International Journal of Research in Agricultural Sciences
Volume 7, Issue 3, ISSN (Online): 2348 – 3997

Estimating Spatial Distribution and Mapping Risk Element Pollution in Urban Agricultural Land of Nhi Binh Area, Ho Chi Minh City, Vietnam

Tuan Quang Tran [1, 2*], Tien Yin Chou [3], Mei Hsin Chen [3], Van Thanh Hoang [3], Tuan Nhi Pham [2], Mon Danh [2] and Luu Hai Tung [2]

[1] Ph.D Program of Civil and Hydraulic Engineering, Feng Chia University, Taiwan, No. 100, Wenhwa Rd., Seatwen, Taichung, 40724, Taiwan.

[2] Department of Land Resources, Ho Chi Minh City Institute of Resources Geography 01 Mac Dinh Chi St., Dist., 1, Ho Chi Minh City, Vietnam.

[3] GIS Research Center, Feng Chia University, Taiwan, 100 Wenhwa Rd, Situn, Taichung 40724, Taiwan.

*Corresponding author email id: tqtuan@vast.hcmig.vn

Date of publication (dd/mm/yyyy): 22/05/2020

***Abstract* – In recent years, heavy metal contamination in urban agricultural soils has been raised as a serious environmental problem and call significant concerns due to rapid urbanization and industrialization. In urban conditions, agricultural land actually is very important variables in both economic and social way. In order to evaluate the current state of quality in urban agricultural soil of Nhi Binh, HCMC, Vietnam, the concentrations of 3 heavy metals: Cu, Pb and Zn has been investigated in this study. A surveying was conducted to collect soil samples from the fields. The results showed that the heavy metal concentrations in agricultural soils of Cu (8.08 – 69.57 mg/kg) and Pb (0 – 27.13 mg/kg) were lower the allowed thresholds. However, the concentration of Zn (0 – 272.5 mg/kg) was much higher than the limit (200 mg/kg). This concentration exhibits a pollution risk in the study area. Farming practices; the usage of fertilizer and pesticides corporate with urban and industrial waste have been considered as the main causes of increasing and changing heavy metals concentrations in soil in case of the study area. In this study, Geostatistics and Geographic Information System (GIS) were employed for estimating and mapping the spatial distribution of risk element pollution in the studied area. The identification of heavy metal concentration and its spatial distribution may provide a basis for taking appropriate action to protect agricultural soil quality in the study area. The results can be used as a reference data source for researcher and environment organizers in planning effectively policies to protect the region's agricultural soil from long-term heavy metal accumulation.**

***Keywords* – Soil Pollution, Heavy Metals Concentration, GIS Technique, Kriging Interpolation.**

I. INTRODUCTION

In urban area, available of agricultural land is one of the most variables and play an important role in producing food in urban space and contributing to greater food security. Urban agriculture also can help local communities in both an economic way and a social way. It allows for people to have more immediate connection to their food, as well as help stimulate a local economy. But the environmental issues are increasing in urban farming, especially soil contaminated problem by heavy metals. Risks from soil contamination include plants absorbing contaminants through the soil; groundwater becoming contaminated as it interacts with and flow beneath the soil [2]. High level of heavy metal content in agricultural soils strongly affect the crop output and quality. Moreover, once the heavy metal contamination of various elements such as Cu, Pb, Zn, Cd…in soil soil exceed the allowed threshold, those toxic heavy metals are threat to human health through food chain and strongly impact on natural ecosystem [3, 4].

In recent years, heavy metal contamination in agricultural soil has been become an important issue due to rapid urbanization and industrialization in many countries and it is becoming a global concern. It harmful to

human health, plant and animals [1]. Agricultural land can be contaminated by both natural and human causes; anthropogenic activities are considered as the main contributor to the pollution of heavy metals in agricultural area [4, 5]. Proshad et al. has been found that heavy metals are most probably industrial origin [24]. Changes in heavy metal concentration may modify soil properties, especially soil biological properties [6]. Crops cultivated in the contaminated agricultural land may cause serious problems to the human body resulting from their consumption [9], particularly the incorporation of toxic heavy metals in the soil comes to the body by food has been recognized a pathway to element pollutant exposure for children [10, 11]. Moreover, the current extend of urban agriculture is poorly understood and it needs to be paid more attention and quantified more rigorously [23]. So, estimating and mapping the spatial distribution of heavy metals are particular interest for the purpose of controlling and managing soil quality in agricultural land. In term of sustainable development, a preventive and monitoring approaches based on predicting spatial distribution of heavy metal content is therefore promising.

