Nutrients and risk elements in agricultural soils of Poland - current problems and possible solutions

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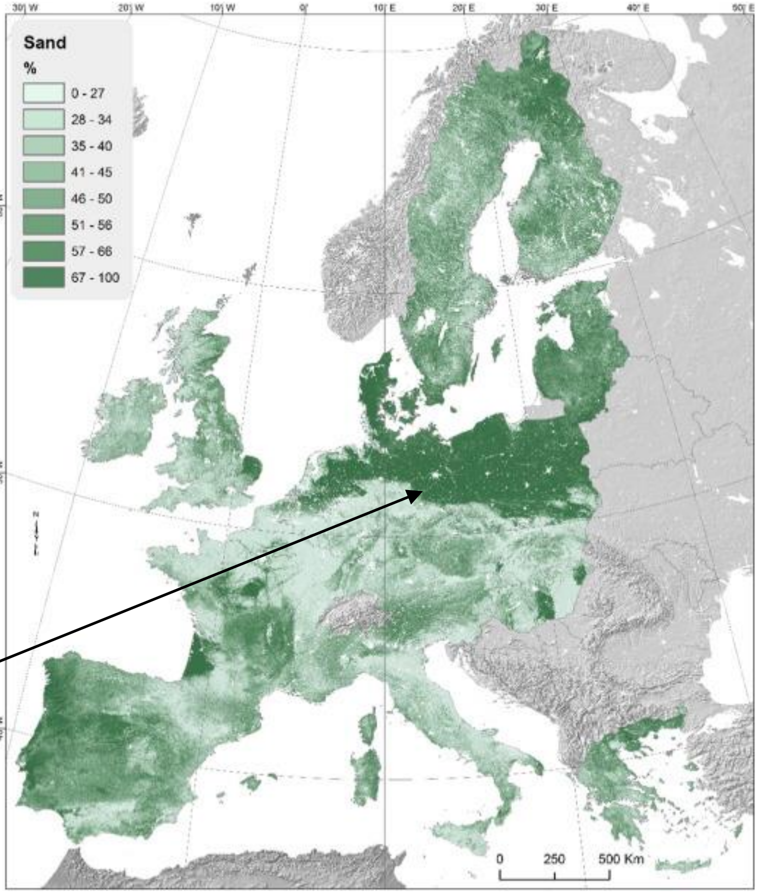
1) General characteristics of Polish soils

Pleistocene post-glacial deposits are the parent material of the most Polish soils

The glaciation occurred during the Pleistocene Epoch (2.6 million to 11,700 years ago)

Topsoil content of sand (0.05–2 mm)



The maximum range of glaciation

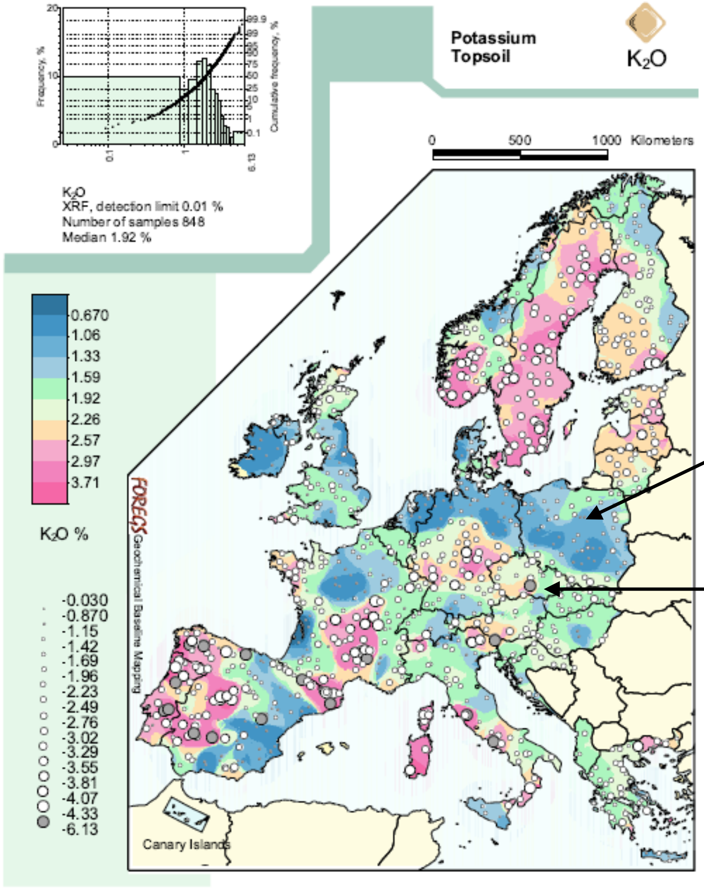
Ballabio et al. 2016, Geoderma 261: 110-123; based on LUCAS (LandUse and Cover Area frame Statistical survey) topsoil data

- Soils made up of sands of various origins constitute nearly 46% of all soil formations
- Soils built of clays – about 25.5%
- Soils made up of silts – nearly 8%
- Soils formed from alluvial deposits (about 5%)
- From organogenic structures (8.5%)
- From carbonate rocks (1%) and massive rocks (6%)

The effects of post-glacial deposits :

