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NÁRODNÉ POĽNOHOSPODÁRSKE A POTRAVINÁRSKE CENTRUM
VÝSKUMNÝ ÚSTAV PÔDOZNALECTVA A OCHRANY PÔDY

Current hygienic state of agricultural soils in Krompachy-Rudňany region

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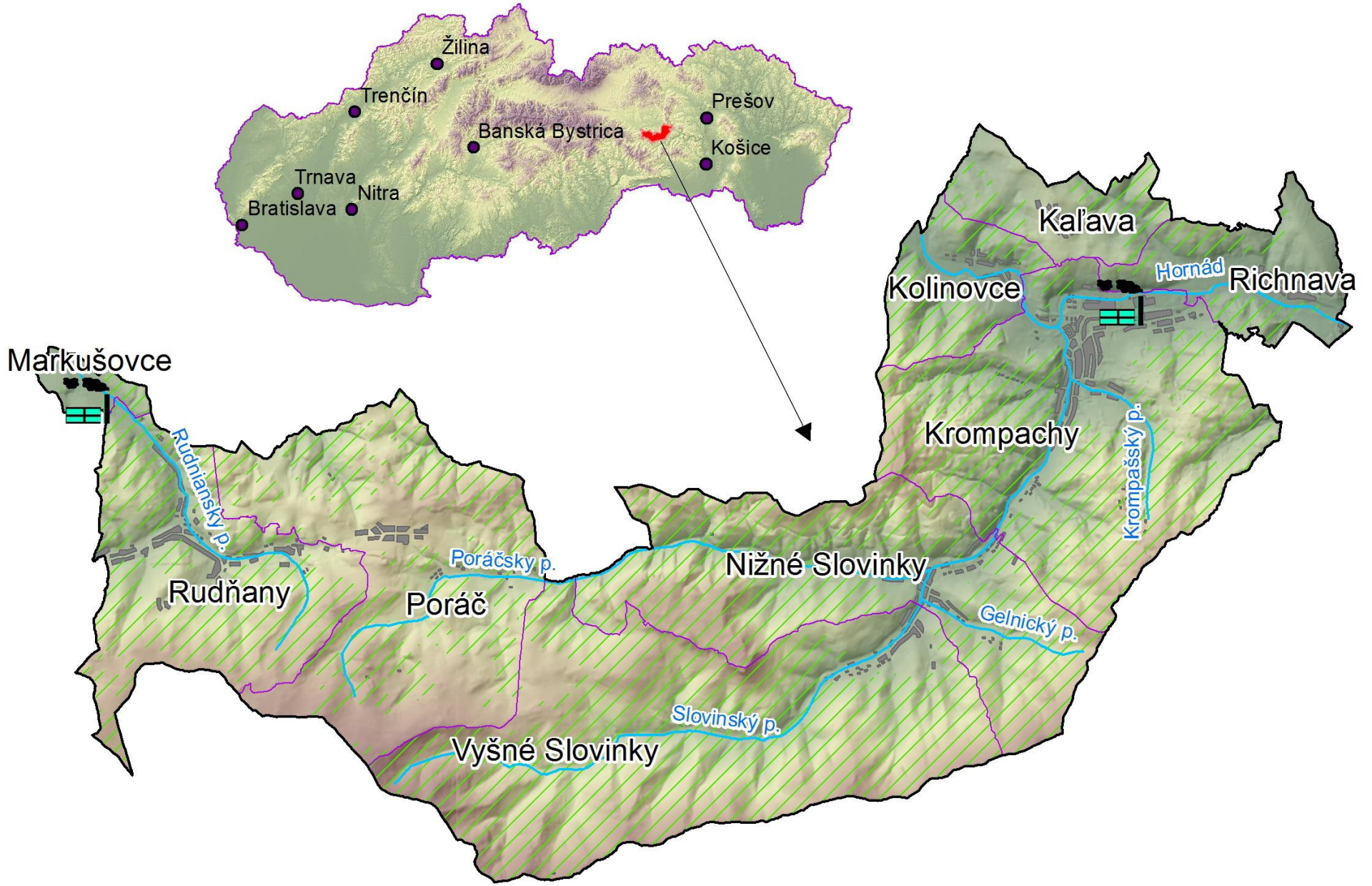
INTRODUCTION

The contaminated region Krompachy – Rudňany is situated on the north edge of Volovské vrchy (hills) in Rudňany and Poráč fold. The paper gives an evaluation of the load of risk elements in agricultural soils around Rudňany and Krompachy during latest soil survey in the 2016 year. This area belongs to the most sensitive areas in Slovakia. As the main causes of soil pollution according to Valko et al. 2011 can be identified here by:

- geological threats to soil from historical maining activities;
- risk elements from metalurgy waste deposits;
- geogenic sources influenced by geochemical anomalies occurrence.


Žilina
Trenčín
Prešov
Banská Bystrica
Košice
Trnava
Nitra
Bratislava
Kaľava
Hornád
Kolinovce
Richnava
Markušovce
Rudnianský p.
Krompachy
Krompašský p.
Poráčsky p.
Nižné Slovinky
Rudňany
Poráč
Gelnický p.
Slovinský p.
Vyšné Slovinky

METHODOLOGY

The obtained results are evaluated based on soil monitoring system in Slovakia and soil survey in more details, which has been sampling in 2016 year. Soil monitoring network in Slovakia is constructed on ecological principles and includes the important data of all main soil types and subtypes, soil substrates, climatic regions, emission regions, contaminated and non-contaminated regions as well as various land use. There were selected 14 monitoring sites on agricultural land in Krompachy – Rudňany area. Monitoring sites have been sampled from topsoil (0 - 10 cm) and subsoil (30 – 40 cm). All soil monitoring sites are located in WGS 84 coordinates. The monitoring site represents the circular shape, with a radius of 10 m and an area of 314 m^2. The most important risk elements concerning soil contamination were analysed (Cd, Cr, Pb, Ni, Zn, Cu, Co extracted with aqua regia) and Hg (total content – using AMA analyzer). Obtained results were evaluated using by standard statistical procedures in a GIS environment.

Arsenic (As)