There are several studies has been carried out for the accumulation of metals in agricultural soil in Vietnam, however, the previous studies mainly focused on the heavy metal contaminated in individual sampling points instead of producing a spatial distribution map for different levels of contaminated heavy metals in soil. In this study, the GIS technique and Geostatistic methods were employed to estimate heavy metal distribution in Nhi Binh commune, Ho Chi Minh City, Vietnam. Geostatistical methods have been used as a successfully method that can provide a reliable estimate at the unsampled locations [7]. Geostatistic also provides a set of statistical tools for incorporation spatial coordinates of observations in data processing [8]. Geo-statistics and Geographic Information System (GIS) allow for faster and more accurate information, that's why they have been widely used in numerous studies for determination of spatial distribution and behaviour of pollutant in urban areas [12, 13, 14, 17, 18]. The distribution of heavy metals contaminated in soil was mapped by Xie et al. [15]; The concentration of metal on soil was determined successfully by using GIS technology [16]. Kriging is one of the most commonly used methods for spatially interpolation in environmental studies [16, 19] that has been successfully described the spatial variability of certain soil parameters and predict value for unknown points/areas [13, 18, 20].

The main objective of this study is to (1) determine the heavy metal in urban agricultural land in Nhi Binh, Ho Chi Minh City, Vietnam; (2) estimate and map the spatial distribution of heavy metals using Geostatistic method and GIS technique in order to provide useful information about soil heavy metal pollution in urban agricultural area.

II. STUDY AREA

The study area located in Nhi Binh commune, Hoc Mon District, Ho Chi Minh City (HCMC), Vietnam (10°54'46"N 106°40'15"E) (Figure 1) and covers an area of about 900 ha, of which more than 70% of the study area was allocated for agriculture (approximately > 600 ha). This area has a tropical climate with two distinct seasons: The rainy season lasts from May to November and the dry season lasts from December to April. This is a large vegetable growing area in Ho Chi Minh City for a long time based on favourable conditions of nature: soil, water, and suitable climate. However, undergoing long-term cultivation; the excessive use of fertilizer and pesticides cause a serious environmental problem in the study area. Similar to other area in HCMC, the study area has experienced rapid urbanization and industrialization in recent years, the disposal of urban or industrial

waste is increasing and being the main causes of polluted agricultural soil. Due to long-term irrigation with domestic sewage and industrial effluent containing heavy metals, contamination is agricultural soils has become significant higher than the back-ground value [21, 22]. Some unwanted metals can be immigrated into soil, water, vegetable and be toxic elements to human health. Therefore, the polluted agricultural soil by heavy metal contamination in the study area needs more and more concerns.

