Conference type workshop with round trip
"Opportunities of tree growth condition improvement - fertilization"
(Latvia – October 11, 2017)

Forest fertilization activities and research results in Lithuania

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I. Forest fertilization in the past.

- **In 1965, cheap mineral fertilizers produced in Lithuania were applied in an area of 6 ha of forests for the first time. After five years, more than 1,000 hectares were fertilized annually.**

Period of fertilization	Area, ha
1965-1970	2,582
1971-1975	11,469
1976-1980	26,675
1981-1985	46,565
1986-1988	27,453
In total	114,744

Ministry of Environment of The Republic of Lithuania/Department of Forests. 2003. The Chronicle of Lithuanian Forests XX *Centure* (edited by L. Kairiūkštis). – 631 p.

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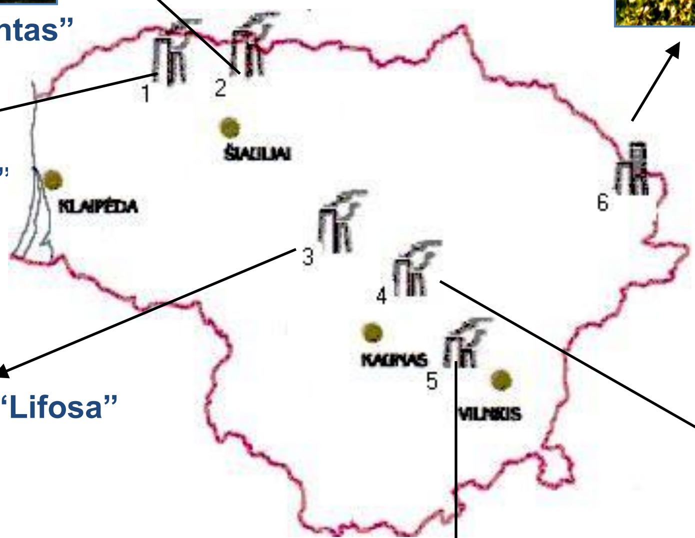
Cement plant SC “Akmenės cementas”

Nuclear power plant in Ignalina



Oil refinery plant SC “Mažeikių nafta”

Phosphorous fertilizers plant JV “Lifosa” (since 1963)

Thermal power station

Nitrogen fertilizers plant SC “Achema” (since 1965)

Major stationary sources of air pollution in Lithuania

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The damages of coniferous forests were observed in the vicinity of nitrogen fertilizer plant Jonavos “Azotas” (SC “Achema” since 1994) and cement plant JV “Akmenės cementas”

Massive dying of Scots pine stands near Jonavos “Azotas” during spring of 1979 after cold winter (minimal air temperature was 27-30ºC below zero)

Discolouration of Norway spruce due to the lack of Mn in the soil near SC “Akmenės cementas”

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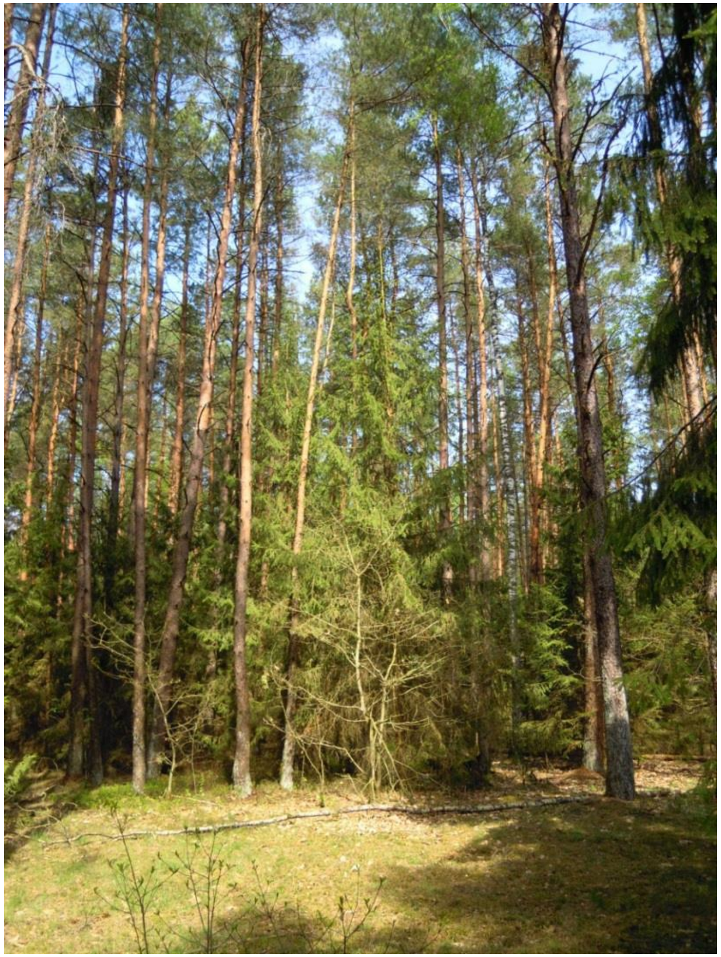
Over a period of 15 years the total (wet and dry) annual nitrogen ($NH_3 + NH_4^+ + HNO_3 + NO_3^-$) deposition comprised 250 kgN ha^{-1} and sulphur ($SO_2 + SO_4^{2-}$) – 300 kgS ha^{-1} near SC "Achema".



Long-term perturbation of Scots pine stands to the oak forest near SC "Achema" (2012)

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I. Forest fertilization in the past (1965-1988).