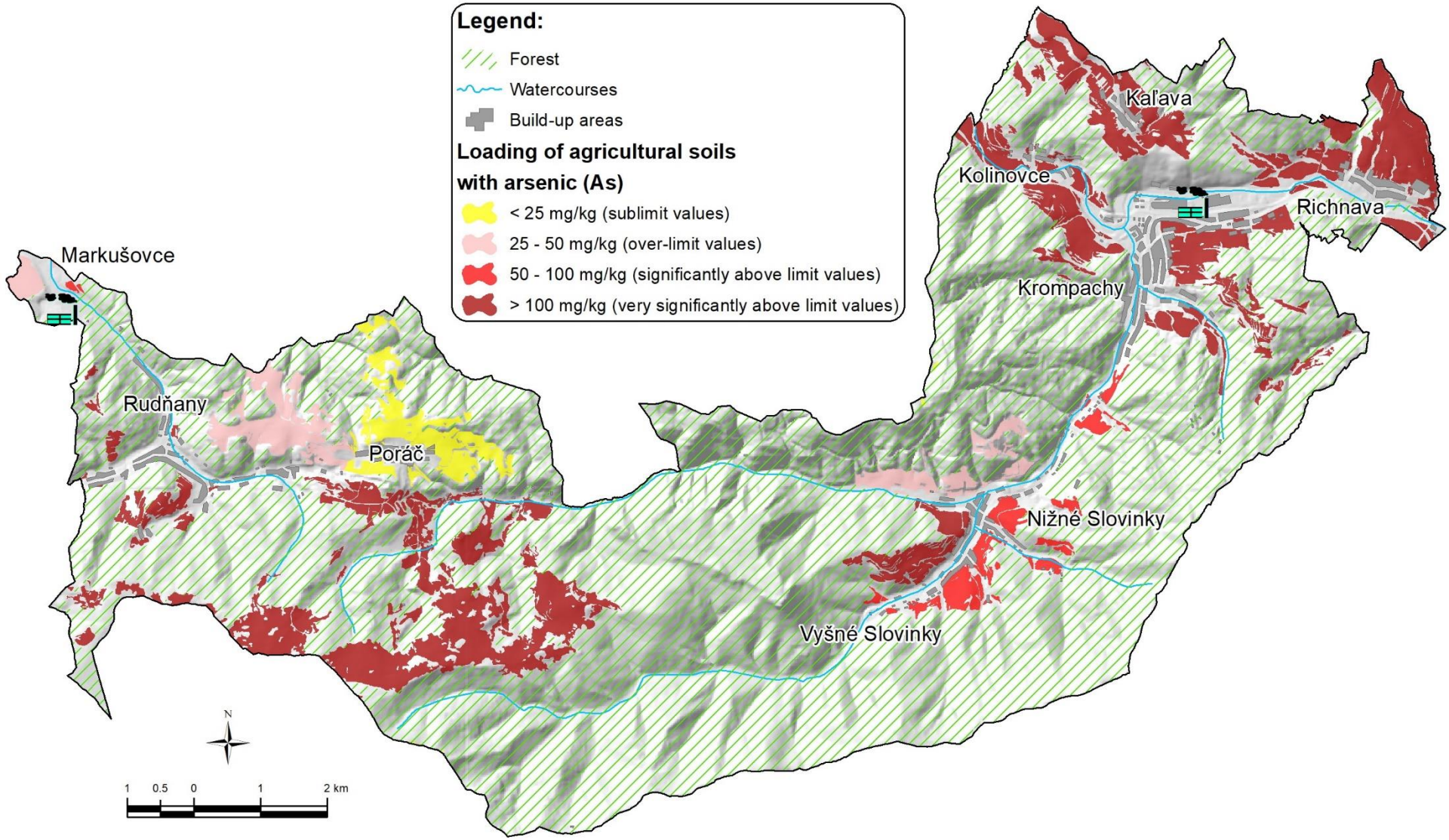
Distribution of risk elements depends on parent material, land use, soil type, texture and potential source of elements origin (geogenic, anthropogenic, resp. mixed influence) (Wilcke et al. 2005, Wedepohl, 1995).

Arsenic is an important component of arsenopyrite (FeAsS), which is the most extended arsenic mineral in Slovakia. Its migration in soil is limited (sorption with clay, hydroxides, oxides and with soil organic matter) – Čurlík, 2011). Average content of arsenic strongly exceed the valid hygienic limit for Slovakia (MPRV SR, 2013) in topsoil and in subsoil, as well.

Total content of arsenic (extracted with aqua regia) in $mg.kg^{-1}$ in agricultural land

Depth in	Basic statistical indicators					
cm	n	X min	X max	X	SX	V(%)
0-10	14	16.6	259.0	**129.5**	85.5	66.0
30-40	14	17.0	533.0	**87.7**	130.4	148.6

n – frequency, X min – minimum value, X max - maximum value, X - arithmetic mean, SX - standard deviation, V – coefficient of variation


Legend:
Forest
Watercourses
Build-up areas
Loading of agricultural soils with arsenic (As)
< 25 mg/kg (sublimit values)
25 - 50 mg/kg (over-limit values)
50 - 100 mg/kg (significantly above limit values)
> 100 mg/kg (very significantly above limit values)
Markušovce
Rudňany
Poráč
Kaľava
Kolinovce
Richnava
Krompachy
Nižné Slovinky
Vyšné Slovinky
N
1 0.5 0 1 2 km

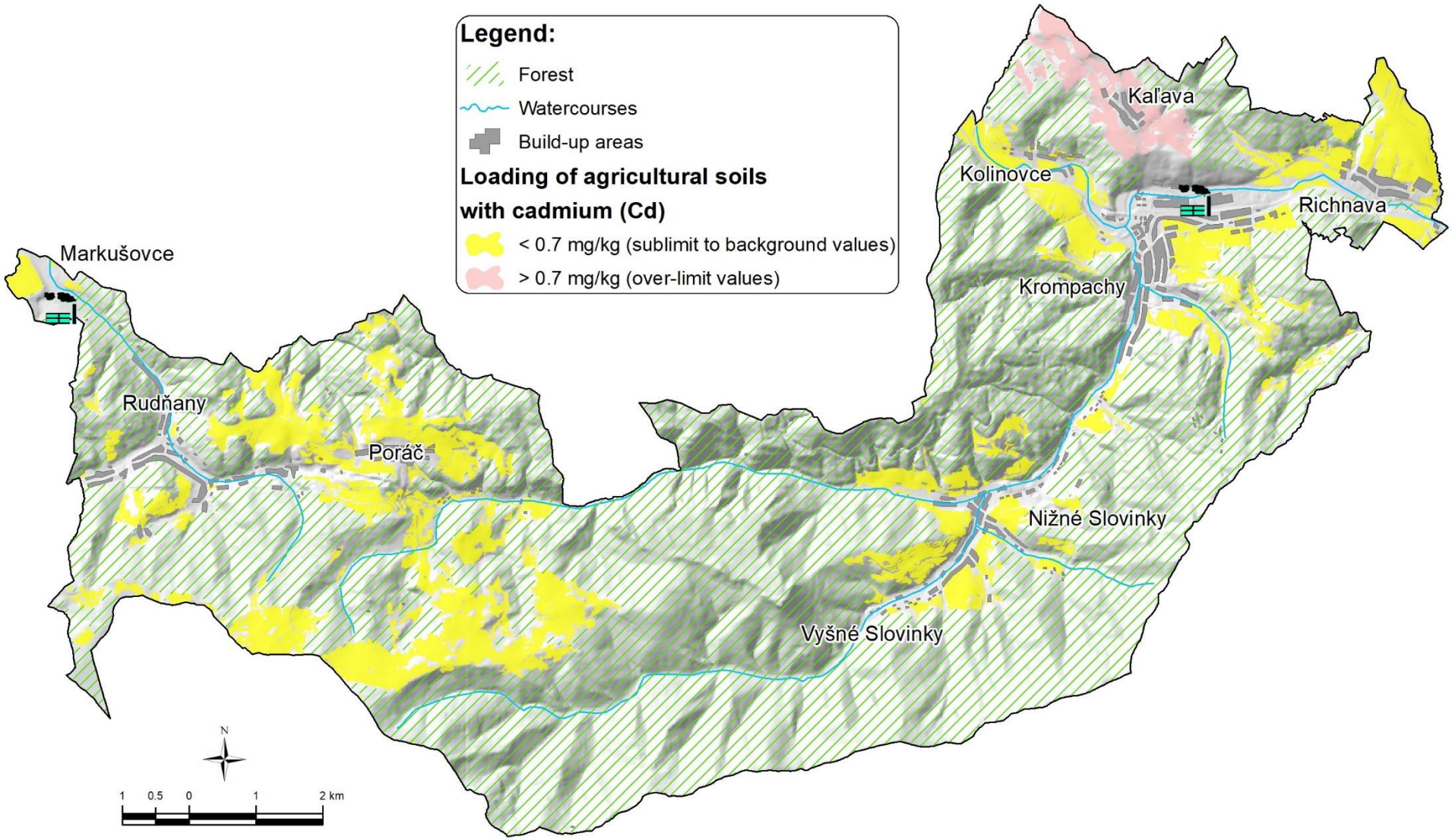
Cadmium (Cd)