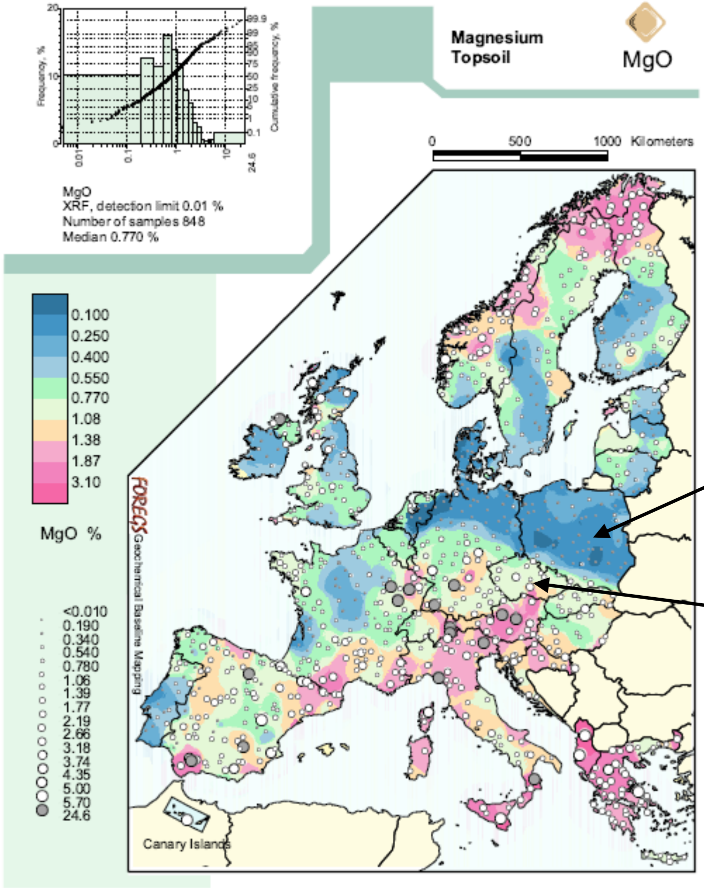
- Low content of total organic carbon and carbonates
- Low capacity of soils in relation to water and nutrients
- Weak buffering against H^+ cations and tendency to acidify
- The risk of the appearance of excessive amounts of toxic forms of aluminum (i.e. ions of Al^{3+})
- Low total nutrient content, especially potassium and magnesium
- High risk of some nutrient leaching from the soil (especially NO_3-N)

Example of the difference between different parts of Europe in total content of potassium (K_2O) and magnesium (MgO)



0.1-1.9%

1.6-2.9%

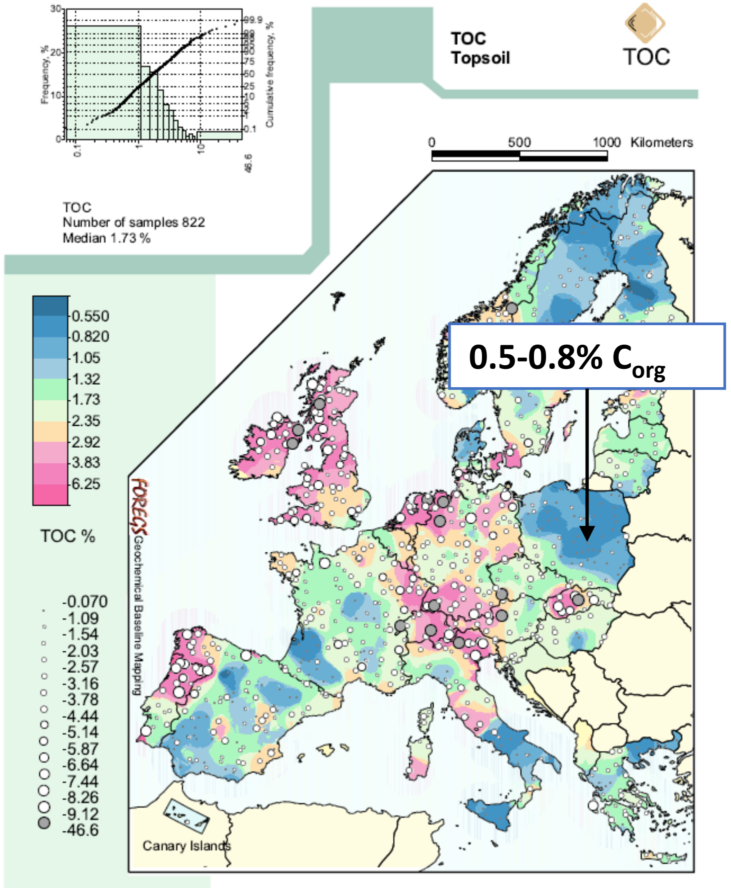


0.01-0.55%

0.55-0.20%

Geochemical Atlas of Europe: http://weppi.gtk.fi/publ/foregsatlas/maps/Topsoil/t_xrf_mgo_edit.pdf

A very big problem in Polish soils is the content of organic matter



1) Sandy, airy and constantly too dry soils do not favor the accumulation of humus in the soil

2) If we adopted the European Soil Bureau (ESB) criterion, about 89% of the agricultural land acreage would fall into the low class

3) In addition, there is low recycling index of organic matter resources in soil. It results above all from the use of increasingly smaller amounts of natural fertilizers

Geochemical Atlas of Europe: http://weppi.gtk.fi/publ/foregsatlas/maps/Topsoil/t_xrf_mgo_edit.pdf

2) Plant-available nutrients content and pH

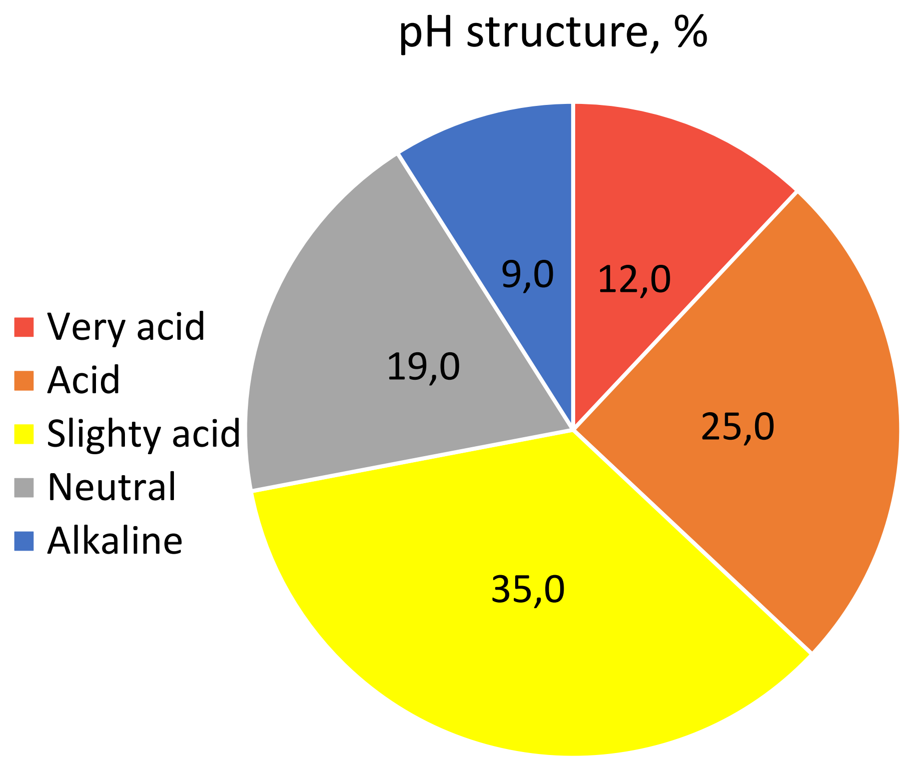
Standard methods in agricultural advisory