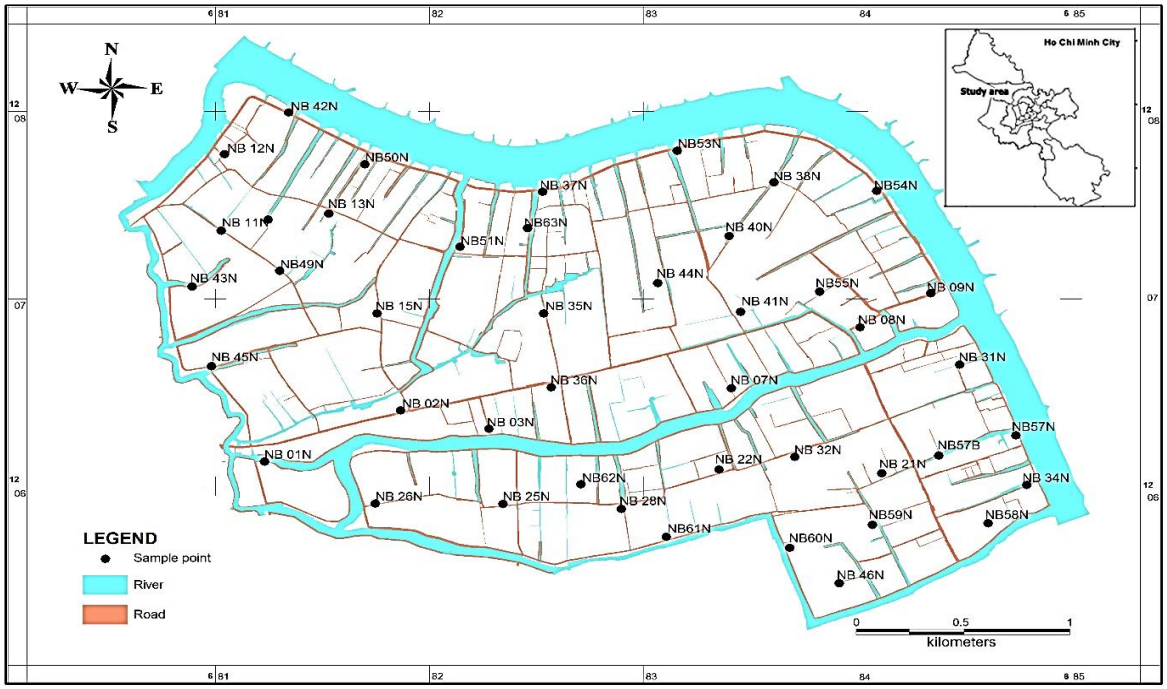

Fig. 1. Soil sampling points denoted in the map of the study area - Nhi Binh commune, HCMC (Source: Based map collected from Vietnam Academy of Science and Technology).

III. DATA

Soil Sampling

A total of 44 surface soil samples (0 – 30 cm depth) were taken from the fields corresponding to agricultural lands. Sampling points were selected randomly over the study area. They are stored in polyethylene bag for transport; air-dried for several days at room temperature and then analyzed in the laboratory for chemical analysis following the guidance of Vietnam standard (TCVN 6647 : 2007 ; ISO 11464 : 2006).

Land Use/Land Cover Map

A land use/ land cover map with scale 1/10,000 in 2014-2015 was obtained from the vietnam academy of science and technology for the study area. This dataset is used as a reference data that acquired mainly for ground survey purpose.

IV. METHODS

Total Heavy Metal Concentrations

The total heavy metal concentration was measured for 3 main elements: Cu, Pb and Zn following the procedure. The soil samples were air-dried at room temperature (20-25^{o}C) for several days then milled to a particle size of < 2 mm after dried. The total concentrations of heavy metal were determined using Flame

Atomic Absorption Spectrophotometry method (TCVN 8246:2009; EPA Method 7000B). This method is simple, rapid and applicable to a large number of environmental samples. In order to determine the concentration of heavy metals, the soil samples were digested in a combination of acids including hydrochloric acid and nitric acid.

Statistical and Geo Statistical Analyses

The descriptive statistics including minimum, maximum, mean, standard deviation and coefficient of variation were calculated. For estimation distribution of three heavy metals: Cu, Pb and Zn, ordinary kriging interpolation method was used and then GIS technique was applied to produce their maps. In GIS applications, spatial interpolation is typically applied to estimate values for unknown points from a set of control points. At basis assumption is spatial interpolation is that the value to be estimated at a point is more influenced by nearby known points that those father away.

Ordinary Kriging is a linear spatial interpolation that estimates spatial data at unknown location using a weight function of adjacent data points [16]. The general equation for estimating the z value as a point is:

$$Z_0 = \sum_{i=1}^{n} Z_x W_x \quad (1)$$

Where Z_0 is the estimated value, Z_x is the known value at point x, W_x is the weight associated with point x. And n is the number of sample points used in estimation. The weight can be derived from solving a set of simulation equations. For example, the following equations are needed for a point (0) to be estimated from three known point (1, 2, 3).

$$W_1\gamma(h_{11}) + W_2\gamma(h_{12}) + W_3\gamma(h_{13}) + \lambda = \gamma(h_{10}) \quad (2)$$

$$W_1\gamma(h_{21}) + W_2\gamma(h_{22}) + W_3\gamma(h_{23}) + \lambda = \gamma(h_{20}) \quad (3)$$

$$W_1\gamma(h_{31}) + W_2\gamma(h_{32}) + W_3\gamma(h_{33}) + \lambda = \gamma(h_{30}) \quad (4)$$

$$W_1 + W_2 + W_3 + 0 = 1.0 \quad (5)$$

Where $\gamma(h_{ij})$ is the semivariance between known points *i* and *j*, $\gamma(h_{i0})$ is the semi variance between the *i*th known point and the point to be estimated, and λ is a lagrange multiplier, which is added to ensure the minimum possible estimation error.