Average values of **cadmium** in topsoil and subsoil in evaluated area is lower than hygienic limit. Increased value of Cd was indicated only in Kaľava surroundings (Map 2). Higher values of Cd were measured in topsoil where are the measured values also more variable. In this case it could be caused probably by anthropogenic input (probably by the influence of emissions from Slovak electrical factory in Krompachy (Kobza et al., 2019).

Total content of cadmium (extracted with aqua regia) in $mg.kg^{-1}$ in agricultural land

Depth in	Basic statistical indicators					
cm	n	X min	X max	X	SX	V(%)
0-10	14	0.2	2.1	0.6	0.5	84.9
30-40	14	0.1	0.4	0.3	0.1	41.6

n – frequency, X min – minimum value, X max - maximum value, X - arithmetic mean, SX - standard deviation, V – coefficient of variation


Legend:
Forest
Watercourses
Build-up areas
Loading of agricultural soils
with cadmium (Cd)
< 0.7 mg/kg (sublimit to background values)
> 0.7 mg/kg (over-limit values)
Markušovce
Rudňany
Poráč
Kaľava
Kolinovce
Richnava
Krompachy
Nižné Slovinky
Vyšné Slovinky
N
1 0.5 0 1 2 km

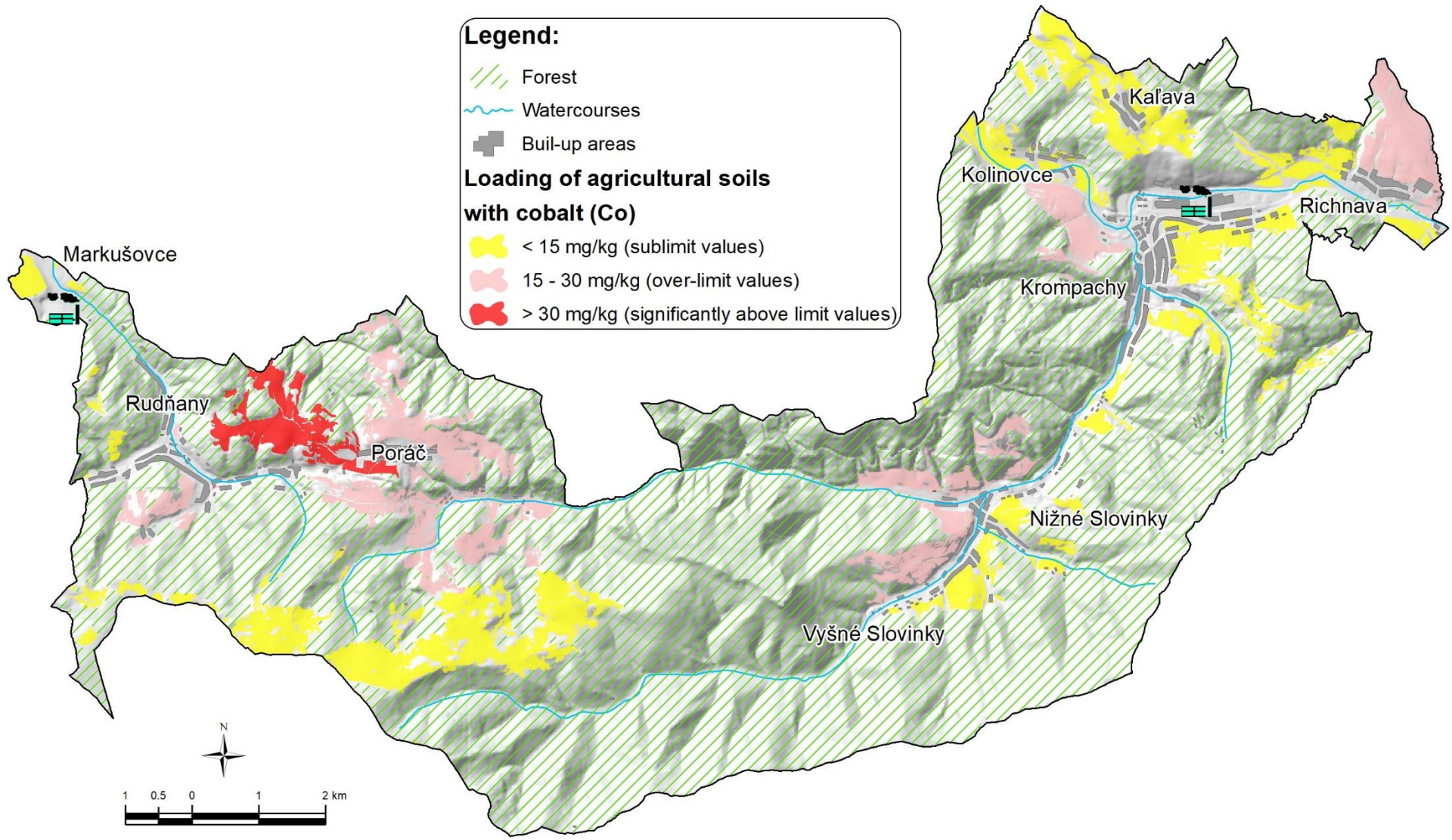
Cobalt (Co)

Average content of **cobalt** in topsoil and subsoil slightly exceeds the hygienic value (MPRV SR, 2013) and it is higher than average content of Co in agricultural soils in Slovakia which is 8.80 $mg.kg^{-1}$ (Kobza et al., 2014) and also with comparison of agricultural soils in Czech Republic is 14 $mg.kg^{-1}$ (Poláková et al., 2011). The variability of cobalt is the lowest from among the evaluated risk elements. Difference in Co content between topsoil and subsoil is not wide, what was also confirmed at evaluated of agricultural soils in Slovakia (Kobza et al., 2014). In addition, it may be said that anthropogenic input of cobalt in soils of Krompachy – Rudňany area is not significant.

