# POTENTIALLY TOXIC ELEMENTS OF VOLCANIC ASH SOILS IN THE CAPPADOCIA REGION OF CENTRAL TURKEY

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**Abstract:** We determined the variability and content of potentially toxic elements (PTEs) in soils formed on volcanic parent materials erupted from Erciyes stratovolcano in the middle Anatolian region of Turkey. The PTE content of soils formed on tuffs were higher than the soils formed on lavas. All the PTE concentrations decrease with increasing soil depth except for those of Cd. Cr, Cd, and Ni increased with elevation, but Co, Cu, Mn, Pb, and Zn concentrations decreased. The high PTE concentrations in soils could be attributed to the volcanic parent materials. The greatest PTE variations in soils were determined by lithological differences and could be attributed to the types of parent material and their compositions. Site specific soil management practices must be applied to soils in the study area because of the high PTE content.

**Key Words:** Volcanogenic parent materials, Mineralogy, Geochemistry

## 1. INTRODUCTION

The products of volcanic activity are the source of potentially toxic elements (PTEs) such as As, Hg, Al, Rb, Mg, Cu, and Zn (Durand et al., 2004). Soil formed on volcanic parent materials, along with high amounts of PTEs, are found in many regions of the world (Amaral et al., 2006). The factors controlling the total and biologic available concentrations of the PTEs in soils are very important for human toxicology and agricultural production (Alloway, 1995). The distribution and amount of PTEs in soils depends on the nature of soil parent material, weathering processes, bio-cycling, and impact of atmosphere and deposition from natural resources (Cortizas et al., 2003). These events influence soil development and the mobility of specific elements, including PTEs, in the soil system. The weathering and *in-situ* alteration of rock-forming minerals are one of the main natural sources of PTEs in the soil system, and metal concentrations in soil can generally be predicted from the element concentrations in the parent material (Palumbo et al., 2000).

Research on four Italian volcanic soils have shown that element distributions in volcanic soils are controlled by at least six main factors: parent material, composition and stratigraphy, organic matter content, age-degree of evolution, climatic conditions, and human activity (Cortizas et al., 2003). In the soil profile, PTE contents are influenced by mechanisms such as weathering, soil-forming factors, and bio-geochemical processes, distributed through elevation and accumulation processes. Some researches concerning the behavior of PTEs in soils indicate that the distribution and extractability of elements in soil increased with increasing the weathering rate of soil (Bain, 1994). Koons et al., (1980) report that trace elements (e.g. Co and Cr) were often associated with iron oxide minerals in the weathering of granite to saprolite. In other words, the distribution and transport of PTEs in the soil profile is connected to the soil type, horizons, weathering, alteration and age of parent

material, ion-substituting minerals, and climate conditions. Characterization of PTEs in soil is commonly based on the determination of their total contents. However, the elements are present in soil in various forms and these can strongly affect their behavior in terms of biological availability, potential toxicity, and mobility within the profile (Ure & Davidson, 2002). Therefore, in order to assess the potential effects of PTEs in soils, the identification of the geochemical phases in which the metals are bound, the evaluation of metal retention and bioavailability, and the assessment of the effect of PTE contamination on plants, soil fauna, soil bacterial diversity, and biological and biochemical soil properties are required.

Gastro-intestinal cancer (GI Ca) is a common global malignancy, accounting for twenty five percent of all cancer-related deaths (Longo, 1998). Esophageal and gastric cancers are the leading malignancies in the geographical belt that extends from the Far East to the Near East, including Turkey (Boland & Schermann, 1995). The poor socio-economic conditions are one of the many environmental risk factors related to the development of upper GI Ca in the so-called 'cancer belt.' The potential cancer risk regions have barren lands, high mountainous areas, and soil rich in PTEs. Epidemiological studies have revealed the high prevalence of systemic cancers, especially GI Ca, in the regions where PTEs, radioactive elements, and their derived products are ubiquitous in an environment polluted with industrial and agricultural waste (Boffetta, 1993; Hayes, 1997). Türkdoğan et al., (2003) reported that PTE contents (Co, Cd, Pb, Zn, Mn, Ni, Cu) in soil, vegetables, and fruits in Eastern Turkey were 2-340 times higher than standard values. Several dietary contaminants (nitrates, nitrites, polycyclic hydrocarbons, alpha toxin) and environmental factors (PTE and radioactivity) play important roles in the pathogenesis of upper GI Ca (Trichopoulos, 1997). Several studies revealed the carcinogenic effects of several PTEs such as Cd, Co, Cr, Ni, Pb, As, and Se (Trichopoulos, 1997; Feig et al., 1994). The long-term intake of Cd may cause renal, prostate, and ovarian cancers (Hartwig, 1998).

Volcanic and volcaniclastic rocks cover a significant part of Turkey. The majority of these rocks are located in the Volcanic Province of Cappadocia (VPC) (300x60 km about 18000 km$^2$). The soils located in this province were formed on volcanic parent materials of Neogene-Quaternary ages. Volcanic activity causes the release of PTEs such as As, Hg, Al, Rb, Pb, Ni, Co, Cr, Mg, Cu, and Zn, which in turn cause water and soil pollution. Ni, Co, and Cr concentrations in andesitic parent material from the Erciyes stratovolcano were found to be between 48-106 ppm, 22-52 ppm, and 65-201 ppm, respectively (Kürkçüoğlu et al., 1998). The limit values for Ni, Co, and Cr are between 10-50 ppm, 1-20 ppm, and 10-80 ppm in soils, respectively (Herrick & Friedland, 1990). The majority of the volcanic ash soils have excellent properties for plant production (high water-retention capacity, high cation-exchange capacity, and high organic matter content, etc.). However, the volcanic parent materials in the VPC have high concentrations of PTEs, which occur in soils. PTEs in these soils also occur in the plants (cereals, vegetables, and fruits) and groundwater. The aim of the present study is to determine the distribution and differences of PTE contents of Mt. Erciyes volcanic ash soils using geochemical techniques.