- **For fertilization the airplane Ан-2 was used in 1971-1975 .**
- **The fertilization was applied mainly for Scots pine stands on nutrient poor *Arenosols.* The nitrophillous grasses and weeds in ground vegetation was detected in young stands.**
- **The doses of mineral NPK fertilizers (superphosphate, ammonium nitrate, carbamide, potassium sulfate) – 45-300 kg N + 60-180 kg P + 60-120 kg K per hectare.**
- **The increase of increment (up to 15-20%) was detected after 2-3 years.**
- **The fertilization should be applied periodically: N – every 5-7; K – 8-10 and P – every 15-20 years.**
- **The fertilization was the most effective (for 5-7 years) 2-3 years before the expected increment maximum revealed in masterchronologies and reflecting the onset of favourable growth period.**

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II. Forest fertilization at present

- **Forest fertilization is allowed mainly in former agricultural land afforested with forest plantations and, especially, with willow and short rotation woody plants (hybrids of aspen, European larch, etc.) energy plantations.**

- **Only wood/forest fuel ash fertilization is recommended in forest land because:**

  - Use of biomass fuels requires recycling of nutrients in sustainable forest management;

  - Removal of nutrients could be by *forest fuel* or *wood* ash recycling.

Five Scots pine *(Pinus sylvestris L.)* stands of different age (10, 20, 40, 50, and 65 years) were sampled for above-ground biomass (needles, dead and living branches, wood, bark and cones) measurements in April 2003.

The forest type - *Pinetum vacciniosum*, the soils were classified as *Haplic Arenosols.*

Stand characteristics of the experimental plots

Age, year	Tree species composition*, %	Number of trees per ha	Average D at breast height, cm	Average height, m	Basal area, $m^2 ha^{-1}$	Volume, $m^3 ha^{-1}$
10	98P2B	2893	6.8	5.1	10.4	47.6
20	93P6O1B	2000	11.0	8.5	18.9	89.9
40	100P	1498	14.3	14.8	24.0	174.4
50	100P	915	20.7	18.8	30.8	277.6
65	100P	727	23.2	20.9	30.7	305.7

*** P - Scots pine (*Pinus sylvestris*); B - Birch (*Betulae pendula*); O - oak (*Quercus robur*)**

Forest & Landscape, Denmark

Skov & Landskab

METLA

Removal of above-ground biomass and macronutrients over a 100-year rotation period (thinnings in 30, 50 and 70 years age and sanitary fellings in 80–90-year-old stands) and final clearcut when forest fuel is prepared in Scots pine stands

Type of fellings	Above-ground compartments	Biomass*, t ha^{-1}	N	P	K	Ca	Mg	S
			kg ha^{-1}					
Thinnings and sanitary fellings	Stem	87.6	78.7±5.4	8.7±0.8	32.0±2.5	81.6±3.9	17.8±1.8	9.5±0.4
	Branches	14.5	63.0±3.9	7.8±0.7	27.0±1.8	35.9±1.6	9.2±0.5	6.5±0.4
	Needles	4.3	56.3±1.4	6.0±0.1	16.0±0.6	11.9±0.6	3.9±0.1	3.8±0.1
	In total	**106.4**	**198.0±10.7**	**22.5±1.6**	**75.0±4.9**	**129.4±6.1**	**30.9±2.4**	**19.8±0.9**
Final clearcut (at 100-year age)	Stem	126.0	82.8±4.8	7.7±0.5	36.6±1.5	66.6±1.5	19.7±1.3	8.7±0.4
	Branches	20.0	86.7±5.6	10.6±1.0	36.9±2.4	50.6±2.1	12.3±0.8	9.0±0.6
	Needles	6.0	77.6±2.9	8.3±0.2	22.1±0.8	16.7±0.5	5.7±0.2	5.7±0.1
	In total	**152.0**	**247.1±13.3**	**26.6±1.7**	**95.6±4.7**	**133.9±4.1**	**37.7±2.3**	**23.4±1.1**
All fellings per 100-year long stand rotation	Stem	213.6	161.5±10.2	16.4±1.4	68.6±4.0	148.2±5.3	37.5±3.5	18.2±0.8
	Branches	34.5	149.7±9.5	18.4±1.7	63.8±4.1	86.5±3.6	21.6±1.3	15.5±1.1
	Needles	10.3	133.9±4.3	14.3±0.3	38.1±1.4	28.7±1.1	9.6±0.3	9.6±0.2
	In total	**258.4**	**445.1±24.0**	**49.1±3.4**	**170.5±9.5**	**263.4±10.0**	**68.7±5.1**	**43.3±0.4**

Per 100-year long stand rotation with felling residues & stems could be lost ~450 kg N, 260 kg Ca, 170 kg K, 70 kg Mg, 50 kg P, and 40 kg S from 1 ha.

The nutrient removal with forest fuel comprise 280 kg ha^{-1} of N, 25-30 kg ha^{-1} of each, S, P and Mg, and 100-110 kg ha^{-1} of K and Ca, respectively.

Comparison of organic C and nutrient losses due to the forest fuel extraction in Scots pine stands during a 100-year-long rotation period with sandy soil (*Haplic Arenosols*) nutrient pools, and influxes with needle litterfall and atmospheric deposition

	C	N	P	K	Ca	Mg	S
Pools	**Mg ha^{-1}**	**---------------------- kg ha^{-1} -------------------**					
Organic layer	**15**	**523**	**29**	**31**	**167**	**30**	**50**
Mineral soil (0-100 cm)	**44**	**2283**	**3308**	**8366**	**3915**	**7581**	**607**
Net accumulation during a 100-years stand rotation (stem + crown)	**129**	**445**	**49**	**170**	**263**	**69**	**43**
In- and output fluxes	**Mg ha^{-1} yr^{-1}**	**-------------------- kg ha^{-1} yr^{-1} ---------------**					
Annual influxes with atmospheric deposition	**-**	**6-11**	**0.8**	**8-16**	**3-4**	**1.4**	**4-6**
Average annual removals with stem + crown	**1.3**	**4.45**	**0.49**	**1.70**	**2.63**	**0.69**	**0.43**
Average annual removals due to forest energy extraction alone (crown biomass)	**0.2**	**2.84**	**0.32**	**1.02**	**1.15**	**0.31**	**0.25**
Internal fluxes							
Annual return with needle litterfall	**1.3**	**27.2**	**2.5**	**4.6**	**9.6**	**2.1**	**1.8**