Total content of cobalt (extracted with aqua regia) in $mg.kg^{-1}$ in agricultural land

Depth in cm	Basic statistical indicators					
	n	X min	X max	X	SX	V(%)
0-10	14	7.6	38.0	**17.2**	8.3	48.4
30-40	14	4.6	42.4	**16.5**	9.6	58.4

n – frequency, X min – minimum value, X max - maximum value, X - arithmetic mean, SX - standard deviation, V – coefficient of variation


Legend:
Forest
Watercourses
Buil-up areas
Loading of agricultural soils
with cobalt (Co)
< 15 mg/kg (sublimit values)
15 - 30 mg/kg (over-limit values)
> 30 mg/kg (significantly above limit values)
Markušovce
Rudňany
Poráč
Kaľava
Kolinovce
Richnava
Krompachy
Nižné Slovinky
Vyšné Slovinky
N
1 0.5 0 1 2 km

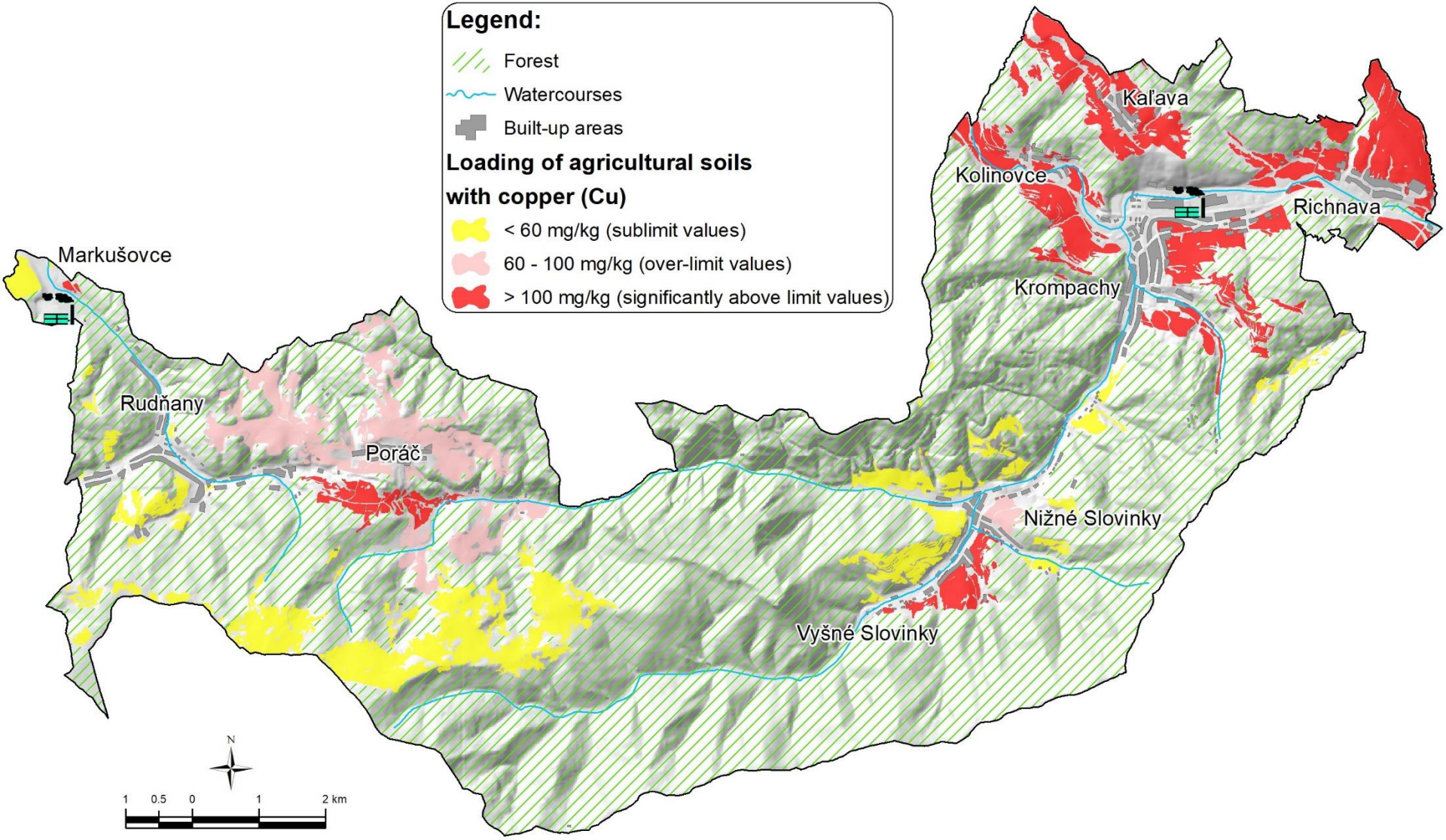
Copper (Cu)

The highest content of copper is strongly higher in topsoil (143.10 mg.kg^{-1}, where average value of Cu exceeds the valid hygienic limit for Slovakia (MPRV SR, 2013). In this area it is caused by industrial input of copper because in the last century (1937 – 1938 years) Krompachy smelter started producing copper (Očvára et al., 1987).

Total content of copper (extracted with aqua regia) in mg.kg^{-1} in agricultural land

Depth in cm	Basic statistical indicators					
	n	X min	X max	X	SX	V(%)
0-10	14	31.2	497.0	**143.1**	135.5	94.6
30-40	14	11.8	124.0	52.3	31.2	59.8

n – frequency, X min – minimum value, X max - maximum value, X - arithmetic mean, SX - standard deviation, V – coefficient of variation


Legend:
Forest
Watercourses
Built-up areas
Loading of agricultural soils with copper (Cu)
< 60 mg/kg (sublimit values)
60 - 100 mg/kg (over-limit values)
> 100 mg/kg (significantly above limit values)
Markušovce
Rudňany
Poráč
Kaľava
Kolinovce
Richnava
Krompachy
Nižné Slovinky
Vyšné Slovinky
N
1 0.5 0 1 2 km