## 2. MATERIALS AND METHODS

### 2.1. The Study Site

This research was carried out on the soils formed on different volcanic parent materials in the VPC of Turkey. The VPC covers about 18000 km$^2$, but the part (2400 km$^2$) of this region selected as the study area is generally located to the east of Erciyes stratovolcano. The five main volcanic parent materials in the study area are volcanic lavas such as basalt, andesite and dacite, and pyroclastic products such as ignimbrite and volcanic ash types of tuffs. Volcanic rocks are generally located in the high elevations (>1500 m above sea level) of Erciyes stratovolcano, and also pyroclastic rocks from other parent materials in the lower elevations (Figure 1).

The slopes are between 1 % and 60 %, and the elevations range from 1100 to 2800 m above sea level (Figures 2a and 2b). The average precipitation is 350-800 mm/year with a maximum of 1200 mm/year in the western region of the study area, in which the soils are under different types of land use, including grassland, pasture, arable field, horticulture, dry agriculture, and irrigated agriculture. Traditionally, conventional tillage is practiced, using the mould board plough (about 20 cm depth), cultivator (about 15 cm depths), and disc harrow (about 10 cm depth).

### 2.2. Soil Sampling

This research used Stratified Random Sampling Design, and the study area was stratified by using the results of initial (field) surveys, archive LANDSAT-ETM+ images, a digital elevation model with 1/25000 scale, and digital soil maps. The reason for this stratification is to determine sampling areas for detailed field studies.
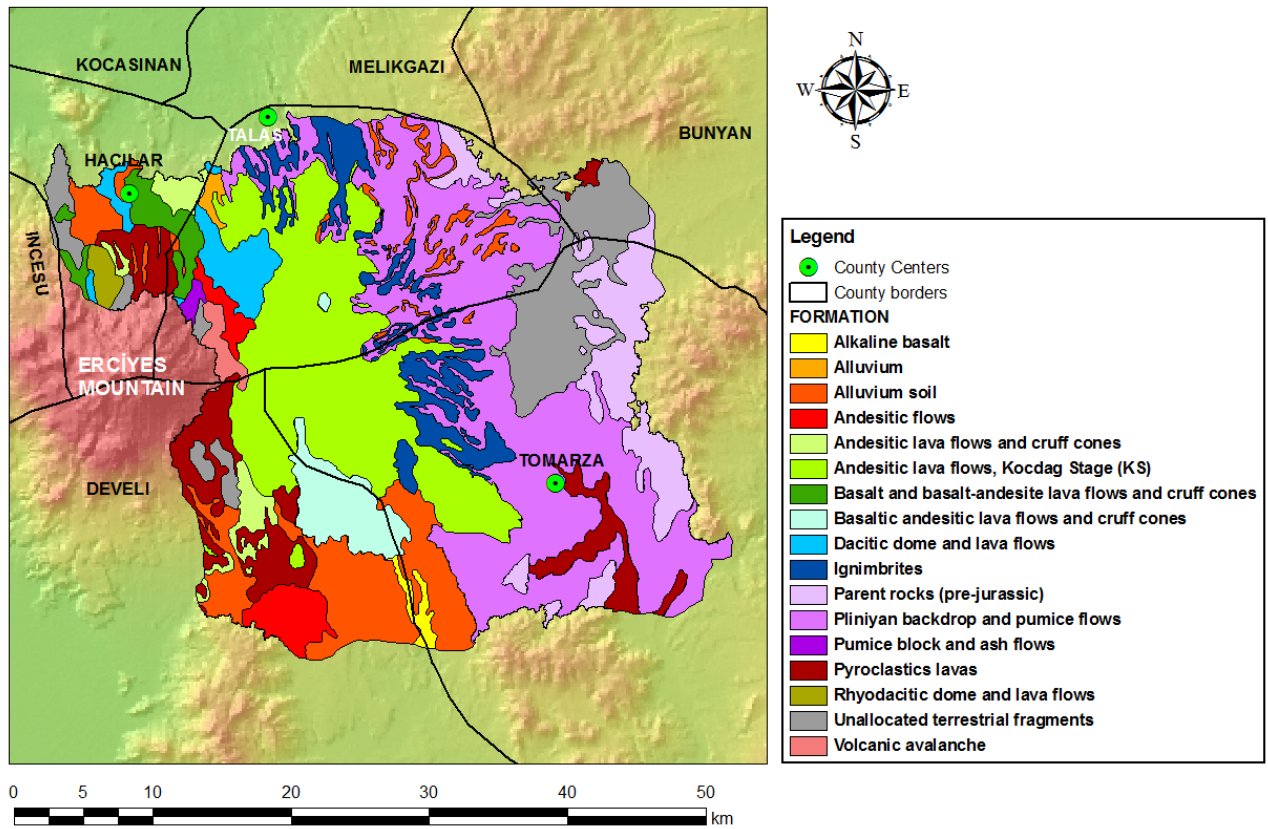
Figure 1. Digital geology map of the study area (modified from Şen et al., 2003).
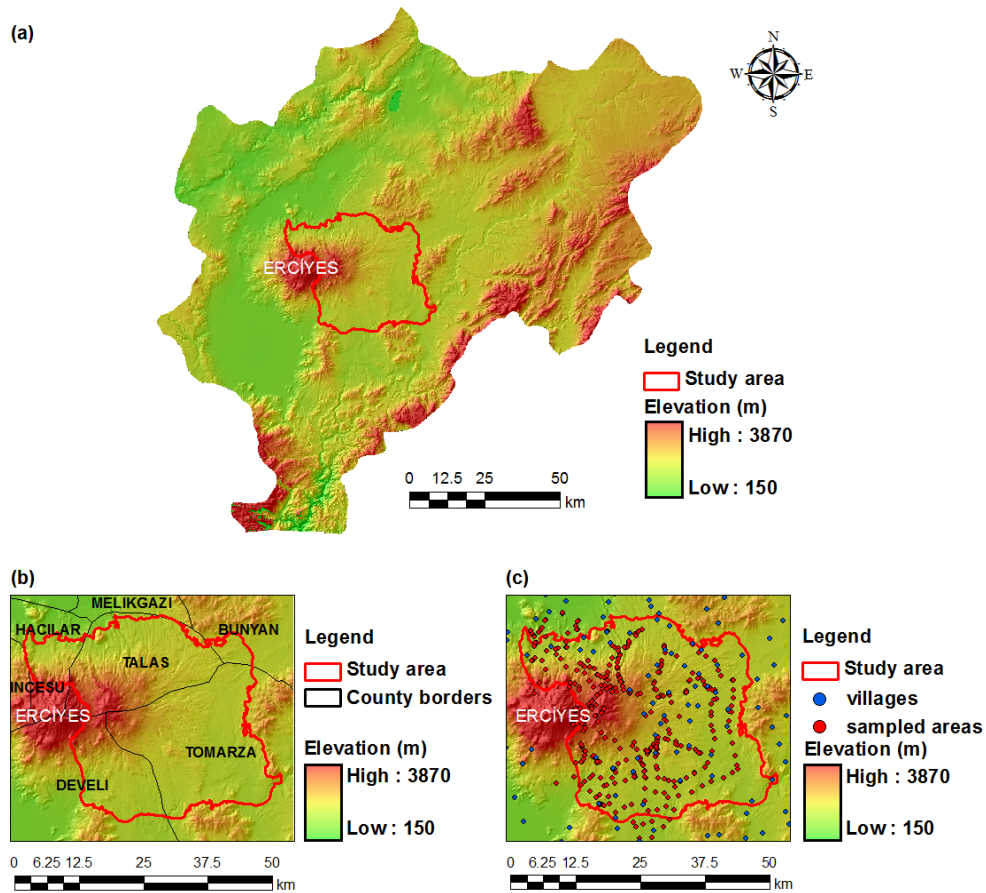