Armolaitis K., Varnagirytė-Kabašinskienė I., Stupak I., Mikšys V., Kukkola M., Wójcik J. 2013. Carbon and nutrients of Scots pine stands on sandy soils in Lithuania in relation to bioenergy sustainability. *Biomass&Bioenergy* 54, p. 250–259.

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Comparing trace metals removals due to the forest energy extraction in Scots pine stands during a 100-year-long rotation period with trace metals pools, the fluxes with atmospheric deposition and litterfall, the possible contamination with forest fuel ash

	Fe	Mn	Zn	Al
Pools	--------------------kg ha^{-1} ---------------			
Organic layer	72.5	20.0	2.1	104.2
Mineral soil (0-100 cm)	58945	1643	184	68905
Net accumulation during a 100-years stand rotation (crown + stem)	4.0	21.4	4.0	20.0
Net accumulation during a 100-years stand rotation (crown)	2.5	10.0	1.2	9.1
In- and output fluxes	---------------- kg ha^{-1} year^{-1} ------------			
Annual influxes with atmospheric deposition	0.34	0.07	0.10	-
Average annual removals with stem + crown	0.04	0.21	0.04	0.20
Average annual removals due to forest energy extraction alone (crown biomass)	0.03	0.10	0.01	0.09
Internal fluxes				
Annual return with litterfall	1.23	2.52	0.58	0.13
Contamination with biofuel ash	----------------------			
Concentrations in forest fuel ash, g kg^{-1}	2.1–7.7	0.4–2.1	0.02–0.52	2.2–4.1
Content in 3 t ha^{-1} of forest fuel ash, kg ha^{-1}	6.3-23.1	1.2-6.3	0.1-1.6	6.6-12.3

Varnagirytė-Kabašinskienė I., Armolaitis K., Stupak I., Kukkola M., Wójcik J., Mikšys V. 2014. Some metals in aboveground biomass of Scots pine stands in Lithuania. *Biomass&Bioenergy* 66, p. 434–441.

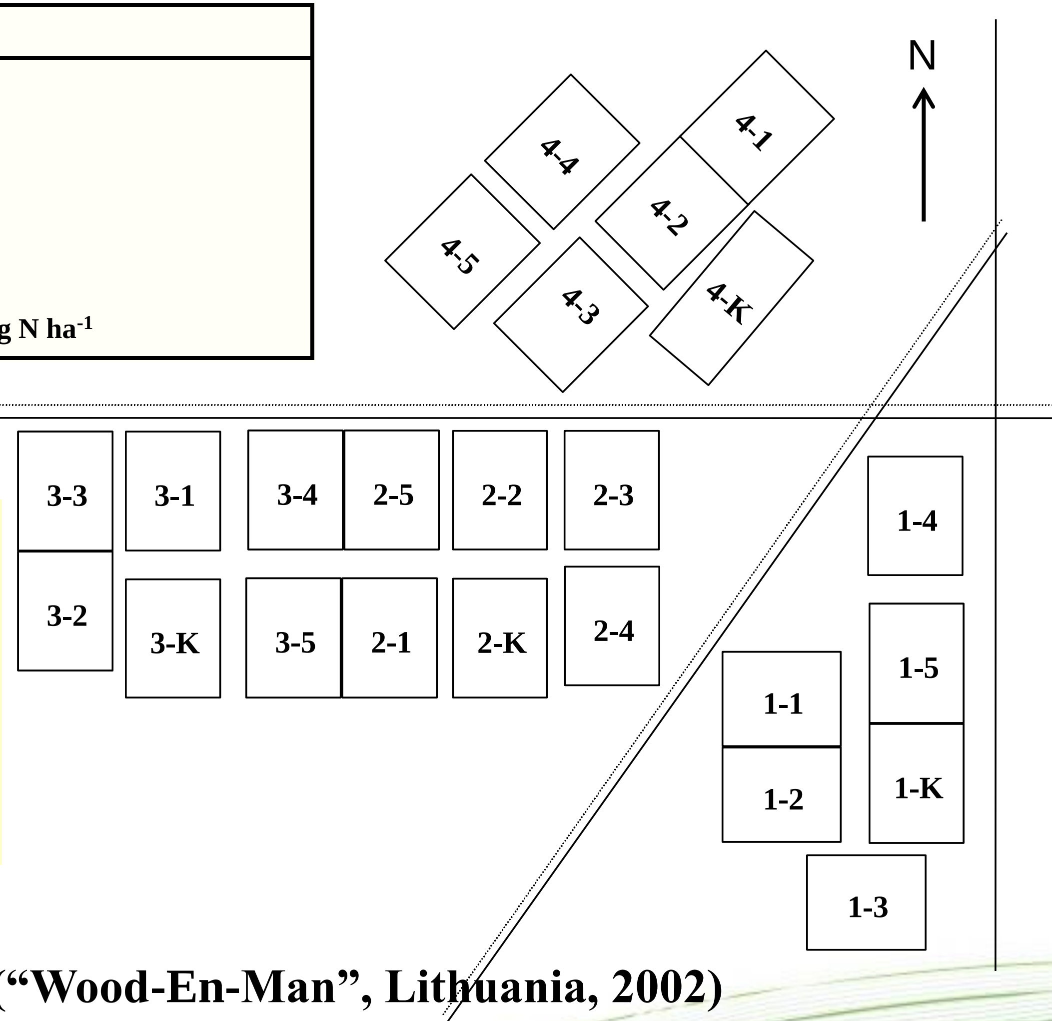
Wood ash field experiment in Lithuania: plot installations and main results 2002-2005

Experiment design and plot installations

• The recycling of wood ash in Lithuanian forests was studied in Scots pine stands growing on sandy soils (*Haplic Arenosols*) in SW Lithuania (*typical Scots pine stands of Lithuania*).