Parameters	Methods	Units	Statistics				
			Minimum	Maximum	Mean	Median	CV
Soil reaction	Potentiometry, 1 M KCl (1: 2.5; w/v)	pH	3.1	7.4	5.08	5.38	70
Available Phosphorus	Double Lactate (Egner-Riehm) method, pH 3.6 (1:50 w/v ratio)	P_2O_5, mg/100 g	1.6	156.6	15.42	10.65	106
Available Potassium		K_2O, mg/100 g	1.5	80.2	17.03	14.2	71
Available Magnesium	Schachtschabel method, 0.0125 M $CaCl_2$ (1:10 w/v ratio)	Mg, mg/100 g	0.1	32.1	7.42	5.8	76
Mineral nitrogen	1% solution of K_2SO_4	NH_4-N, mg /kg	0.43	42.6	8.82	7.99	53
		NO_3-N, mg/kg	< 1	110,1	x	5.42	x

Source: Institute of Soil Science and Plant Cultivation (IUNG) Pulawy, http://www.gios.gov.pl/chemizm_gleb/

Structure of soil reaction (pH_{KCl}) in 2015-2018*

Category	pH KCl
Very acid	< 4.5
Acid	4.6-5.5
Slighty acid	5.6-6.5
Neutral	6.6-7.2
Alkaline	> 7.2



Currently, according to research, in Poland we have:

- 35% of very acidic and acidic soils (pH below 5.5)
- 37% of soils with a slightly acidic reaction (pH 5.6-6.5)
- 28% of soils with a neutral and alkaline reaction (pH> 6.5)

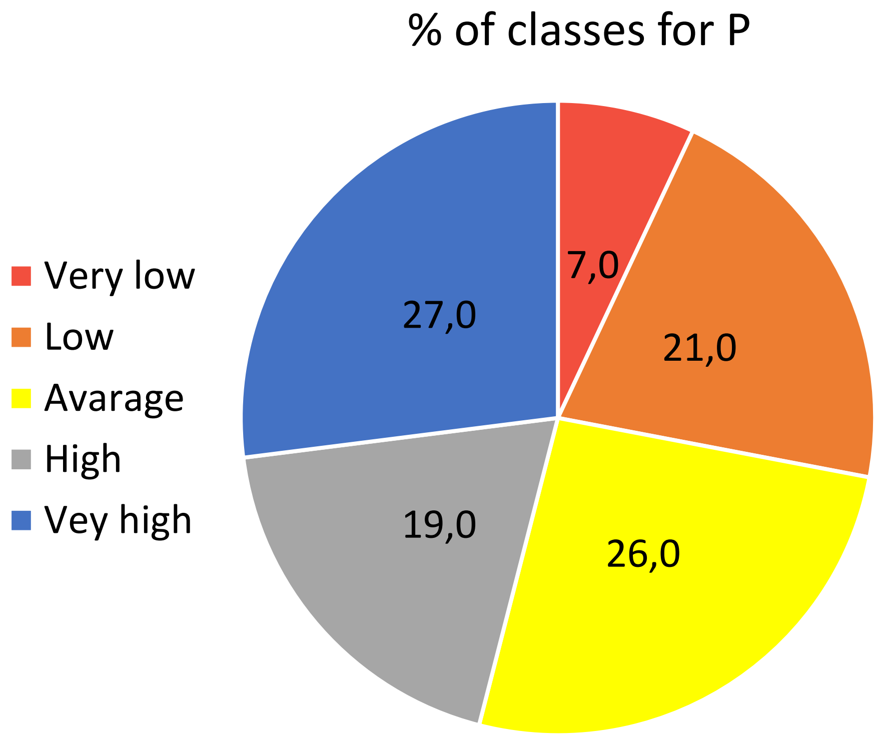
**GUS (Central Statistical Office) 2019; Accessed on 19 May 2021*

Soil classification based on the content of plant-available phosphorus and potassium according to the Egner-Riehm method

