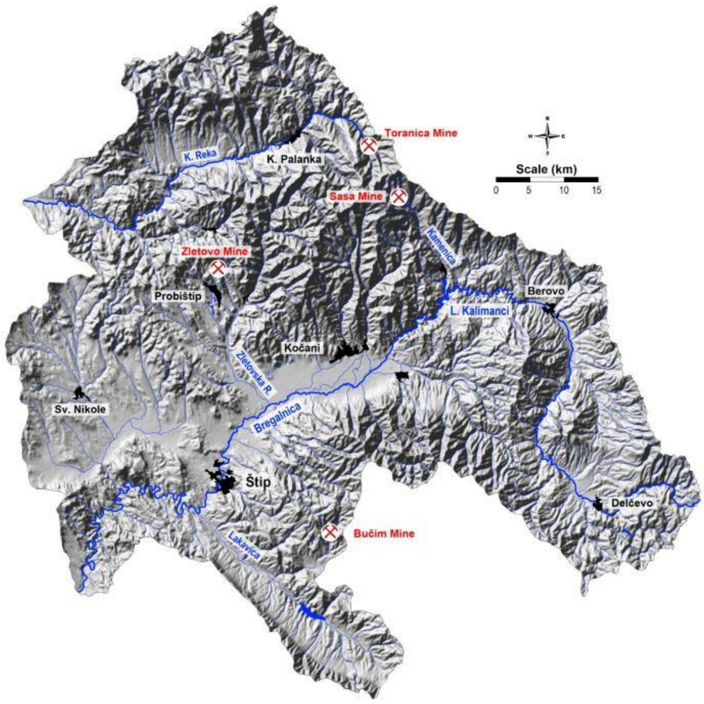

Figure 2. *Digital elevation model of the study area*

The studied area lies on two main tectonic units - the Serbian-Macedonian Massif and the Vardar Zone [15]. The oldest volcanic rocks associated with Oligocene and early Miocene are located in the Bučim, Damjan, Borov Dol and Toranica, Sasa, Delchevo and Pehchevo areas [15]. The generalized geology of the region is presented in Fig. 3.