Symbol	Treatment	Description
K	Control	No treatment
1	Low dose of ash	Raw ash – 1.25 t ha^{-1}
2	Average dose of ash	Raw ash – 2.5 t ha^{-1}
3	High dose of ash	Raw ash – 5.0 t ha^{-1}
4	Fertilised by nitrogen	180 kg N ha^{-1}
5	Ash + N fertilisers	Average dose of ash + 180 kg N ha^{-1}

• The experiment duration – 2002–2005.
• The area of site – 3.2 ha.
• Totally there were 24 plots (25x20 m) grouped into 4 blocks.
• The experiment included altogether 6 treatments.



Field experiment design (“Wood-En-Man”, Lithuania, 2002)

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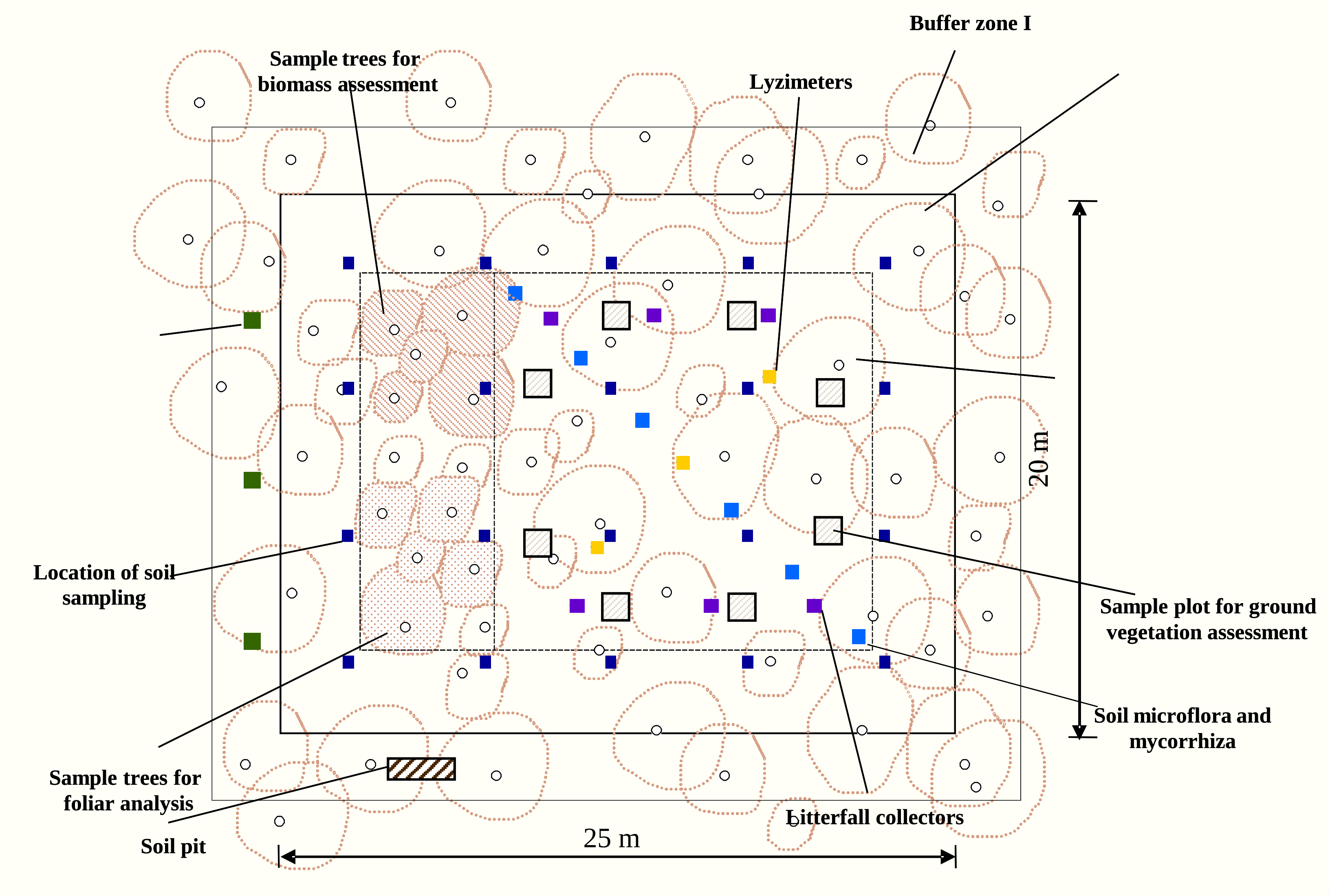
Experiment design and plot installations

Wood ash and N fertilisers application process - field experiment ("Wood-En-Man", Lithuania, 25-27 June, 2002):

- **1** installation of tension lysimeters;
- **2-3** preparation;
- **4** spreading wood ash and N fertilisers;
- **5** litterfall collectors

Experiment design and plot installations



(the experiment includes 24 plots, 25x20 m)