Figure 2. (a) The location of the study area, (b) The map of digital elevation model, (c) The points of soil sampling.

Sampling areas were randomly distributed within established strata. Some necessary observations related to the field data depending on land observation in the field were made, including land use, land cover class, and soil sampling sites, which were linked to their geographic references by using GPS. All geo-referenced observations were compiled in a GIS database along with explanations. Following the determination of soil variability with supervised SPOT-5 images, soil maps and geologic maps, soil samples were taken from 192 sampling points and three different depths (0-30 cm, 30-60 cm and 60-90 cm soil depths) for each sampling location (Fig. 2c). From the study area, a total of 576 soil samples were collected.

GPS and soil analysis data were compiled into the GIS database. The established database was transferred to a GIS environment to produce surface layers of each variable by using Kriging (spherical variogram) method. Next, correlations between these surface layers and SPOT-5 images were investigated. In this study, one SPOT-5 image having 2.5 m resolution was utilized. Both supervised and unsupervised classifications were applied. ARC/GIS and ERDAS 8.7 software were used for GIS and remote sensing applications, respectively. Residual layers were created by using the maps produced by the model and the on-field observations. In this way, the differences between the predicted and observed values were mapped. Consequently, the determined models were tested by using these residual layers. The models were run in a GIS environment.

## 2.3. Mineralogical and Geochemical Analyses

The mineralogical compositions such as whole-rock and clay fractions of representative soil samples were determined by X-ray diffraction (XRD) method. The patterns were recorded using a Rigaku DMAX IIIC model diffractometer at the Laboratories of the Geological Engineering Department at Sivas Cumhuriyet University, Turkey.

For soil samples, 1 g of dried samples was digested with 15ml of $HNO_3$, $H_2SO_4$, and $HClO_4$ in 5:1:1 ratio at $80^oC$ until a transparent solution was obtained (Allen et al., 1986). The solution was filtered through Whatman No. 42 filter paper and was diluted to 50 ml with distilled water. The concentrations of heavy metal in filtrate of soil samples were measured by Perkin-Elmer 2100 model inductively coupled plasma (ICP) emission spectrometry.

## 2.4. GIS and Remote Sensing Applications

We firstly entered heavy metals and soil mineral analyzes results (Z values) into a database file. We also entered geographic references (X and Y values) of the 576 sampling points into this database file. We used a projected output coordinate system (UTM, WGS84, Zone: 36N) as a spatial reference for input coordinates. Using the created (XYZ) database file, we interpolated all tabular information to develop a series of potentially toxic element (Cd, Co, Cr, Cu, Mn, Ni, Pb, Zn) maps for three soil depths (0-30, 30-60, and 60-120 cm) and soil mineral maps for eight minerals (calcite, dolomite, quartz, opal, feldspars, clay minerals, hornblende, and augite). For this interpolation process, we applied the Kriging method with a spherical variogram model in ARC/GIS 9.1 software (ESRI, 2004, 2005). We produced all raster maps with 30×30 m spatial resolution to be compatible with the majority of the spatial database for Turkey.

The SPOT-5 image, acquired on November 26th 2007, was utilized to develop land use map in Erdas Imagine 8.5 software (ERDAS 2003). Spectral characteristics of utilized SPOT-5 image were summarized in table 1. Supervised classification method (maximum likelihood parametric rule), RGB band combination, and statistical filtering (7x7) were used to develop a land use map. A detailed field data including 1040 points was utilized in the supervised classification process. For the correct classification of land use, the number of geo-referenced field sampling was kept high (1040). In the field sampling period, wheat areas were determined easily because germinated wheat covered the study area in that period. However, detailed information about the empty fields were collected and noted by interviewing with the land owners to avoid probable mistakes during the classification process. There was no problem about the observations of vineyards and orchards because they are the most remarkable areas. Total 564 sampled points were used for supervised classification, and the remaining 476 sampled points were utilized for accuracy assessment. Supervised classification obtained 90.97 % overall accuracy with a Kappa coefficient of 0.91, and produced a reliable result.