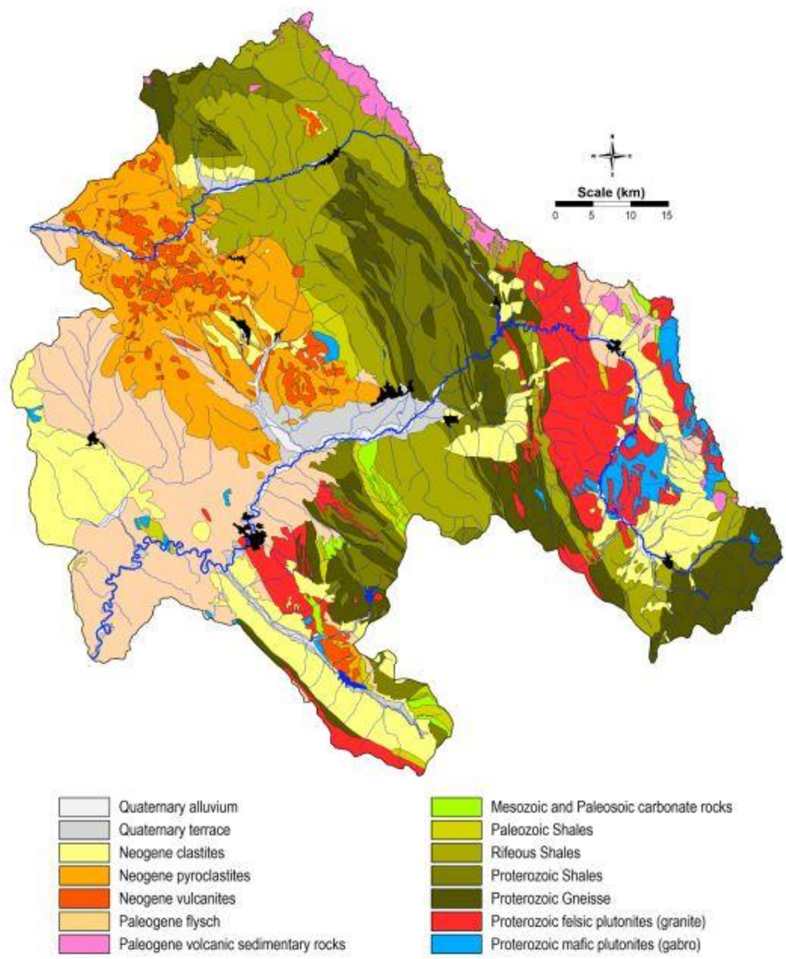

Figure 3*. Basic lithological units*

2.2 Sampling

The total number of topsoil sampling sites was 409, while the total number of moss samples was 286 (Fig. 4). Soil samples were dried and sieved under 125 µm, while the moss samples were digested by the microwave digestion system. Both soil and moss samples were subsequently analysed by inductively coupled plasma atomic emission spectrometry (ICP-MS) in the accredited laboratory ACME Ltd. of Vancouver, Canada.

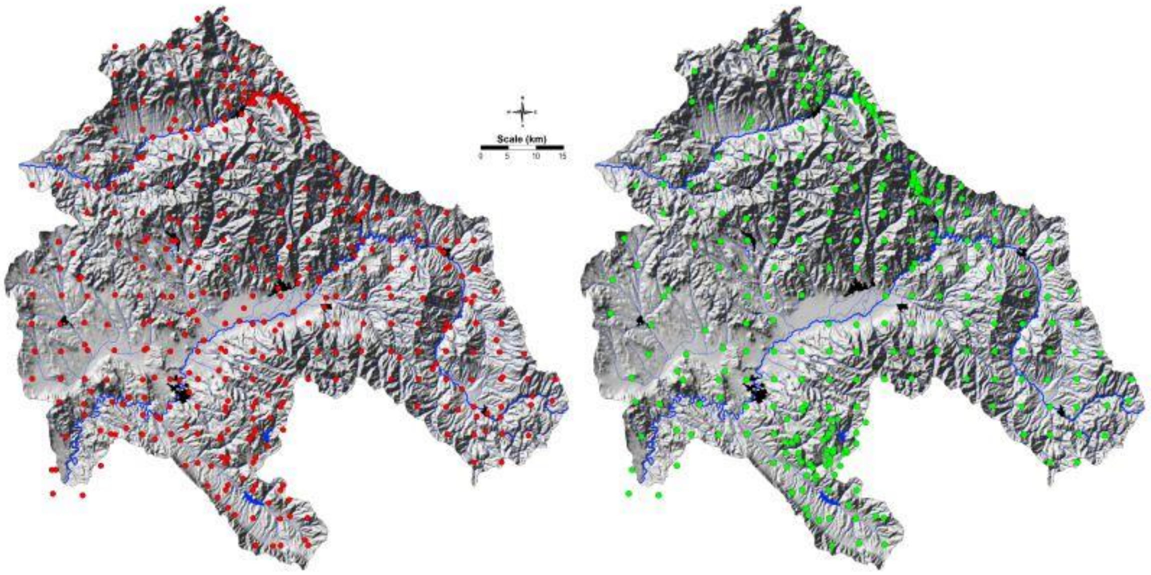

Figure 4. *Locations of topsoil (left) and mosses sampling sites (right)*

2.3 Methods

By digitizing existing topographic maps, various spatial data were first collected. Then, by means of vectorization, standardization of databases, digitization, additional modification and integration with the GIS environment, the isolation of the main lithological units important for the detection of the natural and anthropogenic background was carried out. For this step, the program Surfer 11 (Golden Software) and QGIS (GNU General Public License) were used.

Descriptive parameters such as concentrations of chemical elements in soils as well as in mosses; geospatial data such as lithological unit, land use unit, latitude, longitude, terrain slope, elevation, plan terrain curvature, profile terrain curvature, tangential terrain curvature, distance from Sasa mine area, distance from Zletovo mine area distance from Bučim mine and Landsat spectral bands 1-7, were applied for further modelling.

For the production of distribution maps, the kriging method with linear variogram interpolation and ANN -MLLP method was used. A recall grid was used for modeling with the Artificial Neural Network of the spatial distribution of chemical elements. The entire study area was divided into 100 x 100 grid cells. The total number of recall points is 540 497.