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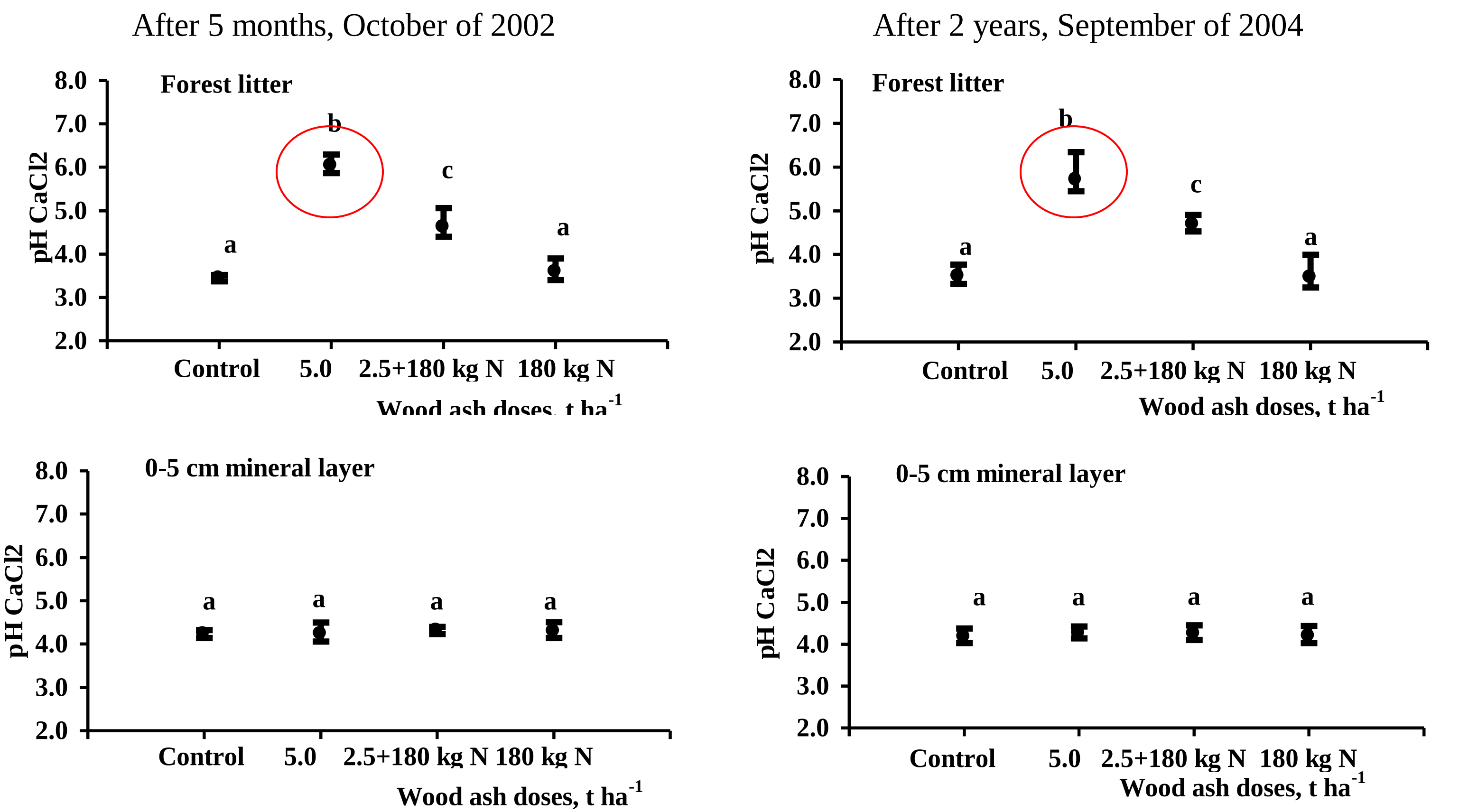
Experiment design and plot installations

The chemical composition of wood ash applied in the field experiment (2002)

Macronutrients, g kg^{-1}		Heavy metals, mg kg^{-1}	
P	2.15	Cr	9.51
K	5.29	Cd	0.62
Ca	72.0	Pb	4.53
Mg	9.45	Ni	8.05
		Cu	13.1
		Zn	73.7

Wood ash from four heating boilers of Lithuania were analysed in Swedish University of Agricultural Sciences

O layer (OL, OF and OH horizons) and mineral topsoil



Effects of the wood ash and N fertilizers on average pH_{CaCl2} of the O horizon and the 0-5 cm layer of the mineral soil 3 months and 25 months after application.

The main changes were recorded in organic layer (forest floor) of *Arenosols*. The raw ash (5.0 t/ha) increased the pH_{CaCl2} by 2.2-2.6 unit.

O layer (OL, OF and OH horizons) and mineral topsoil

Total concentrations of some macronutrients in O layer (forest litter) 3 months and 2 years after the application of wood ash and N fertilizers

Variant of experiment	N	P	K	Ca	Mg
	g kg^{-1}				
2002 (3 months)[a]					
Control	12.02±0.15	0.64±0.06	2.90±0.24	4.10±0.16	0.66±0.06
5 t ash ha^{-1}	9.45±0.58*	1.10±0.02*	7.40±0.58*	28.88±1.68*	4.15±0.36*
180 kg N ha^{-1}	11.91±0.55	0.66±0.04	2.18±0.11	4.60±0.71	0.62±0.07
(2.5 t ash+180 kg N) ha^{-1}	10.62±0.55	0.90±0.12*	4.78±0.35*	14.55±1.98*	1.96±0.17*
2004 (2 years)					
Control	12.73±0.13	0.81±0.03	0.66±0.02	3.50±0.60	0.48±0.06
5 t ash ha^{-1}	9.40±0.55*	1.11±0.12*	1.80±0.20*	15.90±1.29*	1.67±0.13*
180 kg N ha^{-1}	11.67±1.60	0.70±0.11	0.53±0.07	2.93±0.93	0.43±0.11
(2.5 t ash+180 kg N) ha^{-1}	11.07±0.61	0.89±0.02*	0.99±0.06*	9.30±0.68*	1.01±0.11*

* Significant difference from the control at significance level $p<0.05$

[a] The data for comparison are taken from Ozolincius *et al*., 2005.