Once the weights are solved, Eq. (1) can be estimated z_0, $z_0 = z_1W_1 + z_2W_2 + z_3W_3$

V. RESULTS AND DISCUSSION

Heavy Metal Concentration in Urban Agricultural Soils

The basis descriptive statistic for raw data of risk elements is showed in the Table 1. Total concentrations of heavy metals ranged as follows: Pb (0 – 27.13 mg/kg); Cu (8.08 – 69.57 mg/kg); and Zn (0 – 272.5 mg/kg). The data indicated that the largest mean value was found for Zn (38.64 mg/kg) and its maximum value (272.5 mg/kg) observed from soil samples in the studied area are also much higher than allowed threshold (200 mg/kg) (Table 1). Cu and Pb concentrations in agricultural soil were lower than the limit. The statistical results also demonstrated that Pb and Zn has high variation between minimum and maximum values with coefficient of variation of 338 % and 165 % for Pb and Cu, respectively.

Table 1. Descriptive statistical of heavy metal concentration in urban agricultural soil. (mg/kg) (Results of chemical analysis process in lab for determining heavy metal concentration in urban agricultural soil).

Heavy metals	Min	Max	Mean	Standard Deviation	Coefficient of Variation (%)	Allowed Threshold
Pb	0	27.13	1.28	4.33	338.28	70
Cu	8.08	69.57	26.84	12.9	48.06	100
Zn	0	272.5	38.64	63.93	165.45	200

Spatial Distribution of Heavy Metals

The distribution maps of risk elements: Cu, Zn and Pb concentrations are illustrated in Figure 2, 3, and 4 respectively. These maps were generated from raw data using Kriging interpolation method. The distribution of Cu shows a higher heavy metals contaminated in soil in the west and southeast of the study area (Figure 2). There are 3 hotspots with the highest value of heavy metal concentration was found in the west and 2 hotspots in the southeast. Their heavy metal contents in range of 51 – 69 mg/kg.

For Zn distribution map demonstrated high pollution risks are mainly located from the northwest to southeast of the study area. This spatial distribution shows a wide range and similar geographic trends; since there were around a big river (Figure 1), the usage of waste water obviously affects the soil risk element concentration. There were 2 hotspots of polluted Zn observed in the northwest, 1 hotspot in the northeast and one in the southwest part of the study area (Figure 3). The Zn concentrations are in range of 177 – 272 mg/kg that exceed the limit threshold for agricultural land. The high probability of exceeding the limit of Zn are highly correlated with vegetable areas which suggested that the cultivation activities, the use of fertilizer and pesticides; urban and industrial waste water might be the main cause that lead to high Zn concentration immigrated in agricultural soils.

The distribution map of Pb shows the lead concentrations were mainly located in the center and southeast part of the study area. And the levels of Pb contaminated in soil are still much lower than the limit (Figure 4).