3. RESULTS AND DISCUSSION

In figure 5 it is evident that the enrichment of Cu in topsoils as well as in mosses, applying universal kriging technique, is highest near the mines. However, an enrichment at unexplained locations is also evident. This could be explained by the appearance of circles in spatial distribution maps – the so-called Bull Eye's effect. The classic interpolation methods, such as universal kriging, use only chemical concentration data in their methodology, while spatial data, such as the geological background, pedogenic processes, the morphology of the study area, precipitation, wind frequency, etc., are ignored. This can result in illogical data of the spatial distribution of an element, which means that special care must be taken in the interpretation.

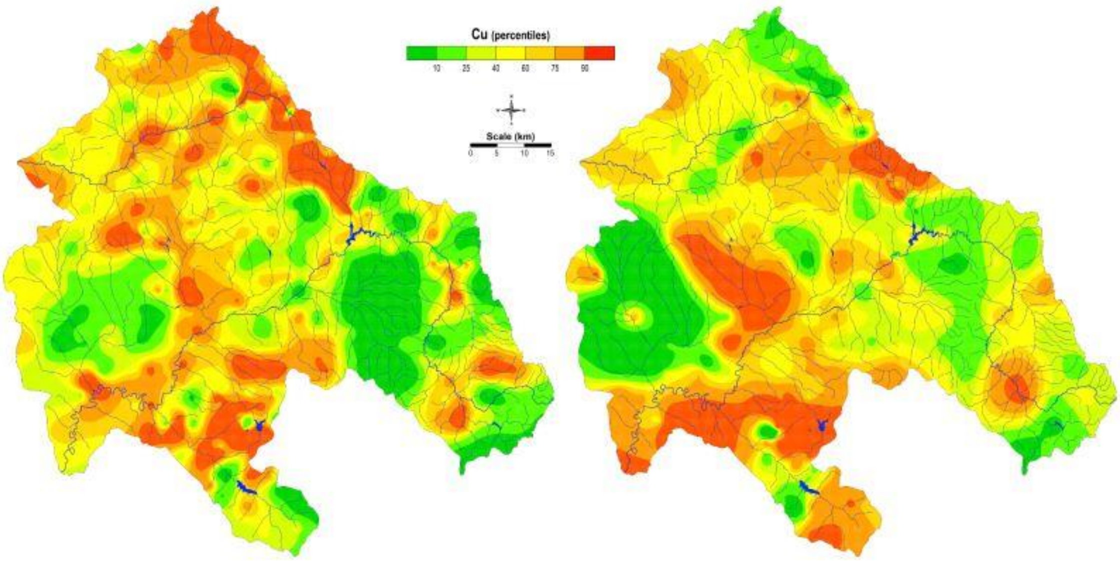

Figure 5. *Copper distribution in topsoil (left) and mosses (right) after universal kriging applying*

On the other hand, from the ANN-MLP model for the topsoil, it can be seen that the enrichment with Cu in the southern part of the study area is related to the Cu mine, while in the northern part the enrichment is related to lithological units that predominate in this area (Fig. 6). Larger Cu concentrations may also be observed near alluvial plains, which may be the result of both lithogenic and anthropogenic influences. Specific natural enrichment with copper is found, as in a previous study, in the area of the Kamenica River and the Zletovska River [16]. Heavy metals can enter water bodies either by weathering of the parent substrate or by mineral degradation. Contaminated particles are subsequently transported by water and can be spilt over alluvial deposits during floods, posing a threat to the environment.