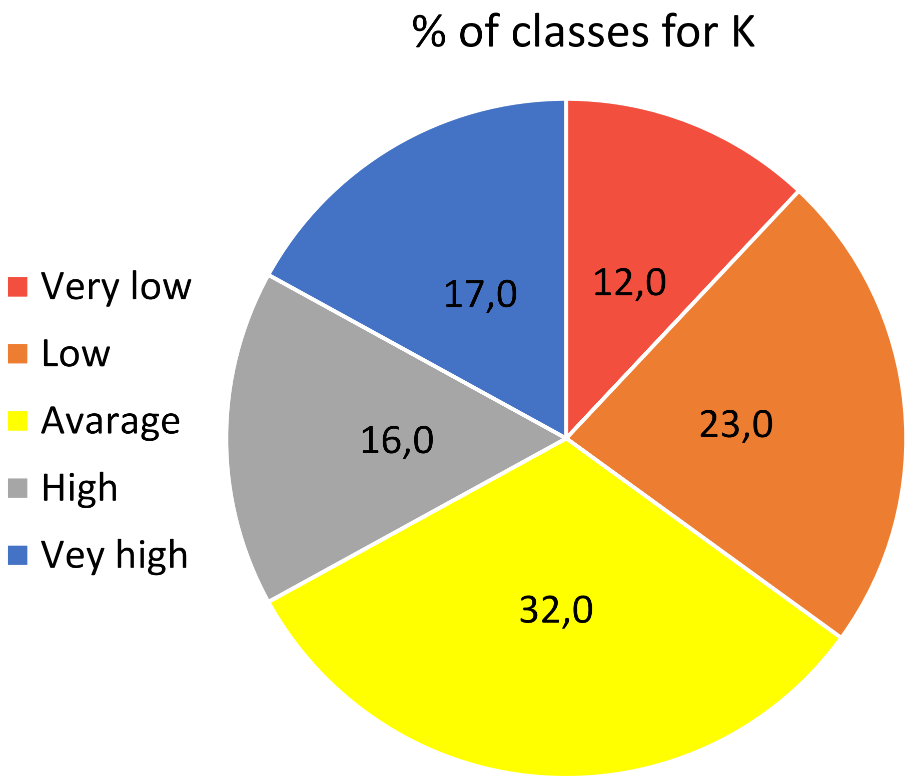
Classes	P content, mg P_2O_5 /100 g	K content, mg K_2O / 100 g Group of soil (granulometric composition)			
		Very light	Light	Medium	Haevy
Very low	< 5.0	< 2.5	< 5.0	< 7.5	< 10.0
Low	5.1 – 10.0	2.6 – 7.5	5.1 – 10.0	7.5 – 12.5	10.1 – 15.0
Medium	10.1 –15.0	7.6 – 12.5	10.1 –15.0	12.6 – 20.0	15.1 – 25.0
High	15.1 – 20.0	12.6 – 17.5	15.1 – 20.0	20.1 – 25.0	25.0 – 30.0
Very high	> 20.1	> 17.6	> 20.1	> 25.0	> 30.1

Source: Institute of Soil Science and Plant Cultivation (IUNG) Pulawy,
http://www.gios.gov.pl/chemizm_gleb/

Plant-available P and K supply in Polish cropland soils: mean in 2015-2018*



- 28% of soils with very low and low content of P
- 26% of soils with medium content of P
- 46% of soil with high content of P



- 35% of soils with very low and low content of K
- 32% of soils with medium content of K
- 33% of soil with high content of K

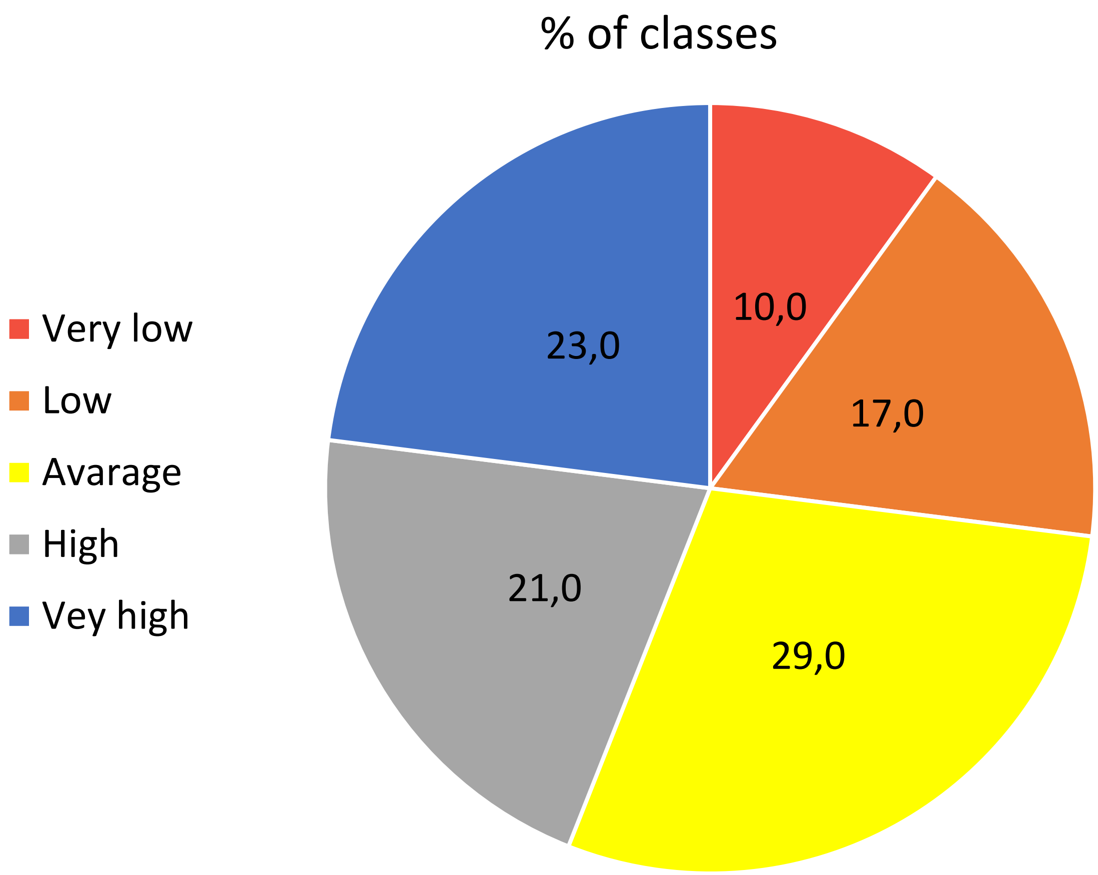
**GUS (Central Statistical Office) 2019; Accessed on 19 May 2021*