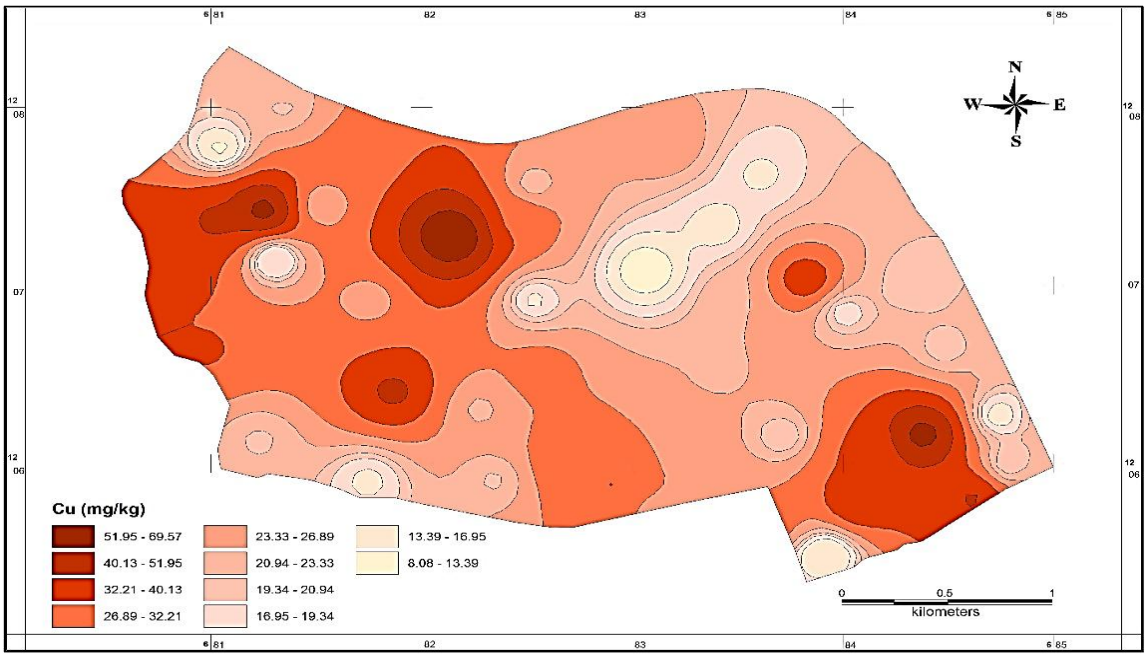

Fig. 2. The spatial distribution map of Cu concentration estimated by using Kriging method.

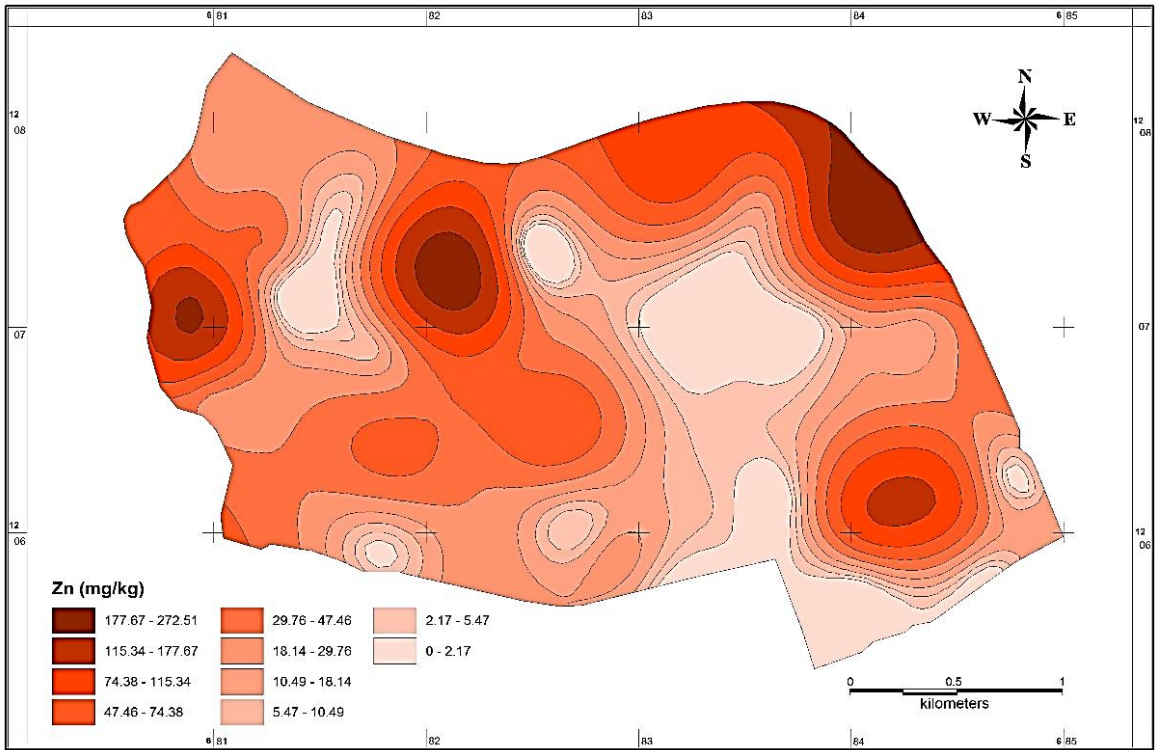

Fig. 3. The spatial distribution map of Zn concentration estimated by using Kriging method.