Table 1.Spectral characteristics of utilized SPOT-5 image.

| Spectral band | HRG (m) |
|---|---|
| PA 0.49 -0.69 µm (RGB) | 2.5 |
| Red    : 0.630-0.690 µm | 2.5 |
| Green : 0.525-0.605 µm | 2.5 |
| Blue   : 0.450-0.515 µm | 2.5 |

Table 2. The mean results of Duncan analysis of PTEs (ppm) according to the parent materials (a, b, c: p<0.01).

| Parent material | Cd | Co | Cr | Cu | Mn | Ni | Pb | Zn |
|---|---|---|---|---|---|---|---|---|
| Andesite | 976.2[b] | 30.87[c] | 84.03[a] | 40.08[b] | 908.57[c] | 485.07[a] | 39.90[a] | 279.08[a] |
| Basalt | 651.0[c] | 31.12[c] | 39.43[a] | 40.33[b] | 997.97[c] | 93.42[b] | 37.23[a] | 218.66[a] |
| Dacite | 694.5[c] | 16.27[d] | 49.86[a] | 30.37[b] | 332.69[b] | 405.13[a] | 31.63[a] | 193.99[b] |
| Ignimbrite | 1750.8[a] | 38.22[b] | 95.08[a] | 43.36[b] | 1247.36[a] | 846.83[c] | 36.57[a] | 255.55[a] |
| Volcanic ash | 1778.7[a] | 43.43[a] | 83.63[a] | 52.82[a] | 1289.23[a] | 611.84[a] | 37.18[a] | 276.78[c] |

Table 3. The mean results of Duncan analysis of PTEs (ppm) according to the soil depths (n: number of samples, a, b, c: p<0.01).

| Soil depth (cm) | n | Cd | Co | Cr | Cu | Mn | Ni | Pb | Zn |
|---|---|---|---|---|---|---|---|---|---|
| 0-30 | 192 | 14.63[a] | 34.11[a] | 74.18[a] | 46.97[a] | 1070.67[a] | 538.60[a] | 42.85[a] | 512.46[a] |
| 30-60 | 192 | 1655.60[b] | 31.09[a] | 82.79[a] | 39.19[b] | 862.27[b] | 447.00[b] | 35.83[a] | 126.44[b] |
| 60-90 | 192 | 2013.9[b] | 31.02[a] | 64.57[a] | 36.42[a] | 817.08[b] | 477.52[a] | 34.06[a] | 119.57[b] |

## 3. RESULTS AND DISCUSSION

### 3.1. The Relationships between PTEs and Soil Parent Materials

PTE concentrations in soils developed on parent materials erupted from Erciyes stratovolcano were found to be higher than standard limit values (Table 2). For Cd, Co, Cu, and Mn in the volcanic ashes, the minimum values were 0, 2.23, 11.09, and 23.71 ppm, the maximum values were 9358, 105.3, 109.4, and 3988 ppm, and the mean concentrations were 1778.7, 43.43, 52.82, and 1289.23 ppm, respectively. For Cr and Ni in the ignimbrites, the minimum values were 1.86 and 9.07 ppm, the maximum values were 1853 and 8239 ppm, and the mean concentrations were 95.08 and 846.83 ppm, respectively. For Pb and Zn in the andesites, the minimum values were 4.21 and 43.02 ppm, the maximum values were 242 and 3236 ppm, and the mean concentrations were 39.90 and 279.08 ppm, respectively As a result, in the andesites and dacites Cd had the highest mean concentration, and Co has the lowest mean concentration. In the basalts and ignimbrites, Mn has the highest mean concentration, and Co has the lowest mean concentration. In the volcanic ash, Cd has the highest mean concentration, and Pb has the lowest mean concentration. Soils developed from the volcanic ash have larger mean concentrations of Co, Cu, Mn, Pb, and Zn than the soils developed from andesite, basalt, dacite and ignimbrite except for Cd, Cr, and Ni. PTEs distributions for all parent materials were generally as follows: volcanic ash > ignimbrite > andesite > basalt > dacite, with the greatest shifts seen in relative amounts of Cd, Mn, Ni, and Zn among PTEs. The high amount of PTEs in andisol parent materials may be related to the greater amount of noncrystalline oxides and hydroxides found in soils of volcanic parent materials (data not shown). The presence of noncrystalline Al and Fe oxides within soils has been reasoned to be a cause for the decreased mobility of PTEs (Burt et al., 2003). High concentrations of PTEs such as Cr, Cu, Ni, and Zn could be explained by the origin of parent materials (Doelsch et al., 2006a, 2006b; Cortizas et al., 2003). Kierczak et al., (2007) reported that the immobility of Cr compared to Ni in soils due to its presence as Cr (III) in oxides and silicates. Anda (2012) studied heavy metal content in seven Endonesian soils, and reported that Cr and Ni contents were less than 11 ppm, and also concentration of heavy metals such as Cr in soils was controlled by parent rocks as revealed by its order of magnitude in soils. Soils developed from volcanic parent materials have heavy metals contents of high than acceptable level, suggesting heavy metal risk for human health when those soils are cultivated for agricultural food crops.

In most parent materials, Fe presenting in minerals such as augite, hornblende, clay and amorphous glass are adsorbed PTEs in these minerals. Anand & Gilkes (1984) reported that natural iron oxides may also host trace elements, including Zn, Cu, Mn, Ni, Co, Mg, Cr and Ti. Iron oxides have a high sorption capacity of trace elements such as Cr, Mo, Ni, Pb and Zn (Bigham et al., 2002). Sterckeman et al., (2004) founded similar relationships between heavy metals and Al and Fe, suggesting that Fe– and Al–bearing minerals are reservoir for PTE in soils.

### 3.2. Variability of PTEs according to the Different Soil Depths

The variations in PTE concentrations in the different soil depths were compared with the limit concentrations, with the former being found to be higher than the latter. Cd concentrations increased

with depth (Table 3). The mean concentration of Cd according to the different soil depth is 14.63 ppm, 1655.6 ppm, and 2013.9 ppm, respectively. The spatial distribution and variability of PTEs is presented in maps of figures 3 and 4. Cd concentrations were generally found to be highest in the northern and middle parts of the study area, with a maximum concentration range from 4700 to 9400 ppm at the 30-60 cm soil depth.

Co concentrations do not show an important change from surface layer to deep layer, and were 34.11 ppm, 31.09 ppm, and 31.02 ppm, respectively. The highest Co concentrations were found in the northeastern and middle parts of the study area. Co concentration increased with soil depth in the volcanic ash parent materials although it decreased with soil depth in the andesite, dacite, and ignimbrite parent materials.