Soil classification based on the content of plant-available magnesium

Classes	Magnesium content, mg Mg / 100 g Group of soil (granulometric composition)			
	Very light	Light	Medium	Haevy
Very low	< 1,0	< 2,0	< 3,0	< 4,0
Low	1,1 – 2,0	2,1 – 3,0	3,1 – 5,0	4,1 – 6,0
Medium	2,1 – 4,0	3,1 – 5,0	5,1 – 7,0	6,1 –10,0
High	4,1 – 6,0	5,1 – 7,0	7,1 – 9,0	10,1 – 14,0
Very high	> 6,1	> 7,1	> 9,1	> 14,1

Source: Institute of Soil Science and Plant Cultivation (IUNG) Pulawy,
http://www.gios.gov.pl/chemizm_gleb/

Plant-available Mg supply in Polish cropland soils: mean in 2015-2018



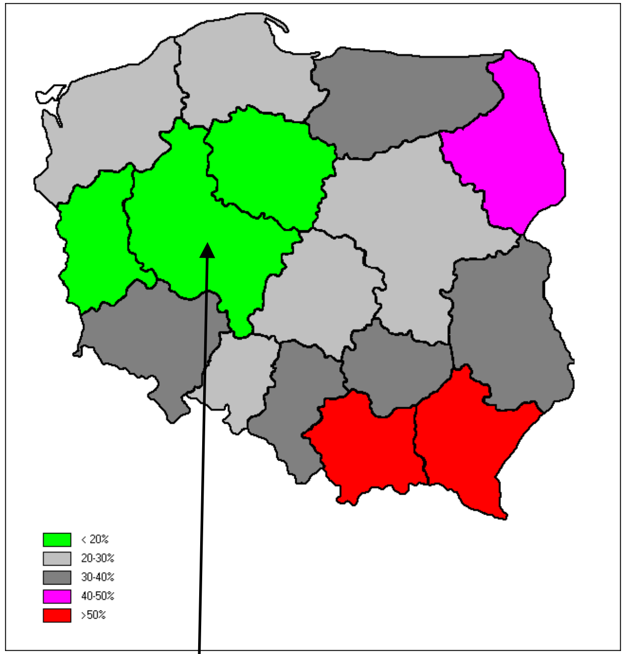
- 27% of soils with very low and low content of Mg
- 29% of soils with medium content of Mg
- 44% of soil with high content of Mg

**GUS (Central Statistical Office) 2019; Accessed on 19 May 2021*

Contribution of soils with very low and low content of plant-available P, K and Mg by regions in Poland (% of total soil samples)

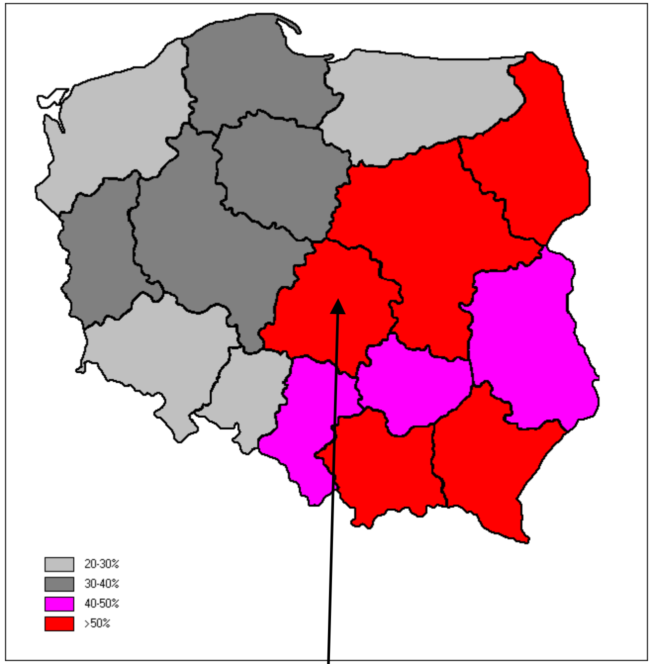
<20% | 20-30% | 30-40% | 40-50% | >50%

Phosphorus



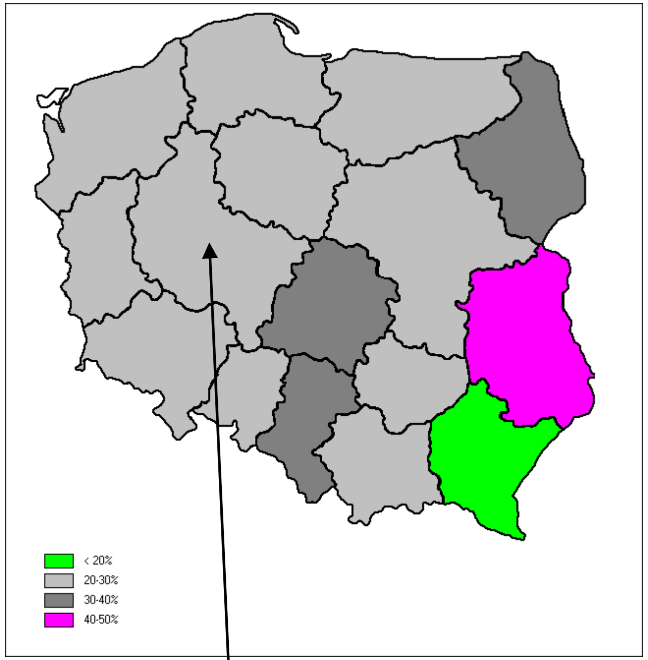
Only 20% of phosphorus-poor soils

Potassium



> 50% of soils poor in potassium

Magnesium



20-30% of soils poor in magnesium

Plant-available microelements supply in Polish cropland soils

Element	% of soils in categorie		
	Low content	Medium content	High content
B	74	25	1
Mn	3	93	4
Cu	34	57	9
Zn	17	59	24
Fe	21	73	6
Mo	no current data		

Standard method: 1 M HCl (1:10 w/v ratio)