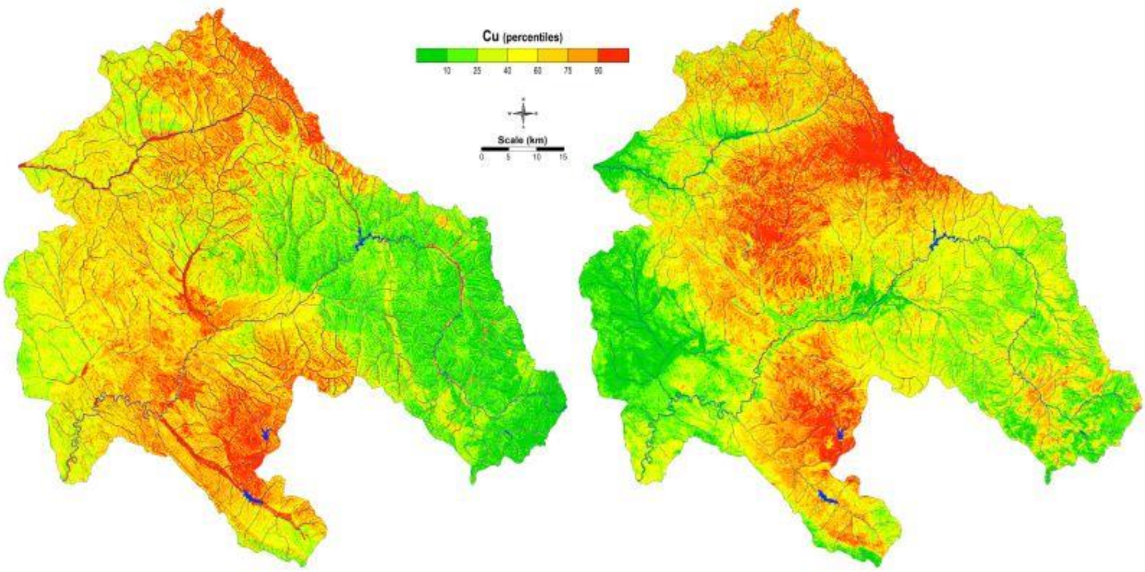

Figure 6. *Copper distribution in topsoil (left) and mosses (right) after ANN-MLP applying*

ANN -MLP model for mosses, similar to the topsoil model, shows the influence of wind on the spatial distribution of Cu, with dispersal dependent on the main wind direction. Mining of copper minerals in Bučim mine has been carried out continuously since 1979, resulting in exposure to airborne dust [17]. The highest values in mosses are representative for the surroundings of the Cu Bučim mine, Zn-Pb mines Sasa and Zletovo, while the geological characteristics and lithogenic units do not play a significant role in this case.

The spatial distribution of lead in topsoil is associated with natural enrichment in certain lithological units and associated Pb mining activity (Zletovo, Sasa-Toranica) (Fig. 7). However, the enrichment of this element can also be detected along the Bregalnica River and its floodplain. Pb enrichment in mosses is associated with its long-distance transport by wind. Along with other elements such as Cd, Zn and Sb, Pb enrichment is identified as an anthropogenic marker for the whole area of the Republic of Macedonia [18,19]. There are two dominant sub-areas from which particles are transported by wind, (i) an area of Neogene pyroclastites and volcanic rocks associated with Pb-Zn hydrothermal exploitation ("Zletovo" mine); (ii) an area of Paleogene volcanic sedimentary rocks and Paleogene flysch ("Sasa & Toranica" mine) [20], and during precipitation, the heavy metal particles can be taken up by mosses.