Cr concentrations generally showed a decrease from the surface to the deep layer: 74.18 ppm for the surface layer, 82.79 ppm for intermediate layer, and 64.57 ppm for the deep layer. The highest Cr concentrations were found in the northwestern parts of the study area, with a maximum value of 1900 ppm at the surface layer. The amounts of Cu, Mn, and Ni were found to be higher in the northern and middle parts of the study area than in the remaining parts, with the exception of Pb and Zn. The amounts of Pb and Zn were generally high in the entire study area. All PTEs appeared to be present above the limit levels at all soil depths.

The data obtained were applied to the Duncan test to determine whether the variables of the concentrations of PTEs differed according to the different soil depths. The values of Zn, Ni, Mn, and Cd were statistically significant at the different soil depths ($p < 0.05$), except for Co, Pb, Cu and Cr. Amaral et al., (2006) found that Cd and Co concentrations increased as a result of depth in Portuguese volcanic soils, and similar results for Cd and Co were reported by Palumbo et al., (2000) in various soil types developed from volcanic parent materials. They showed that Cd and Co concentrations increased with depth in andisols. Doelsch et al., (2006a) reported that Cr, Cu, Ni, and Zn concentrations were constant with soil depth, but Cd concentrations decreased from the surface to the intermediate layer and stayed constant in the deep layer.

### 3.3. Variability of PTEs according to the Elevation

The sampling points in the study area were divided into two different elevations, with one from 1000 to 1500 m and the other from 1500 to 3000 m.
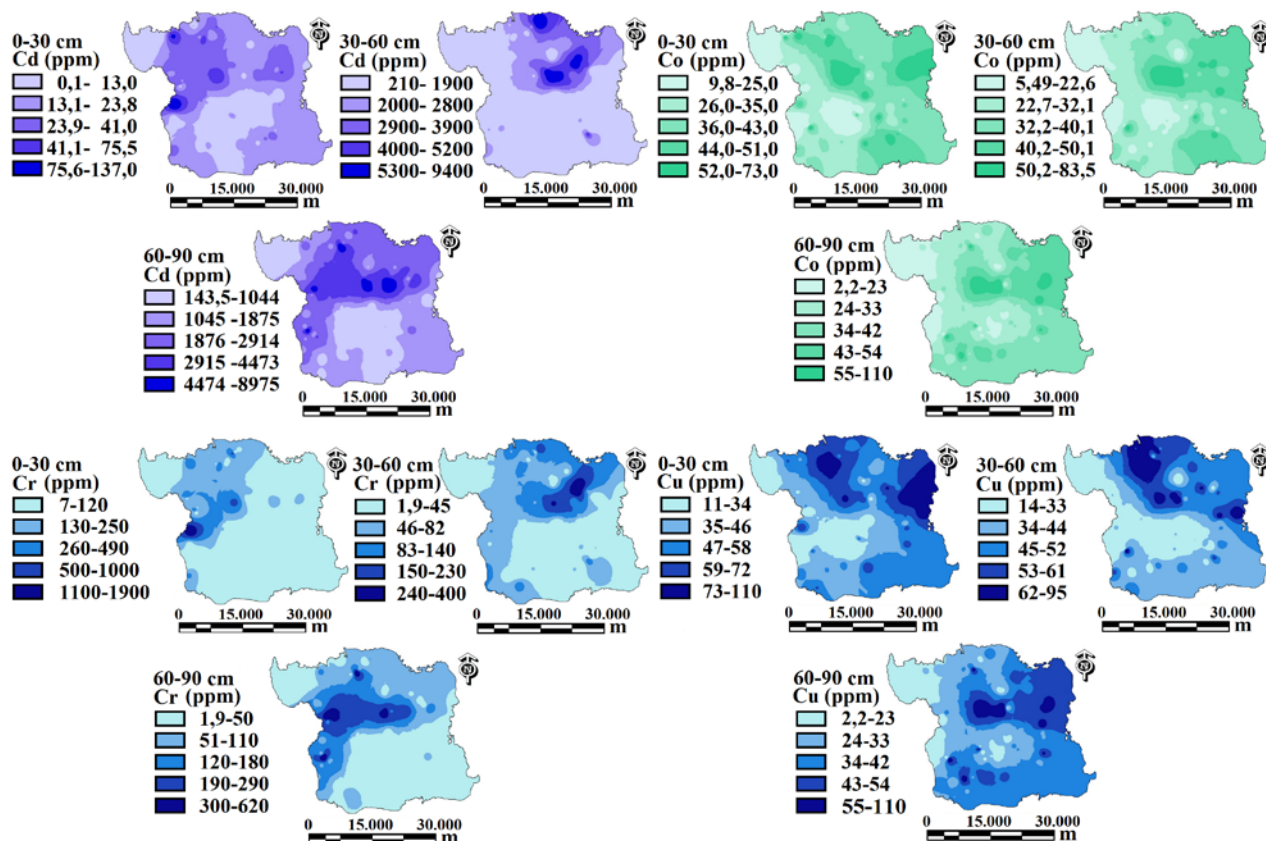