Source: Lipiński 2013

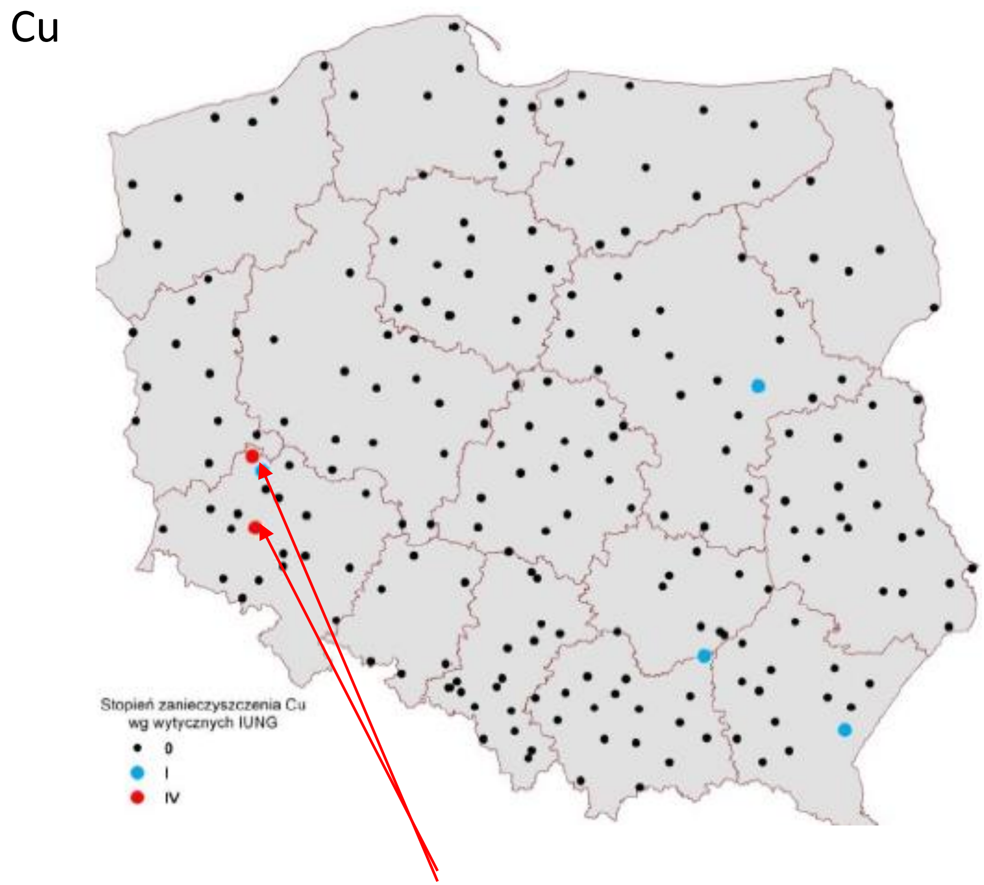
3) Trace (risk) elements

Critical values of trace metals according to the recommendations of IUNG in Pulawy (mg/kg): 6-point scale

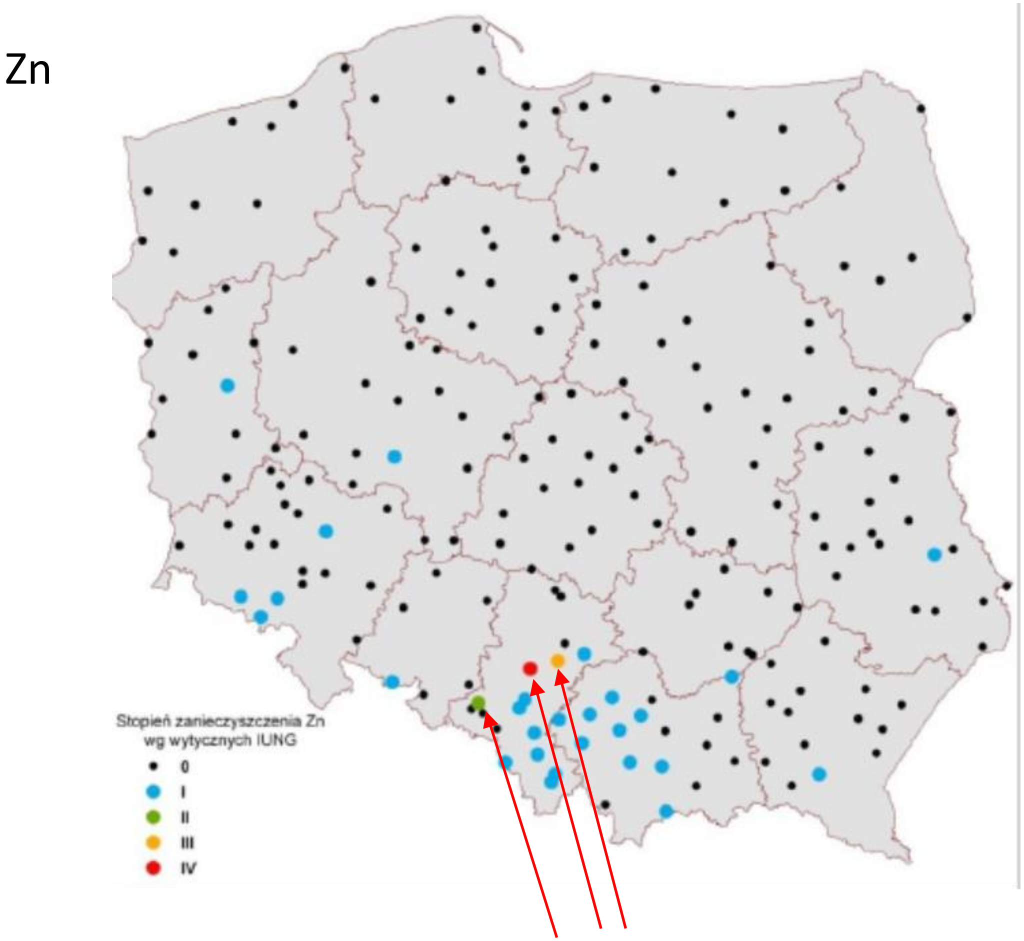
Element	Group of soils	Degree of content					
		0 natural	**I slightly increased**	**II low**	**III medium**	**IV high**	**V very high**
Cadmiumu (Cd)	Light	0.3	1.0	2	3	5	>5
	Medium	0.5	1.5	3	5	10	>10
	Haevy	1.0	3.0	5	10	20	>20
Copper (Cu)	Light	15	30	50	100	300	>300
	Medium	25	50	80	150	500	>500
	Haevy	40	70	100	250	750	>750
Lead (Pb)	Light	30	700	100	500	2500	>2500
	Medium	50	100	250	1000	5000	>5000
	Haevy	70	200	500	2000	7000	>7000
Zinc (Zn)	Light	50	100	300	700	3000	>3000
	Medium	70	200	500	1500	5000	>5000
	Haevy	100	300	1000	3000	8000	>8000