Wood ash, and wood ash+N fertilizers increased the concentrations of P, K and Mg. Wood ash decreased on N concentrations in forest floor.

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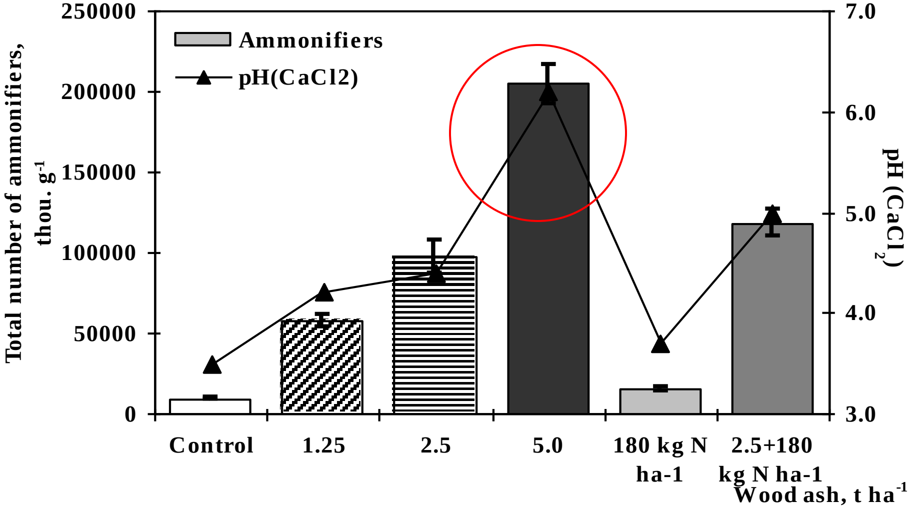
O layer

A



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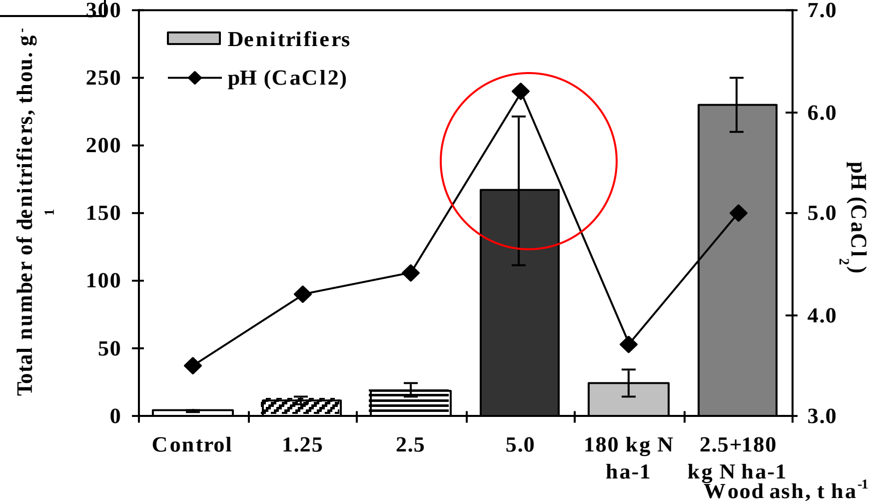

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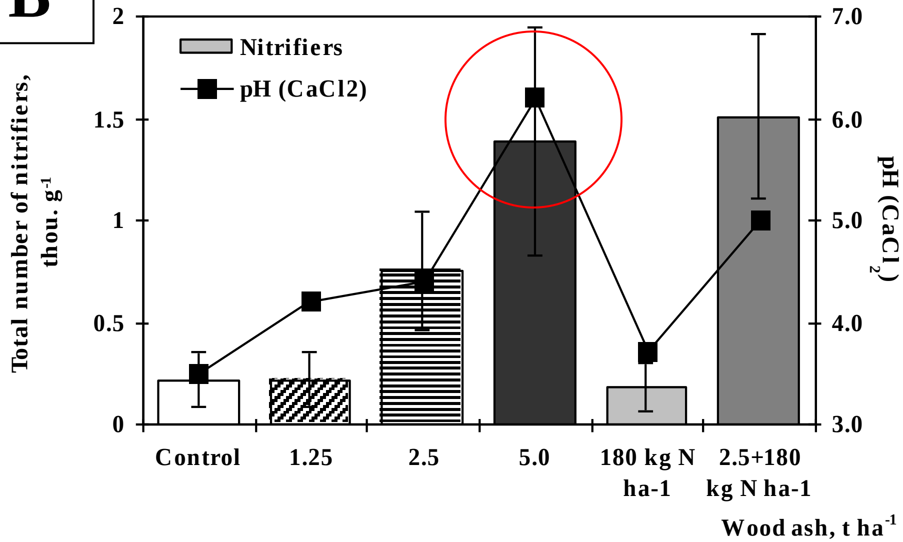

The distribution of ammonifying (A), nitrifying (B) and denitrifying (C) microorganisms in the forest floor 3 months after wood ash and N fertilizers application.

Soil microbiological activity increased after the application of wood ash.