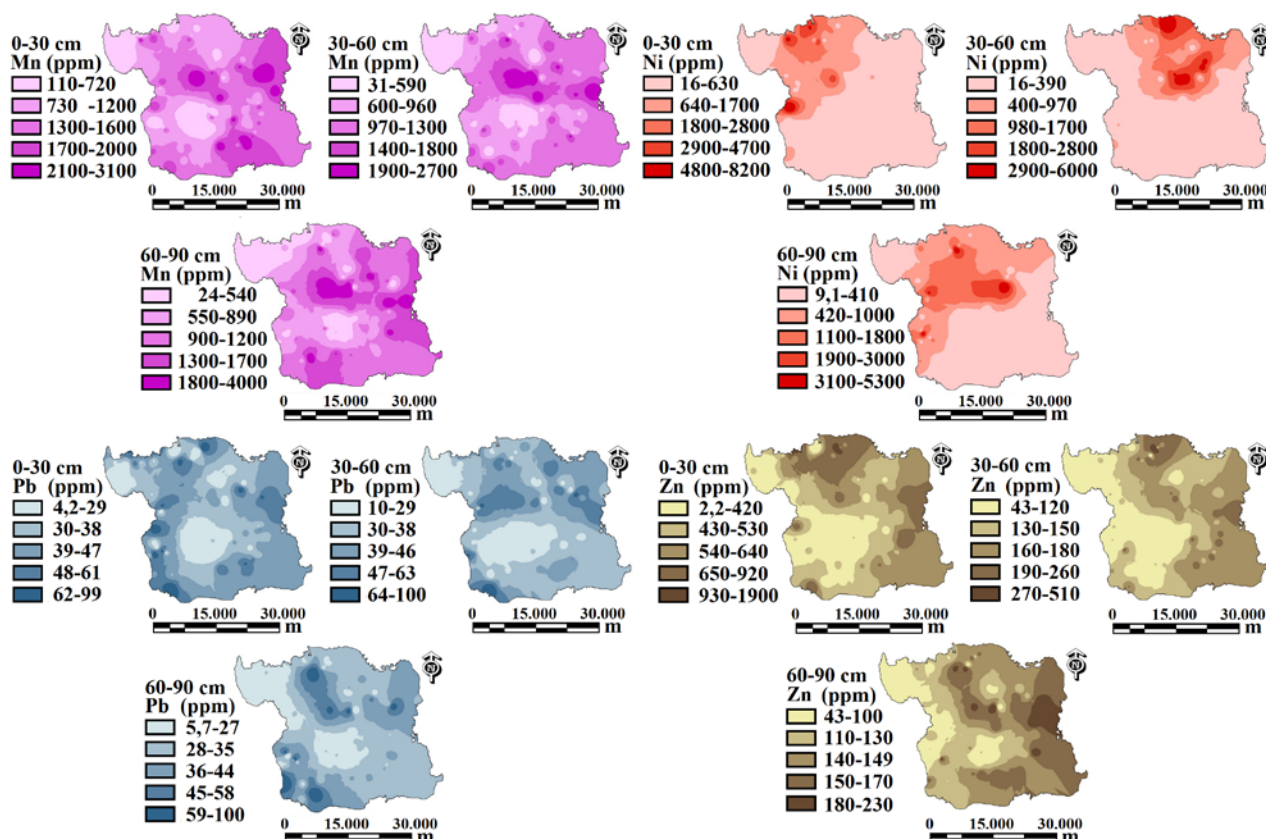Figure 3. Spatial variability of potentially toxic elements such as Cd, Co, Cr and Cu.

Figure 4. Spatial variability potentially toxic elements such as Mn, Ni, Pb and Zn.

The mean concentrations of Cd, Cr, Cu, Ni, and Pb were statistically different between 1000-1500m and 1500-3000m elevations ($p<0.05$), although the concentrations of Co, Mn, and Zn were not significant between elevations (Table 4). The amounts of Cd and Ni increase with elevation in all parent materials while the amount of Pb decrease with elevation in all parent materials.

The amounts of Co and Mn decrease with elevation in andesite and volcanic ash while they increase in ignimbrite and dacite. PTE concentrations in andisols (Cd, Cu, Ni, Cr, and Zn) were found to be higher at low altitudes than at high altitudes (Doelsch et al., 2006a). The soils at 1000-1500 m elevations are generally cultivated, but not at 1500-3000 m elevations. The high concentrations of Cu, Mn, Pb, and Zn in cultivated soils can be related to agricultural practices such as fertilization. Thus, high Cu and Zn concentrations in cultivated soils could be explained by the geologic origin rather than agricultural practices (Doelsch et al., 2006a).

Cr and Ni appeared to be particularly concentrated in uncultivated soils, suggesting that geologic origin was prevalent although agricultural practices cannot be ruled out. The high concentrations of Cr and Ni in high elevations and uncultivated soils could be attributed to the hornblende and augite minerals (Figs 5 and 6).

The concentrations of heavy metals such as Cr, Ni, Co, Cu and Pb are related to the abundance of mafic minerals such as hornblende $NaCa_2(Ti,Fe,Al,Mg)_5(Al_{1-2}Si_{6-7}O_{22})(OH)_2$ and augite $(Ca,Mg,Fe,Al)_2(Si,Al)_2O_6$, and partly clay minerals in regard to chemical compositions and elemental substitutions. However, Huang (1989) states that these elements are nearly always present in plagioclase types of feldspars $(Na,Ca)_{1-2}(Al_{1-2}Si_{2-3}O_8)$.

### 3.4. Raster maps of soil variables and minerals

Developed raster maps for Cd, Co, Cr, Cu, Mn, Ni, Pb, and Zn were given in figures 3 and 4. In those maps, changing values (ppm) of each heavy metal between minimum and maximum in three soil depts. (0-30, 30-60, and 60-120 cm) were shown. In general, heavy metal concentrations increased with increasing soil depth. The highest concentration (9400 ppm) was determined for Cd at 30-60 cm soil depth. However, the lowest concentration (0.1 ppm) was determined for Cd at 0-30 cm soil depth. This situation emphasized how heavy metal concentrations change with different soil depths.