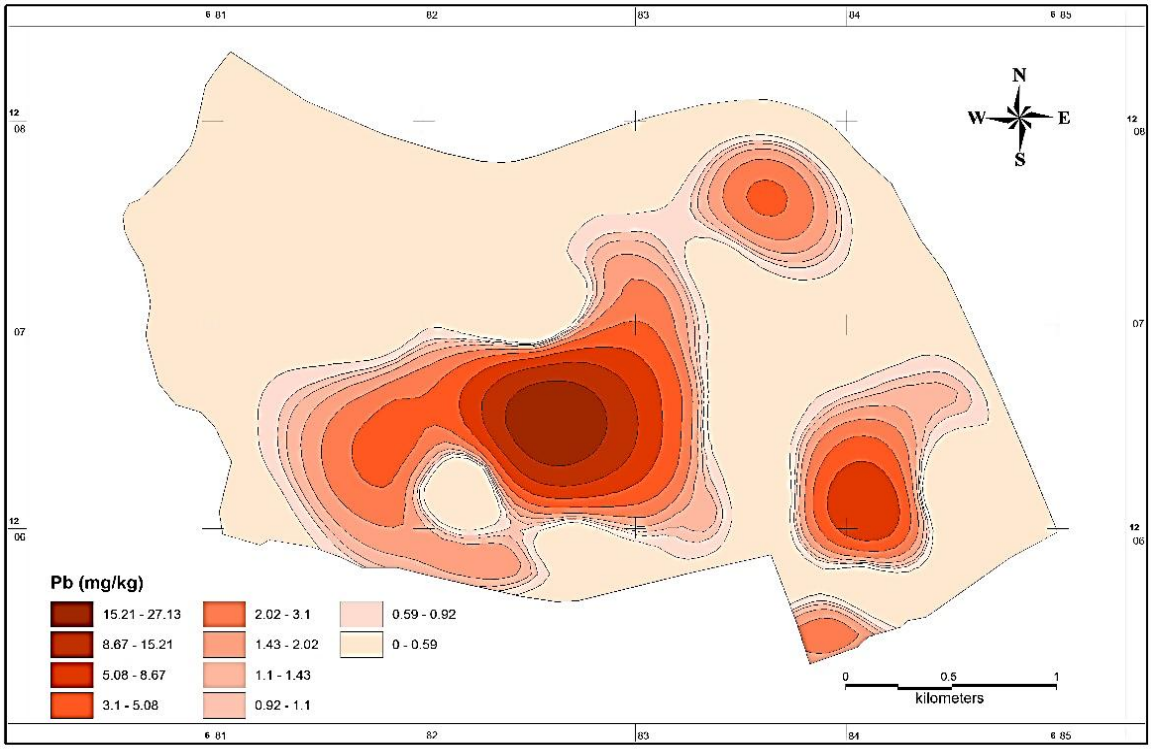

Fig. 4. The spatial distribution map of Pb concentration estimated by using Kriging method.

VI. CONCLUSIONS

The risk element concentration maps (Cu, Pb, and Zn) in urban agricultural land of Nhi Binh area, HCMC was successfully generated using geostatistical method and GIS technique. Zn concentrations shows a wide range of distribution from northwest to southeast of the study area. Similarly, high concentrations of Cu were

also mainly located in these both sides of Nhi Binh, while high Pb contents were mostly identified in the center of the study area. Although the concentration of Cu and Pb in the agricultural soil of Nhi Binh area were lower the limit defined by Vietnamese standard (*QCVN 03-MT: 2015/BTNMT*), but the Zn concentration in the studied area has been exceed the allowed threshold. This result indicated that farming activities incorporated with irrigated by urban and industrial wastewater might be the reason which had a large effect on high heavy metal concentration in soil. This result also suggested the fact that the state of pollution risks in urban agricultural soil in Nhi Binh with estimated probability cannot be regarded as a safe region for vegetable growth. Since the cultivation practices tend to has more contribution to the contaminations of heavy metals in agricultural soils.

This study did an investigation to examine the heavy metal concentration in vegetable growing area in urban land. And this preliminary results may use as a reference data source for researcher and environment organizers in planning effectively policies to protect the region's agricultural soil from long-term heavy metal accumulation.