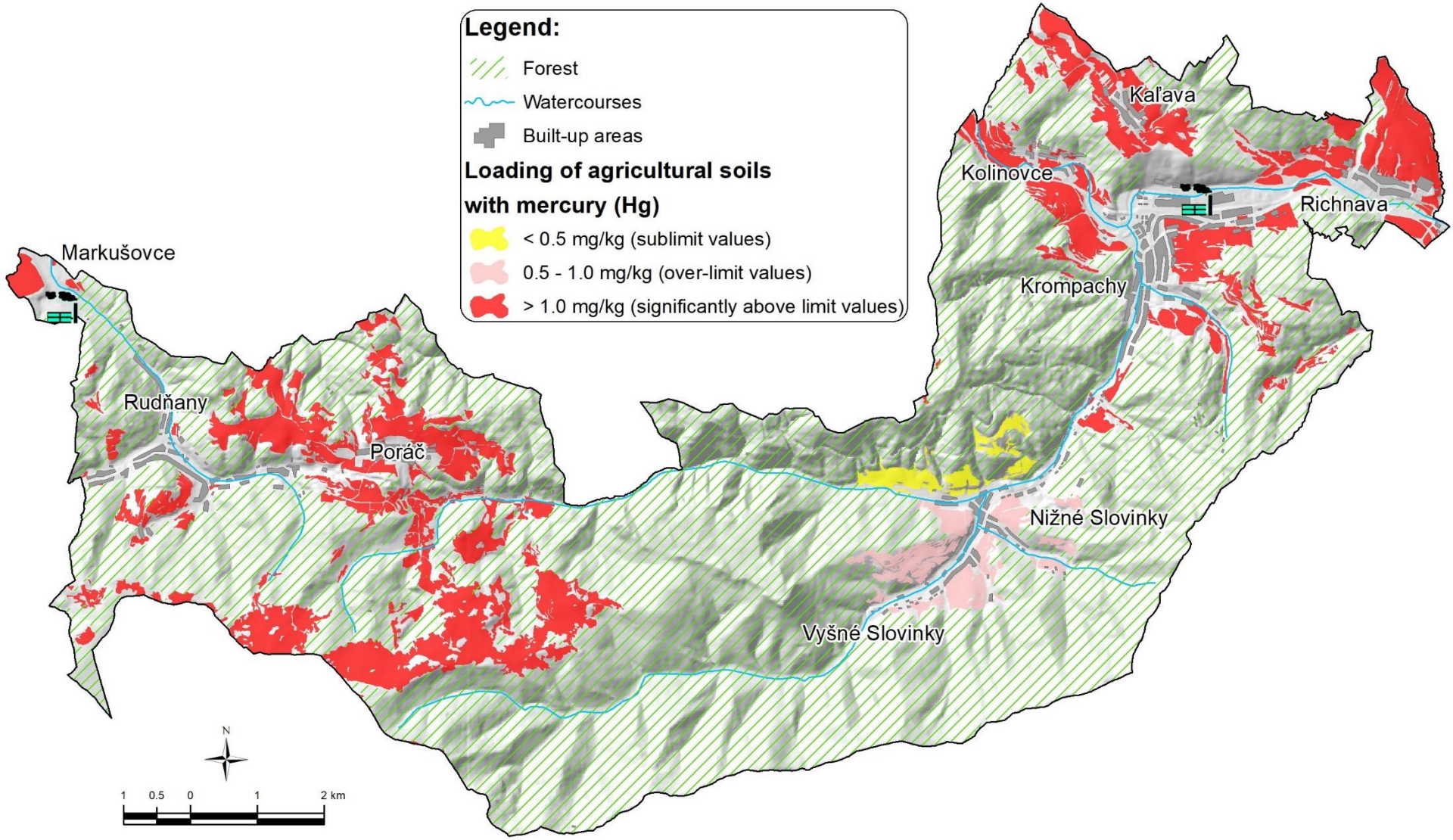
Mercury (Hg)

Average content of **mercury** in agricultural soils of Krompachy – Rudňany region is strongly high as a result of natural mineralogical composition (occurrence of cinabarite – HgS) and hazards from metalurgy where the mercury rich ores were processed. The high variability (the highest from among the evaluated risk elements) is characteristic for mercury in evaluated soils (>100 %) caused by volatility of Hg, what was also confirmed in our previous works (Kobza et al., 2014, 2019).

Total content of mercury (used AMA analyzer) in $mg.kg^{-1}$ in agricultural land

Depth in cm	Basic statistical indicators					
	n	X min	X max	X	SX	V(%)
0-10	11	0.46	83.6	**12.2**	24.3	198.8
30-40	11	0.1	8.4	**1.8**	2.5	136.2

n – frequency, X min – minimum value, X max - maximum value, X - arithmetic mean, SX - standard deviation, V – coefficient of variation


Legend:
Forest
Watercourses
Built-up areas
Loading of agricultural soils with mercury (Hg)
< 0.5 mg/kg (sublimit values)
0.5 - 1.0 mg/kg (over-limit values)
> 1.0 mg/kg (significantly above limit values)
Markušovce
Rudňany
Poráč
Kaľava
Kolinovce
Richnava
Krompachy
Nižné Slovinky
Vyšné Slovinky
N
1 0.5 0 1 2 km

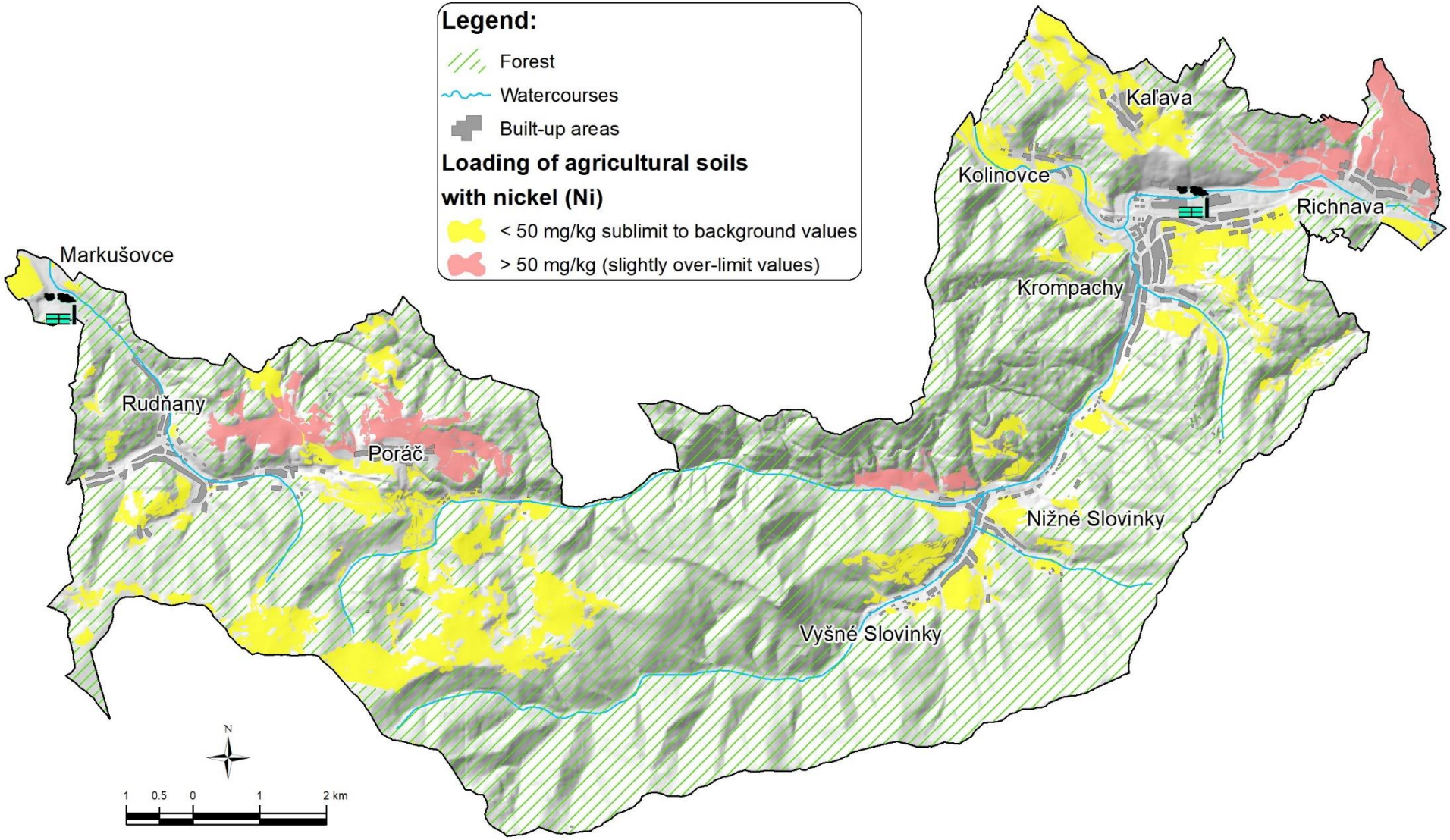
Nickel (Ni)

Average content of **nicke**l in topsoil and subsoil is lower (39 – 35.60 mg.kg^{-1}) than valid hygienic limit for predominated loamy soils (50 mg.kg^{-1}). Increased values of Ni were indicated only in Richnava and Nižné Slovinky surroundings. In comparison with average content of Ni in agricultural soils of Slovakia (29.43 mg.kg^{-1}) (Kobza et al., 2014), in this case it is probably only increased background value of Ni. Finally, similar values of Ni in agricultural and forest land of Slovakia were found out also by Čurlík and Šefčík, 1999 (on average 25 mg.kg^{-1}).