Produced raster maps for calcite, dolomite, quartz, opal, feldspar, clay, hornblende, and augite minerals were given in figure 5.
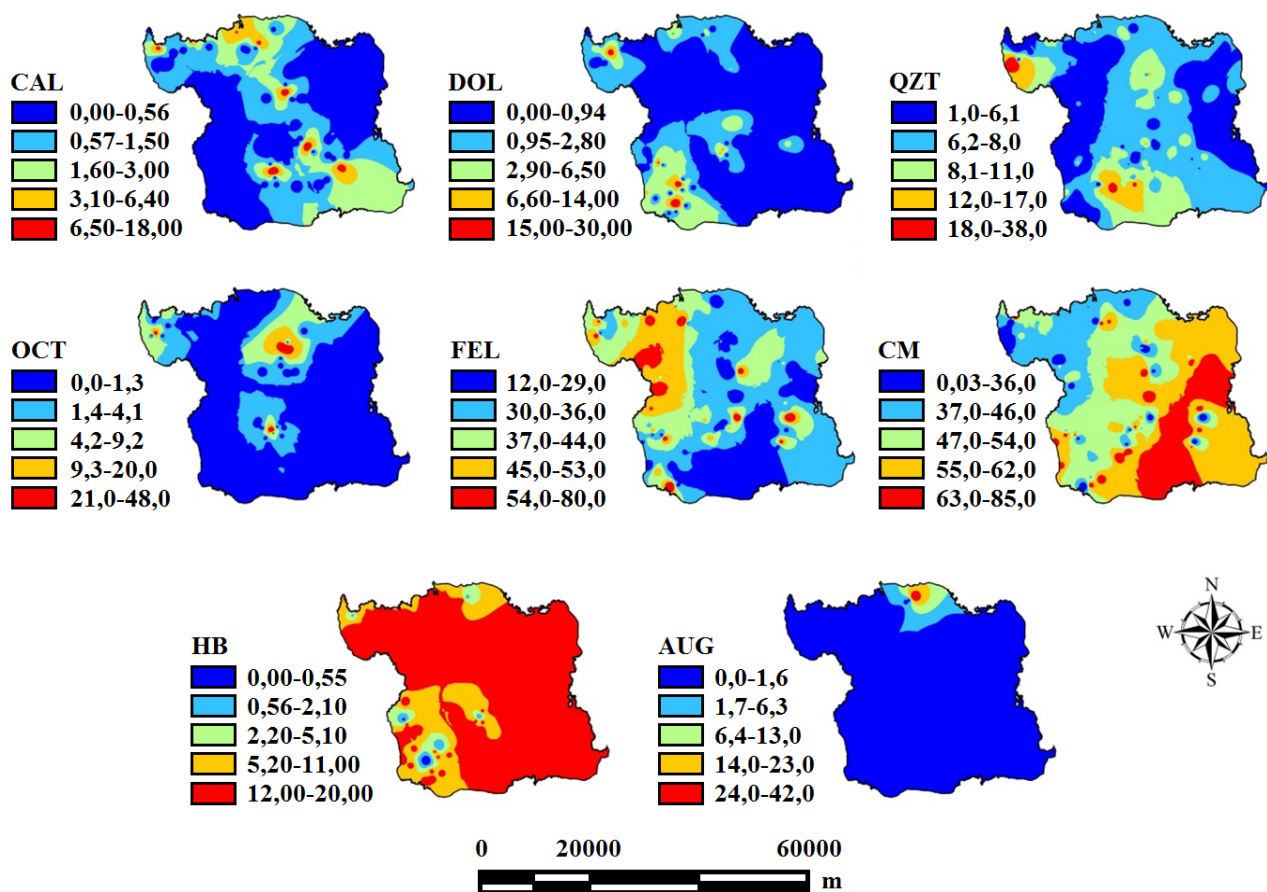
Figure 5. Spatial variability of soil minerals in the study area (CAL: Calcite, DOL: Dolomite, QZT: Quartz, OCT: Opal-CT, FEL: Feldspar, CM: Clay minerals, HB: Hornblende, AUG: Augite).
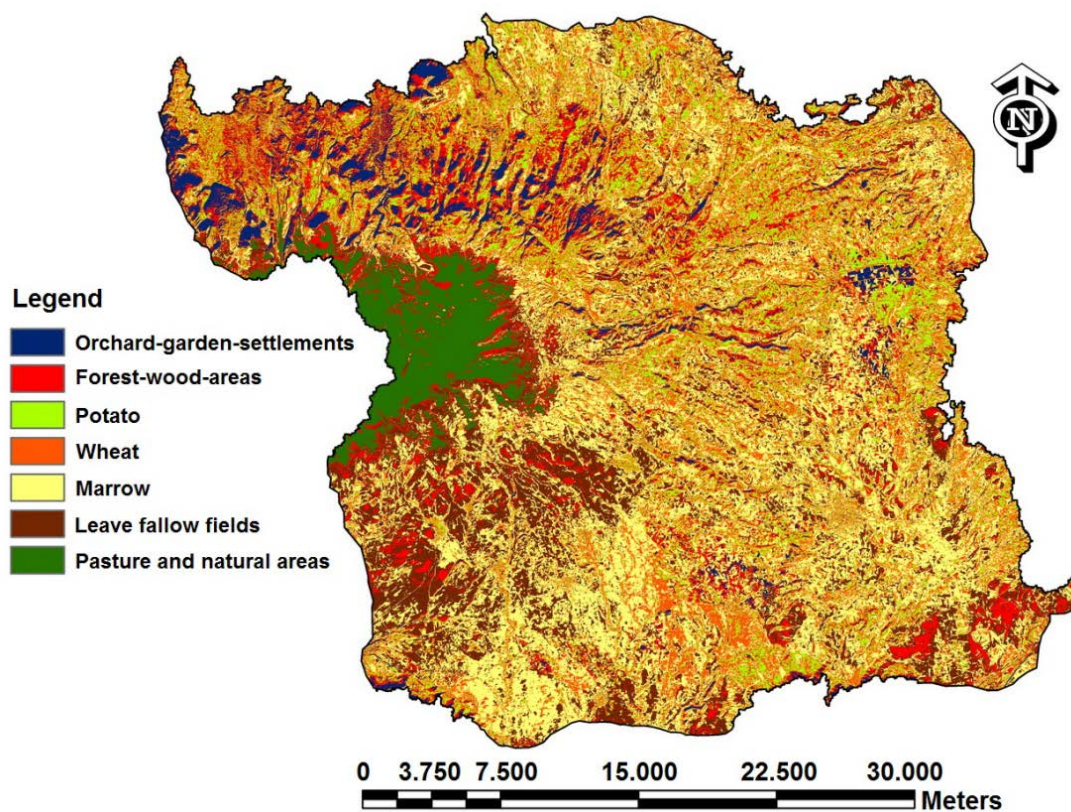


Figure 6. The land use map of the study area.

Table 4. The mean results of Duncan analysis of PTEs (ppm) according to the elevations (a, b, c: p<0.01).