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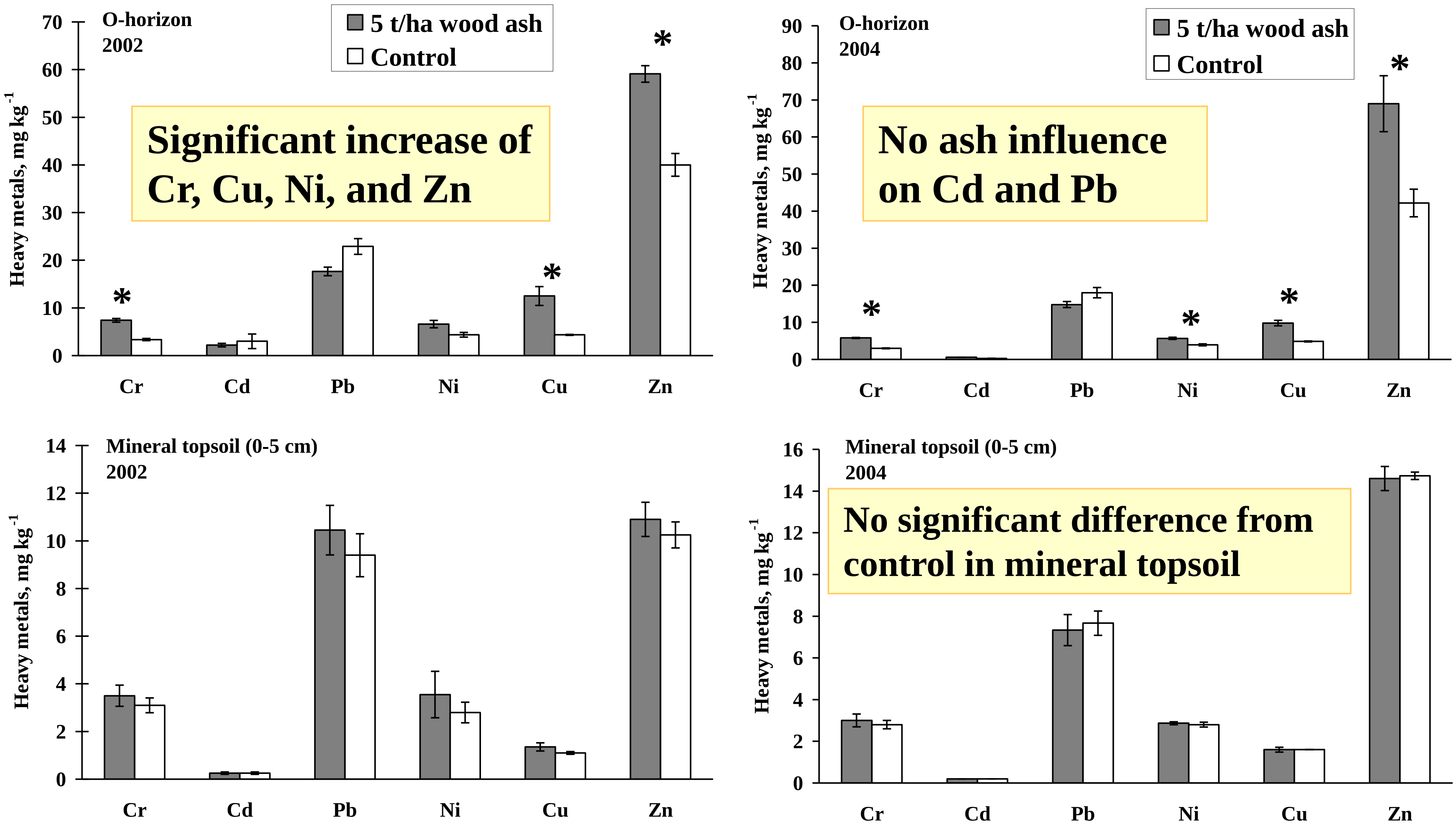
O layer (OL, OF and OH horizons) and mineral topsoil



Mean concentrations of heavy metals in O layer and mineral topsoil

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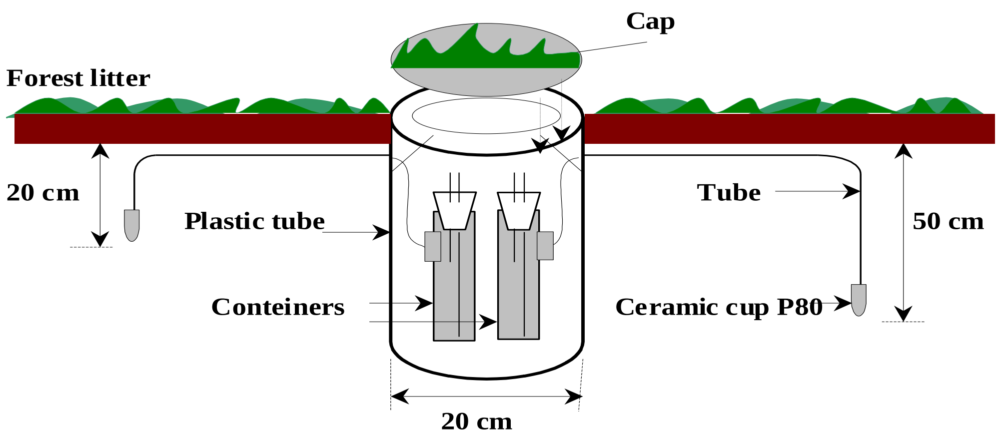
Tension lysimetry

(ceramic cup P80 of *PRENART Equipment* ApS, Denmark; pores size 1 µm; -80 kPA for 2-3 weeks)



***"…the chemical composition of soil water solution using tension lysimetry usually represents the end of e.g. buffering and neutralization processes in the different soil horizons"* (from Derome and Bille-Hansen, 2001).**

Onetime vacuum of -80 kPA enables to collect soil water from sandy soils (*Arenosols*) that contain only about 5% hygroscopic soil water (capillary soil water during drought periods).