Total content of nickel (extracted with aqua regia) in mg.kg^{-1} in agricultural land

Hĺbka v cm	Základné štatistické ukazovatele					
	n	X min	X max	X	SX	V(%)
0-10	14	17.1	83.0	39.0	20.1	51.5
30-40	14	12.7	70.7	35.6	17.2	48.2

n – frequency, X min – minimum value, X max - maximum value, X - arithmetic mean, SX - standard deviation, V – coefficient of variation


Legend:
Forest
Watercourses
Built-up areas
Loading of agricultural soils
with nickel (Ni)
< 50 mg/kg sublimit to background values
> 50 mg/kg (slightly over-limit values)
Markušovce
Rudňany
Poráč
Kaľava
Kolinovce
Richnava
Krompachy
Nižné Slovinky
Vyšné Slovinky
N
1 0.5 0 1 2 km

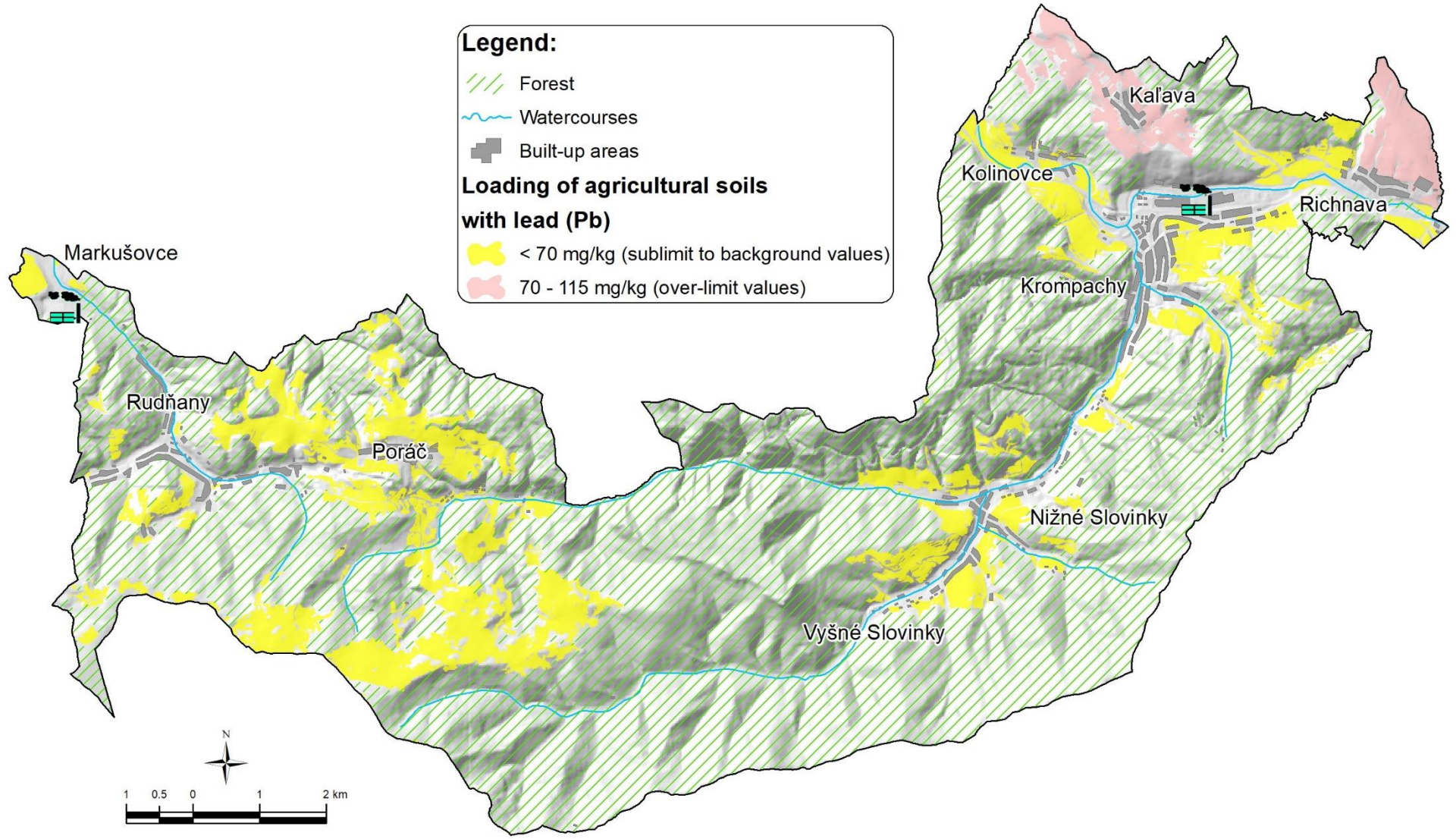
Lead (Pb)

Average content of **lead** in topsoil and subsoil is lower than valid hygienic limit (MPRV SR, 2013). Increased values of Pb were indicated only in Kaľava and Richnava surroundings.

Total content of lead (extracted with aqua regia) in $mg.kg^{-1}$ in agricultural land

Depth in	Basic statistical indicators					
cm	n	X min	X max	X	SX	V(%)
0-10	14	13.8	112.0	41.3	28.8	69.7
30-40	14	7.0	28.7	14.7	7.3	49.9

n – frequency, X min – minimum value, X max - maximum value, X - arithmetic mean, SX - standard deviation, V – coefficient of variation


Legend:
Forest
Watercourses
Built-up areas
Loading of agricultural soils with lead (Pb)
< 70 mg/kg (sublimit to background values)
70 - 115 mg/kg (over-limit values)
Markušovce
Rudňany
Poráč
Vyšné Slovinky
Nižné Slovinky
Krompachy
Kolinovce
Kaľava
Richnava
N
1 0.5 0 1 2 km