REFERENCES

[1] Lu AX, Wang JH, Qin XY, Wang KY, Han P, Zhang SZ. (2012). Multivariate and geostatistical analyses of the spatial distribution and origin of heavy metals in the agricultural soils in Shunyi, Beijing, China. Science of the total environment. 425, 66–74.
[2] Hiller, E., Lachka, L., Jurkovi˘c, L., Durža, O., Faj˘c ˇ íkova, K., Vozar, J. (2016). Occurrence and distribution of selected potentially toxic elements in soil of playing sites: A case study from Bratislava, the capital of Slovakia. Environ. Earth Sci. 75, 1390.
[3] Zahra, A.; Hashmi, M.Z.; Malik, R.N.; Ahmed, Z. (2014). Enrichment and geo-accumulation of heavy metals and risk assessment of sediments of the Kurang Nallah - Feeding tributary of the Rawal Lake reservoir, Pakistan. Sci. Total Environ. 470–471, 925–933.
[4] Han FX, Banin A, Su Y, Monts DL, Plodinec JM, Kingery WL, et al. (2002). Industrial age anthropogenic inputs of heavy metals into the pedosphere. Naturwissenschafen (Natural sciences). 89: 497-504.
[5] Vare L. (2006). Anthropogenic inputs of heavy metals to the Kongsford area. Geophysical research abstracts. 8: 06079.
[6] M. Friedlova. (2010). The influence of heavy metals on soil biological and chemical properties. Soil and water research, vol. 5, no. 1, pp. 21–27.
[7] Kerry, R., Oliver, M.A., (2004). Average variograms to guide soil sampling. *International Journal of Applied Earth Observation and Geo information* 5(4): 307-325.
[8] Goovaerts P. (1999): Geostatistics in soil science: state–of–the–art and perspectives. Geoderma, *89*: 1–45.
[9] Proshad R, Ahmed S, Rahman M, Kumar T. (2017). Apportionment of hazardous elements in agricultural soils around the vicinity of brick kiln in Bangladesh. Journal of Environmental and Analytical Toxicology, 7: 439.
[10] Proshad R, Islam MS, Kormoker T, Bhuyan MS, Hanif MA, Hossain N, et al. (2019) Contamination of Heavy Metals in Agricultural Soils: Ecological and Health Risk Assessment. SF J Nanochem Nanotechnol, 2(1): 1012.
[11] Guney M, Zagury GJ, Dogan N, Onay TT. (2010). Exposure assessment and risk characterization from trace elements following soil ingestion by children exposed to playgrounds, parks and picnic areas. Journal of Hazardous Materials, 182: 656-664.
[12] Gong, M., Wu, L., Bi, X.Y., Ren, L.M., Wang, L., Ma, Z.D. (2010). Assessing heavy-metal contamination and sources by GIS-based approach and multivariate analysis of urban–rural topsoils in Wuhan, central China. Environ. Geochem. Health 32 (1), 59–72.
[13] Lee, C.S.L.; Li, X.; Shi, W.; Cheung, S.C.N.; Thornton, I. (2006). Metal contamination in urban, suburban, and country park soil of Hong Kong: A study based on GIS and multivariate statistics. Sci. Total Environ. 356, 45–61
[14] Mihailovíc, Lj. Budinski-Petkovíc, S Popov, J. Ninkov, J. Vasin, N.M. Ralevíc, M. Vucinic Vasic. (2015). Spatial Distribution of Metals in Urban Soil of Novi Sad, Serbia: GIS-based Approach. Journal of Geochemical Exploration 150, 104-114.
[15] Xie, W., Chen, D., Zhang, H., Song, G. and Chang, X. (2009). 'An investigation into heavy metals pollution in a landfill of Guangzhou', in iCBBE2009: Proceedings of 3rd international conference on bioinformatics and biomedical engineering, Beijing, China, pp.1–4.
[16] Mihailovíc, Lj. Budinski-Petkovic, S Popov, J. Ninkov, J. Vasin, N.M. Ralevic, M. Vucinic Vasic. (2015). Spatial distribution of metals in Urban Soil of Novi Sad, Serbia: GIS-based Approach. Journal of Geochemical Exploration 150, 104-114.
[17] Morton-Bermea, O., Hernandez-Alvarez, E., Gonzalez-Hernandez, G., Romero, F., Lozano, R., Beramendi-Orosco, L.E., (2009). Assessment of heavy metal pollution in urban top soils from the metropolitan area of Mexico City. J. Geochem. Explor. 101, 218–224.
[18] Imperato, M., Adamo, P., Naimoa, D., Arienzo, M., Stanzione, D., Violante, P., (2003). Spatial distribution of heavy metals in urban soils of Naples city (Italy). Environ. Pollut. 124, 247–256.
[19] Lin, Y., Cheng, B., Chu, H., Chang, T., Yu, H. (2011). Assessing how heavy metal pollution and human activity are related by using logistic regression and kriging methods. Geoderma 163, 275–282.
[20] Kishne, A.S.; Bringmark, E.; Bringmark, L.; Alriksson, A. (2003). Comparison of ordinary and lognormal kriging on skewed data of total cadmium in forest soil of Sweden. Environ. Monit. Assess. 84, 243–263.
[21] Rodriguez J.A., Nanos N., Grau J.M., Gil L., Lopez-Arias M. (2008): Multi scale analysis of heavy metal contents in Spanish agricultural top soils. Chemosphere, *70*: 1085–1096.
[22] A. Hani1, E. Pazira, M. Manshouri, S. Babaie Kafaky, M. Ghahroudi Tali. (2010). Spatial distribution and mapping of risk elements pollution in agricultural soil of southern Tehran, Iran. Plant soil environ., *56* (6): 288–296.
[23] Jordana, N., Jelena, M., Dusana, B., Janko, C., Snezana, J., Milorad, Z., Borislav, B. (2018). Urban garden soil pollution caused by fertilizers and copper-based fungicides application. Ratar. Powrt, 55(1), 12-21. Doi:10.5937/rapov55-15489.
[24] Proshad, R., Islam, MS., Kormoker, T., Bhuyan, MS., Hanif, MA., Hossain, N., Roy, R., Sharma, AC. (2019). Contamination of heavy metals in agricultural soils: Ecological and health risk assessment. SF Journal of Nanochemistry and Nanotechnology, 2(1): 1012.