Pollution-free soils

Degrees of soil contamination with Cu and Zn at monitoring points (n = 213) according to IUNG* guidelines



The number of copper-contaminated soils = 2 (on a scale IV – high) (Cause: Cu mining and metallurgy)

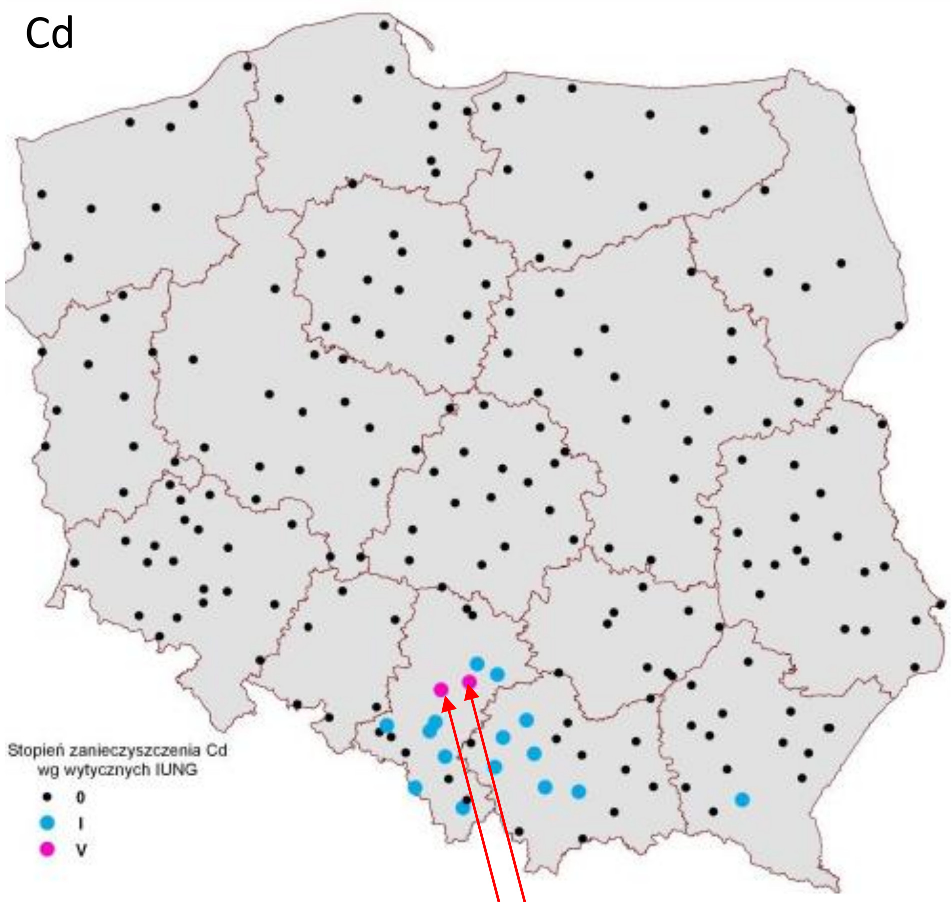


The number of zinc-contaminated soils = 3 (scale II-IV) (Cause: Zn and Pb mining and metallurgy)

*Source: Institute of Soil Science and Plant Cultivation (IUNG) Pulawy, http://www.gios.gov.pl/chemizm_gleb/

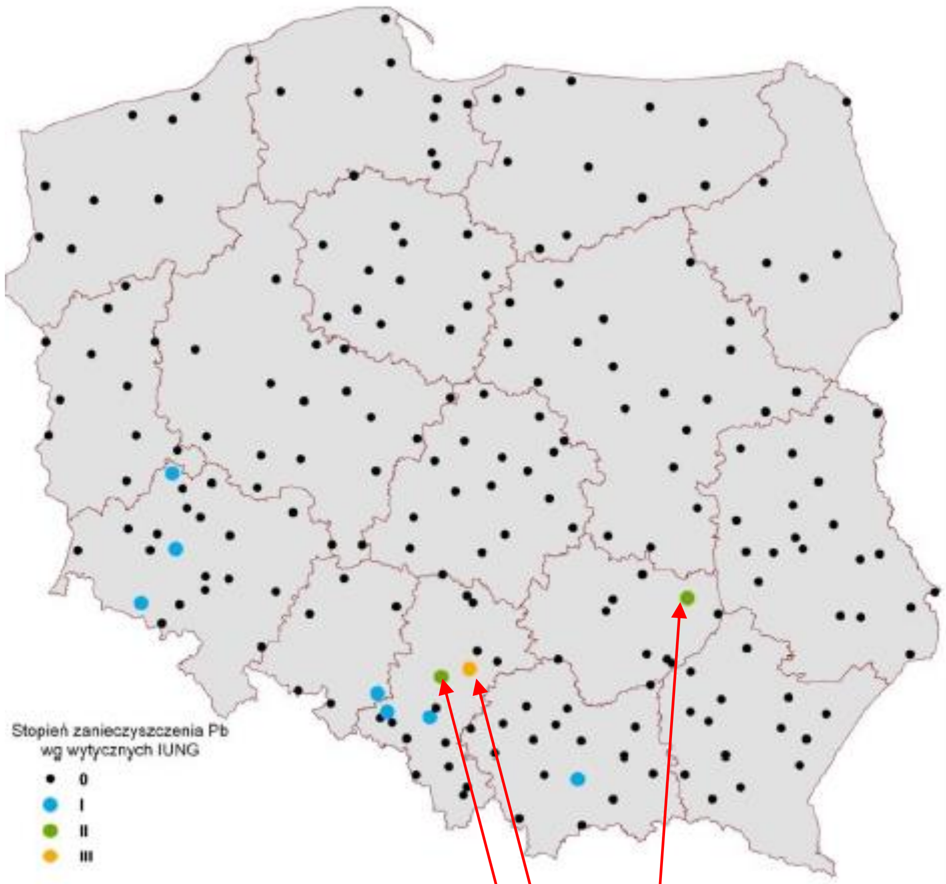
Degrees of soil contamination with Cd and Pb at monitoring points (n = 213) according to IUNG* guidelines