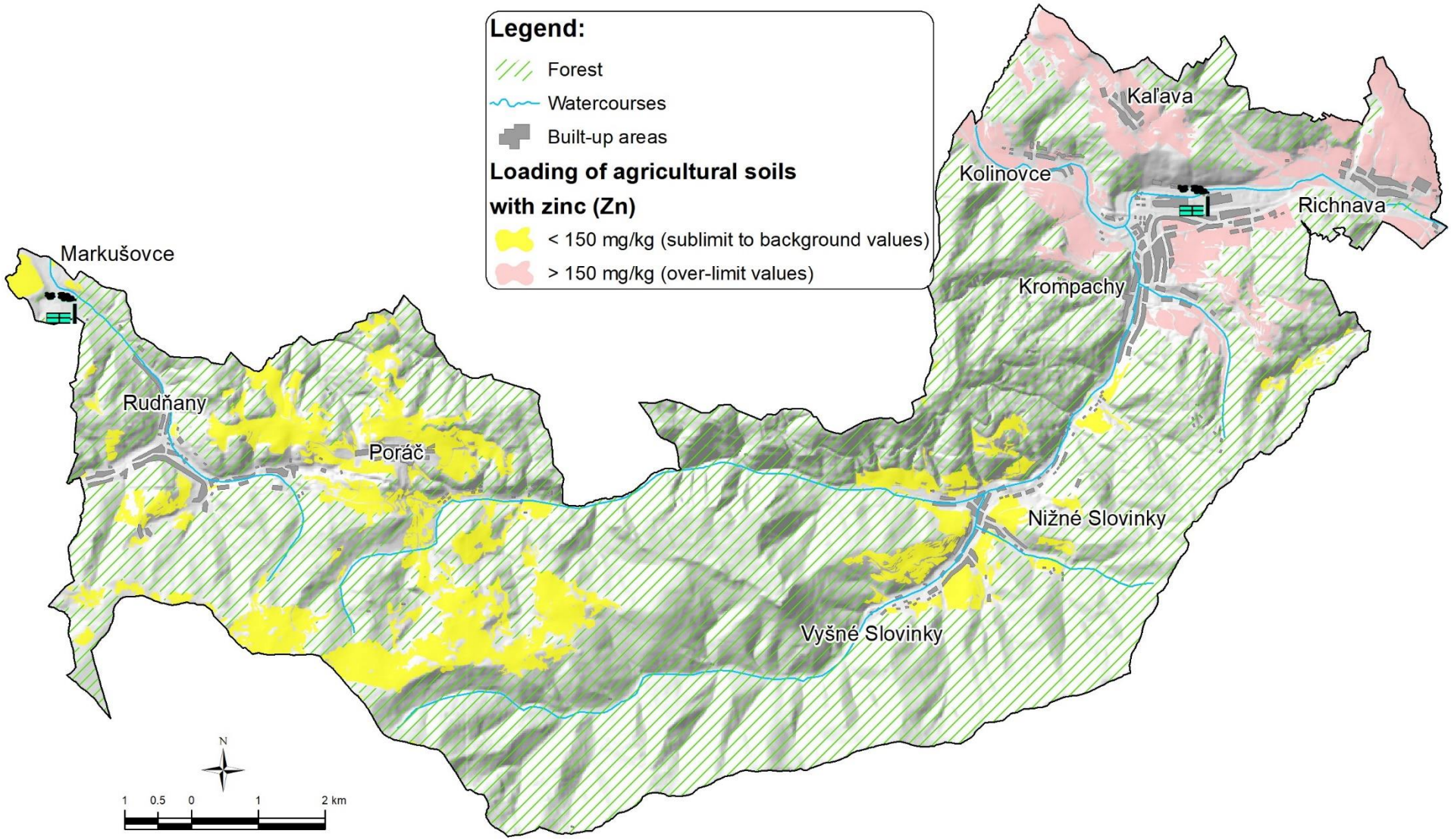
Zinc (Zn)

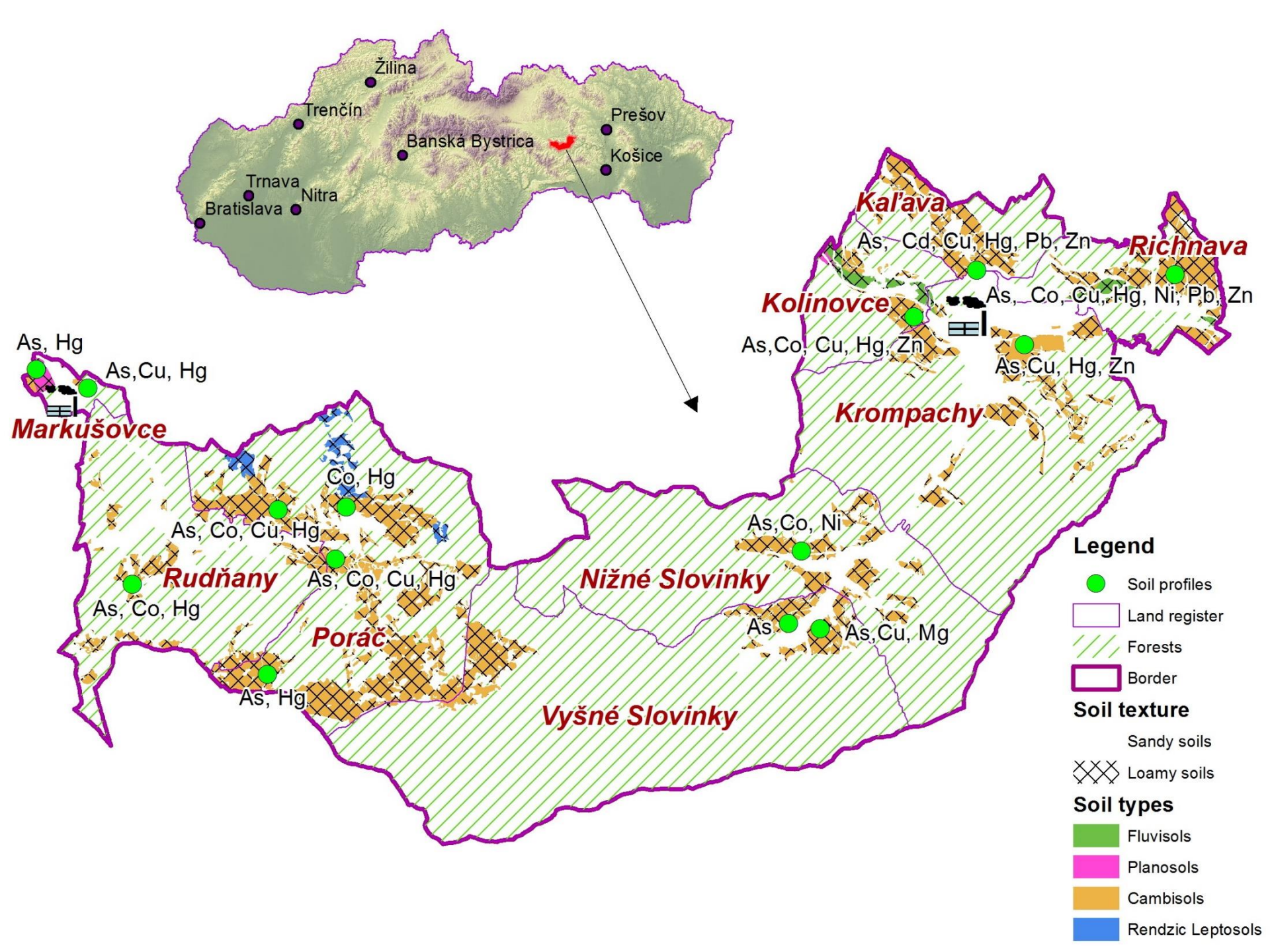
High content of **zinc** was determined in topsoil (average value is 171.10 mg.kg^{-1}). Its content in agricultural soils in Slovakia is running in the range 40 – 120 mg.kg^{-1}) (Kobza et al., 2014). Content of Zn in subsoil is significantly lower. Zinc is rather variable in topsoil and in subsoil (Coefficient of variability is higher than 50 %). According to our latest results about 36 % of agricultural land of evaluated area is affected by zinc (Kobza et al., 2019).