AUTHOR'S PROFILE

First Author
Quang Tuan Tran, M.Eng. obtained Bachelor on Environmental Geology at Technology of University, Vietnam National University in 2004. He graduated on master in using & protection in natural resources at institute of environment and resources, Vietnam National University in 2014. His major field includes soil science, agricultural, environment. Currently, he is studying on a PhD program in civil and hydraulic engineering, Feng Chia University, Taiwan.

Second Author
Prof. Tien Yin Chu had his Ph.D. degree from department resources development at Michigan State University in 1990. He has been the director of Geographic Information Systems (GIS) research center at Feng Chia University (FCU), Taiwan for above 20 years, and honored as distinguished professor at Dept. of Urban Planning and Spatial Information and Dept. of Land Management. With his profession and enthusiasm, prof. Chou has performed an outstanding achievement with his 250 full-time staff members at GIS research center to bring the GIS. FCU as one of the leading role in the GIS-related academic and industry fields domestically and globally.
email id: jimmy@gis.tw.

Third Author
Dr. Mei Hsin Chen received her MSc degree from Feng Chia University, Taiwan, and PhD dgree from National Chung Hsing University. She is an associate professor at GIS research center. Her major is Geographic Information Systems, Geographic Information Systems practices, Geospatial information and environment planning.
email id: ivy@gis.tw.

Fourth Author
Dr. Van Thanh Hoang received her MSc in geography department at Thai Nguyen University, Vietnam (2008) and PhD degree from PhD program of civil and hydraulic engineering at Feng Chia University, Taiwan (2015). Currently, she is an assistant professor at GIS research center, Feng Chia University, Taiwan. Her major includes Geographic Information Systems, agriculture model, climate change impact analysis.
email id: van@gis.tw.

Fifth Author
Tuan Nhi Pham, M.Eng. obtained bachelor on Geology at Natural Science of University, in 1998. He graduated on master in Geology in Natural Science of University, in 2006. His major field includes geology, materials, mineral, environment. Currently, he is a head of land resources department in Ho Chi Minh institute of resources geography.
email id: ptnhi@hcmig.vast.vn.

Sixth Author
Danh Mon received MSc degree in university of social sciences and humanities in HCMC, Vietnam (2018) a. He is working in HCM institute of geography resources. His major includes Pedology, welland and environment.
email id: dmon@hcmig.vast.vn.