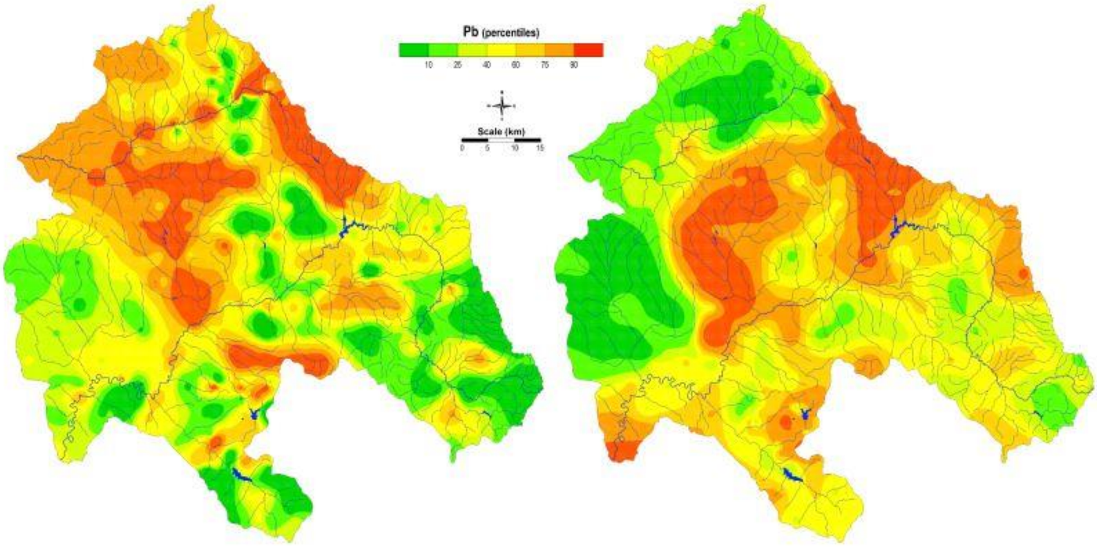

Figure 7. *Lead distribution in topsoil (left) and mosses (right) after universal kriging applying*

Comparing the kriging method model with the ANN-MLP, some similarities can be observed (Fig. 8). The enrichment with Pb in topsoil and mosses is related to Pb mining areas and some lithological units. Besides wind transport, water transport is also significant, which in principle leads to high Pb concentrations in the soil. The alluvial plains of Kamenička and Zletovska Rivers, that flow into the surrounding areas, are polluted with lead. Pollution of these areas as a result of mining and mining-related activities has already been pointed out in a previous study [21]. In contrast, high concentrations were not isolated in the middle flow of the Bregalnica River at ANN. This means that the polluted sediments are accumulated in Kalimanci Lake.

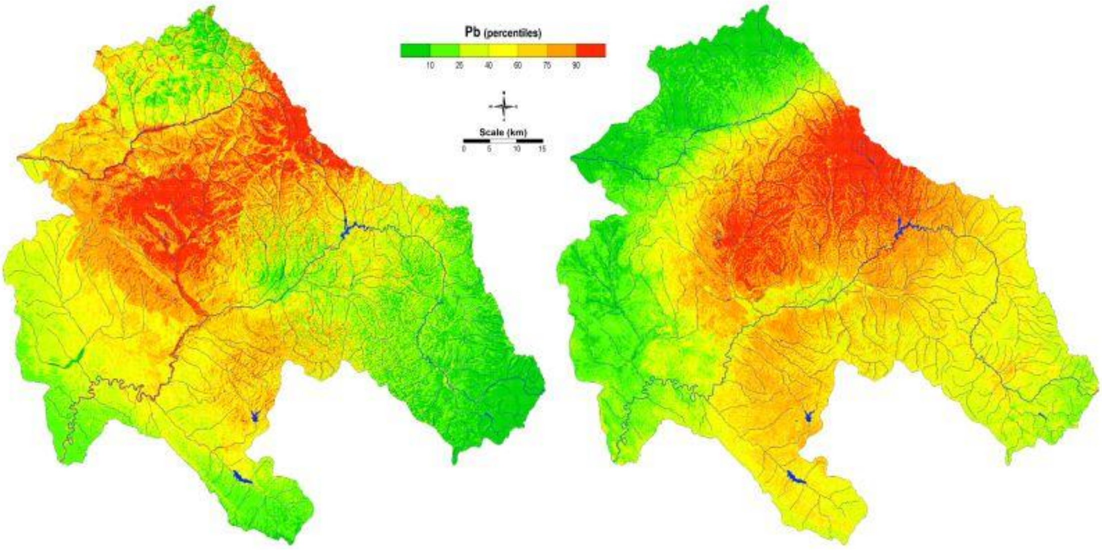

Figure 8. *Lead distribution in topsoil (left) and mosses (right) after ANN-MLP applying*

4. CONCLUSIONS

By comparing the two methods; the universal kriging and the ANN-MLP methods, it was found that the ANN-MLP method generally showed more accurate results The spatial distribution of Cu using the kriging method in topsoil and mosses shows superficial results due to the so-called "bull's eye" effect, where spatial data such as geological background, pedogenic process, the morphology of the study area, precipitation, wind frequency, etc. are not considered. The kriging method may be easier to use, but its results may be erroneous and incoherent due to the failure to consider the mentioned essential factors (see above). Adding some subjectivity to the model might give better results and thus avoid the bull's eye effect. The ANN-MLP technique provides an unlimited number of algorithms during exploration and consequently provides better and more acceptable results than the universal kriging method, which provides only a limited number of training algorithms. Thus, the use of the ANN-MLP method could replace the use of the classic method - universal kriging.

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