Total content of zinc (extracted with aqua regia) in mg.kg^{-1} in agricultural land

Depth in cm	Basic statistical indicators					
	n	X min	X max	X	SX	V(%)
0-10	14	48.7	495.0	**171.1**	137.6	80.4
30-40	14	28.7	166.0	79.0	41.4	52.4

n – frequency, X min – minimum value, X max - maximum value, X - arithmetic mean, SX - standard deviation, V – coefficient of variation

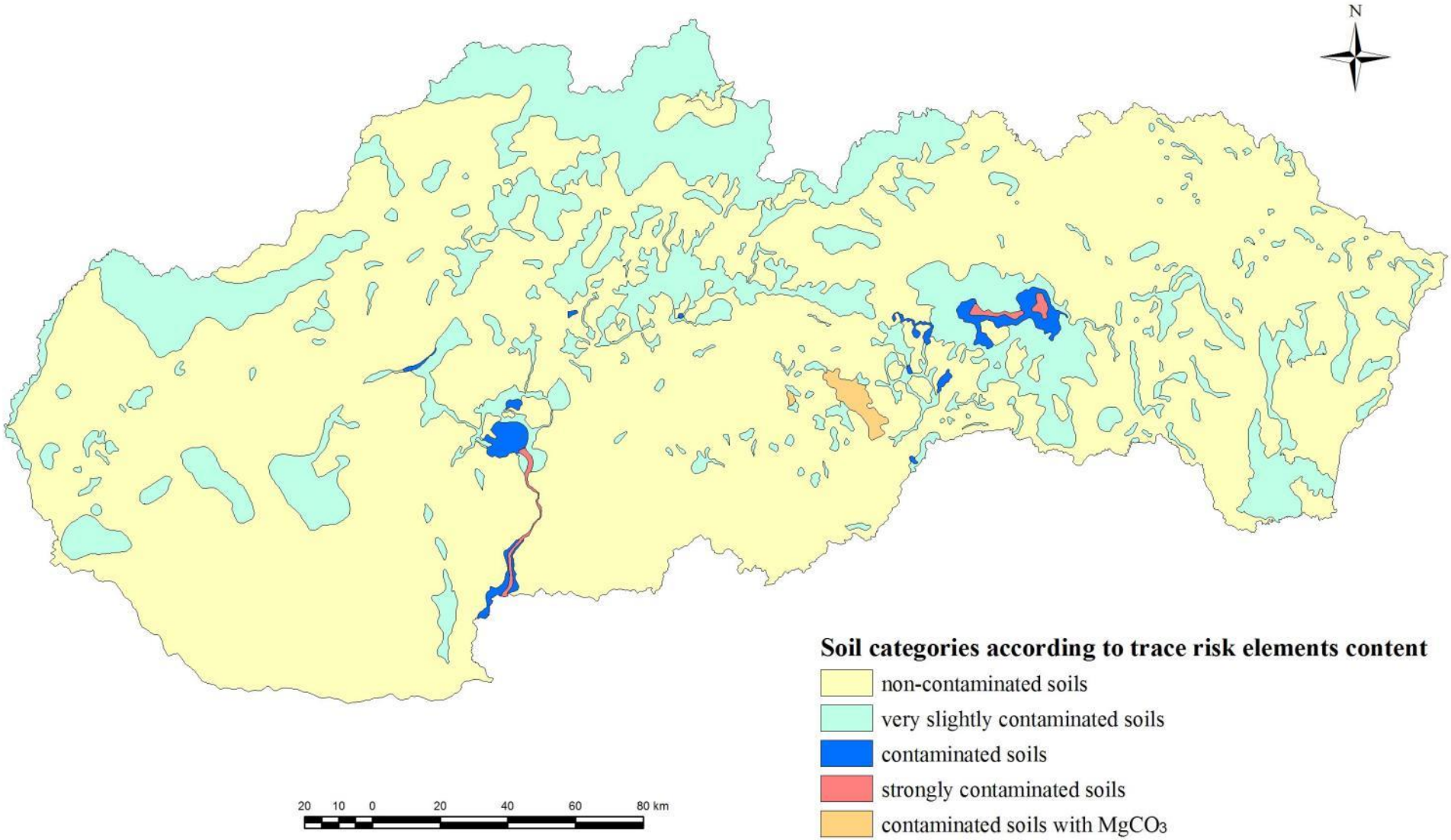

Legend:
Forest
Watercourses
Built-up areas
Loading of agricultural soils with zinc (Zn)
< 150 mg/kg (sublimit to background values)
> 150 mg/kg (over-limit values)
Markušovce
Rudňany
Poráč
Kaľava
Kolinovce
Richnava
Krompachy
Nižné Slovinky
Vyšné Slovinky
N
1 0.5 0 1 2 km


Žilina
Trenčín
Prešov
Banská Bystrica
Košice
Trnava
Nitra
Bratislava
Kaľava
As, Cd, Cu, Hg, Pb, Zn
Richnava
As, Co, Cu, Hg, Ni, Pb, Zn
Kolinovce
As,Co, Cu, Hg, Zn
As,Cu, Hg, Zn
As, Hg
As,Cu, Hg
Markušovce
Krompachy
Co, Hg
As, Co, Cu, Hg
As, Co, Cu, Hg
Rudňany
As, Co, Hg
Poráč
As, Hg
As,Co, Ni
Nižné Slovinky
As
As,Cu, Mg
Vyšné Slovinky
Legend
Soil profiles
Land register
Forests
Border
Soil texture
Sandy soils
Loamy soils
Soil types
Fluvisols
Planosols
Cambisols
Rendzic Leptosols

Excessive occurrence of risk elements in Krompachy – Rudňany region

Risk element	Cadastral areas	Area in ha
Hg	Kaľava, Kolinovce, Krompachy, Markušovce, Nižné Slovinky, Poráč, Richnava, Rudňany, Vyšné Slovinky	1708.63
As	Kaľava, Kolinovce, Krompachy, Markušovce, Nižné Slovinky, Poráč, Richnava, Rudňany, Vyšné Slovinky	1628.66
Cu	Kaľava, Kolinovce, Krompachy, Markušovce, Nižné Slovinky, Poráč, Richnava, Rudňany, Vyšné Slovinky	1113.65
Co	Kolinovce, Krompachy, Nižné Slovinky, Poráč, Richnava, Rudňany, Vyšné Slovinky	790.33
Zn	Kaľava, Kolinovce, Krompachy, Richnava	636.83
Ni	Nižné Slovinky, Poráč, Richnava	434.03
Pb	Kaľava, Richnava	276.90
Cd	Kaľava	153.32

Soil contamination categories in the Slovak Republic



CONCLUSIONS

Based on obtained results the most risk elements on agricultural soils of Krompachy – Rudňany region are in the following order: Hg, As, Cu, Co, Zn, Ni, Pb and Cd. Contaminated sites are mostly situated in the industrial (metalurgical) areas (anthropogenic impact) and also are affected by occurrence of geochemical anomalies, as well. Finally, it may be said that despite the cessation of industrial activities, the unfavourable hygienic situation persists and therefore it will be necessary these unsuitable hygienic conditions of soils to monitor also in the future.

Thank you for your attention

Kovohuty a. s. Krompachy

Želba š. p. Rudňany