Cd



The number of cadmium-contaminated soils = 2
(Cause: Pb and Zn mining and metallurgy)

Pb



The number of lead-contaminated soils = 3
(Cause: Pb and Zn mining and metallurgy)

*Source: Institute of Soil Science and Plant Cultivation (IUNG) Pulawy, http://www.gios.gov.pl/chemizm_gleb/

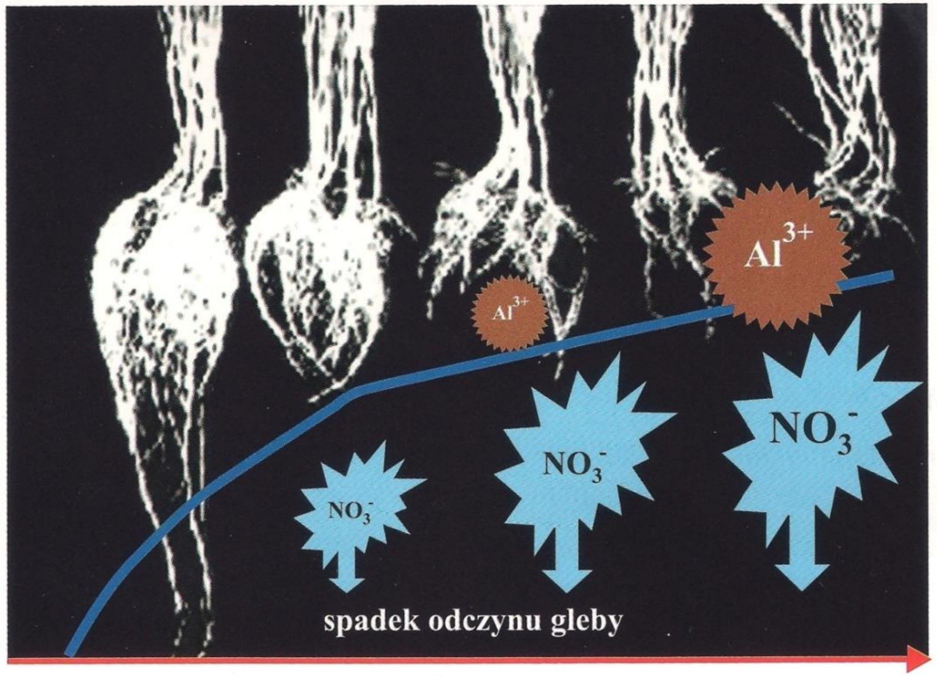
Summary of analyzes on the content of trace (risk) elements

1) According to the IUNG* standards 78.3% of soil is in class 0 (natural content); 18.6% in class I (slightly increased content).
2) This means that 97% of the soil can be used for agricultural production without any restrictions
3) According to the Regulation of the Minister of the Environment 98.1%** of soils should be considered not contaminated with trace elements
4) Exceedances of the norms concern such elements as: Cd, Cu, Pb, Zn and As. They apply only to the location near the mines and non-ferrous metal industry
5) Since 1995, no increase in the content of any of the analyzed trace metals has been observed

*Source: Institute of Soil Science and Plant Cultivation (IUNG) Pulawy, http://www.gios.gov.pl/chemizm_gleb/
** it is reason of slight difference in standards compared to IUNG

Aluminum - current problem of Polish soils

- The share of very acidic soils (< 4,5) has increased in the last years from **18.1%** (2000) to **36.1%** (2015)
- Poland is the only country in Europe where the acidification of agricultural land is so large
- It is the result of not only soil quality, lower consumption of calcium fertilizers, but also stronger pressure on soil pH by agricultural activities (increased consumption of mineral nitrogen fertilizers)
- The content of toxic aluminum (**Al^{3+}**) is related to the acidic reaction of the soil
- The increase in the amount of exchangeable aluminum (**Al^{3+}**) results in yield losses and nitrogen pollution of the environment



Effect of pH on the content of Al, root morphology and potential nitrogen losses from soil. Grzebisz et. al. 2009

4) Summary

Basic problems and possible solutions

1) In general, Polish soils are poor in nutrients compared with the neighbouring countries. Hawever, the main problem is not the genetic poverty of soils but issues which result from inappropriate soil management
2) In view of the decreasing use of natural fertilizers, the structure of crops should be more diversified, not only based on cereal crops (3/4 share), e.g. the increase in crop legumes acreage had a positive impact on the C_{org} balance
3) In respect to risk of soil contamination by exchangeable aluminium (Al^{3+}). It is necessary to develop a liming subsidy program
4) A characteristic feature is the strong spatial differentiation of nutrient content. Reason → the level of fertilizer consumption is strongly diversified in different parts of the country (and on farms). Nitrogen is not always balanced by other components.
5) It is necessary to encourage more farmers to constantly monitor the quality of the soil and fertilize it according to its nutrient content
6) It is necessary to adapt the Mehlich 3 method to routine soil analyzes in Polish conditions (currently the method is optional, optional)

Thank you for your attention!

Děkuji za pozornost !