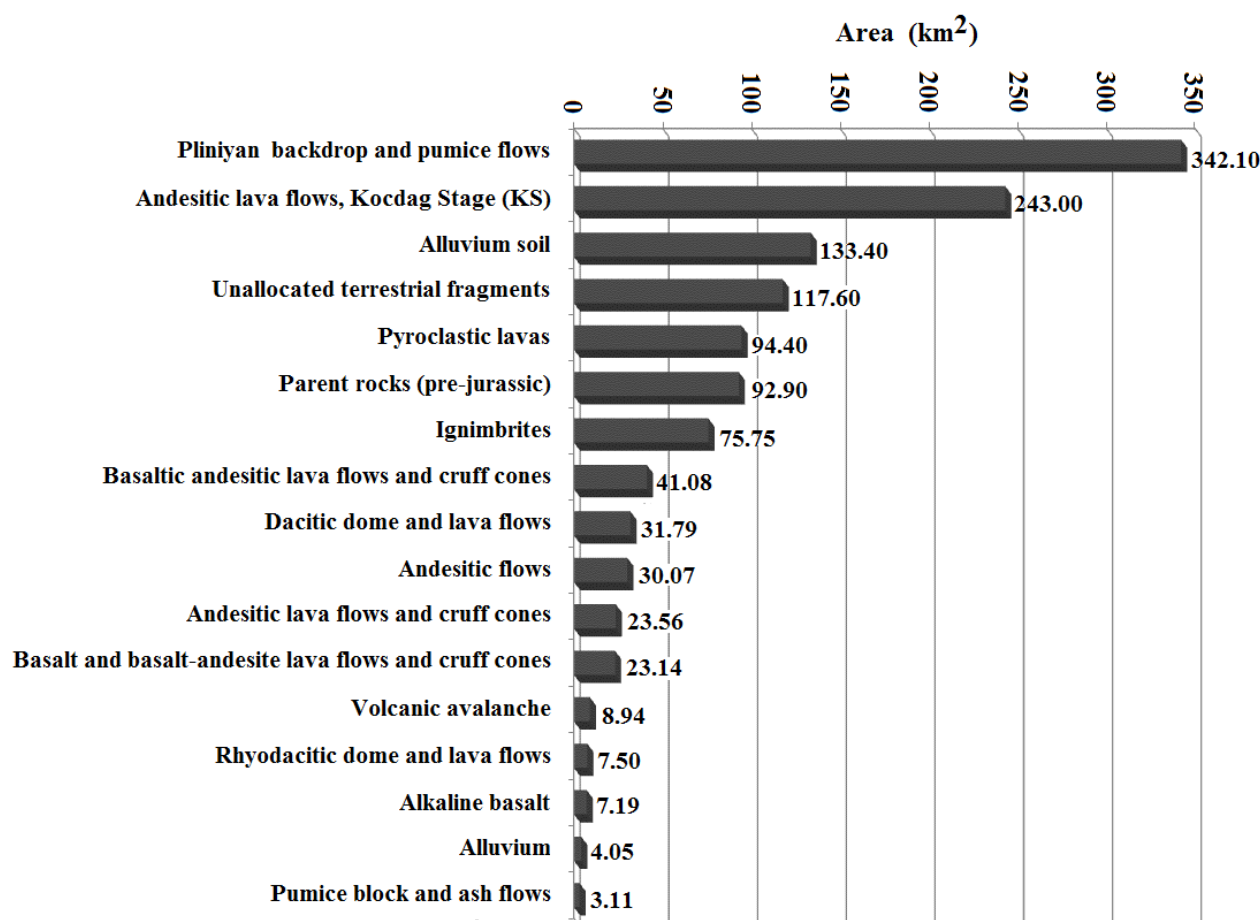| Elevation (m) | Parent material | Cd | Co | Cr | Cu | Mn | Ni | Pb | Zn |
|---|---|---|---|---|---|---|---|---|---|
| 1000-1500 | Tuffs | 14.60[a] | 35.86[a] | 74.43[b] | 54.47[a] | 1132.18[a] | 454.49[b] | 49.78[a] | 585.21[a] |
| 1500-3000 | Lavas | 18.98[b] | 31.15[a] | 131.81[a] | 36.82[b] | 987.22[a] | 652.78[a] | 33.46[b] | 413.74[a] |



Figure 7. Graphical presentation of the parent materials in the study area.

In those maps, changing values (%) of each mineral between minimum and maximum were illustrated. In general, the higher concentrations were determined for clay (85 %) and feldspar (80 %). However, the lowest concentration was also determined for clay (0.027 %).

### 3.5. Land use map

The produced land use raster map from SPOT-5 Image was given in figure 6. According to land use map, the study area was classified in seven classes including (1) orchard-garden-settlements, (2) forest-wood areas, (3) potato, (4) wheat, (5) marrow, (6) leave fallow fields, and (7) pasture-natural areas. Cover areas of these classes were summarized in Table 5. According to land use map, the main land uses are the marrow, wheat and fallow (Table 5 and Fig. 7).

Table 5. Land use and cover areas.

| Land use | Area (km²) |
|---|---|
| Pasture-natural areas | 62.04 |
| Orchard-garden-settlements | 63.66 |
| Potato | 174.46 |
| Forest-wood areas | 187.75 |
| Leave fallow fields | 197.82 |
| Wheat | 203.78 |
| Marrow | 390.49 |

## 4. CONCLUSIONS

This study presents the variability according to the parent material, soil depth, and elevation of PTEs in soils formed on volcanic parent materials erupted from the Erciyes stratovolcano in the middle Anatolian region of Turkey. All the PTE concentrations in soils were higher than standard

values. All findings demonstrated that PTE concentrations in soils originated from volcanic parent materials and typically increased with increasing elevation and soil depth. The PTE contents of soils formed on ignimbrite and volcanic ash were higher than the soils formed on basalt, andesite, and dacite. In addition, the PTE content of soils in the northern and middle regions of the study area were found to be higher than in other areas because of the high elevations. The results indicate that the agricultural practices were not affected by the PTE contents. The high PTE concentrations in the uncultivated soils could be attributed to the mineralogical composition. Hornblende and augite could account for the high PTE concentrations in high elevations. PTEs in soils seem to affect the ecosystem and human health. The high PTE concentrations could be absorbed by plants and interfere with the groundwater. Different soil management systems were applied at the cultivated areas such as the site specific management practices and the appropriate plant species having minimum PTE uptake.

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