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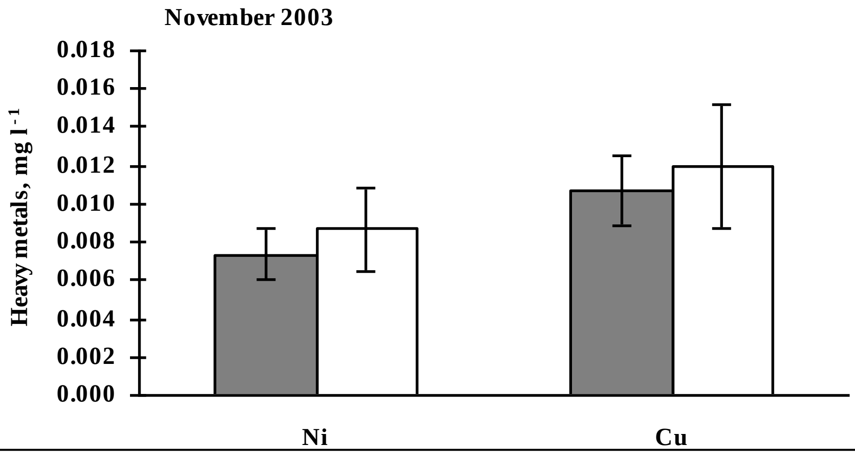
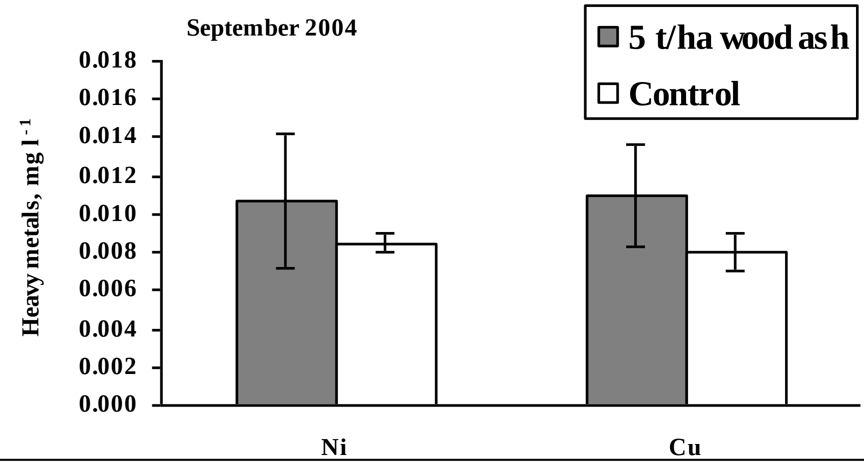
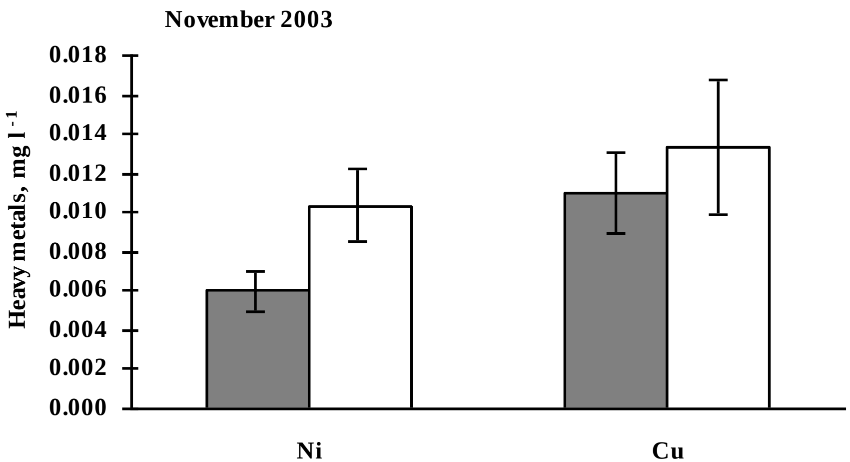
Soil solution at 20 and 50 cm depths

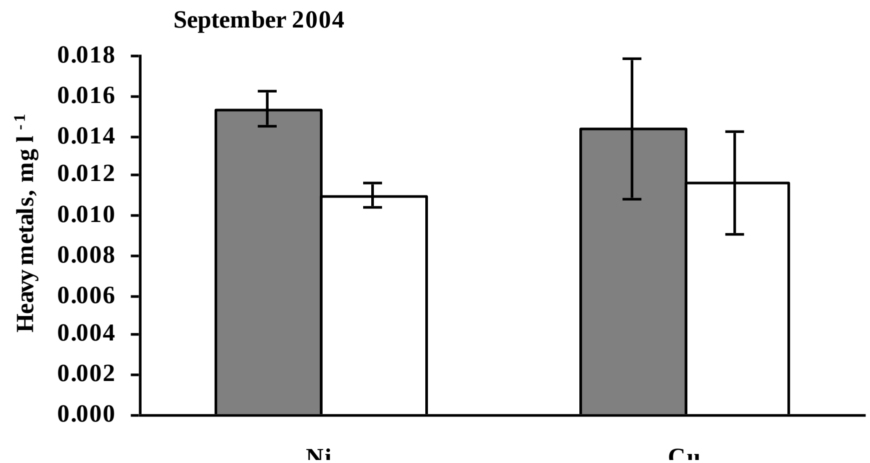
20 cm depth





50 cm depth





The concentrations of Ni and Cu in soil solution 15 months (November, 2003) and 2 years (September, 2004) after the application of wood ash.

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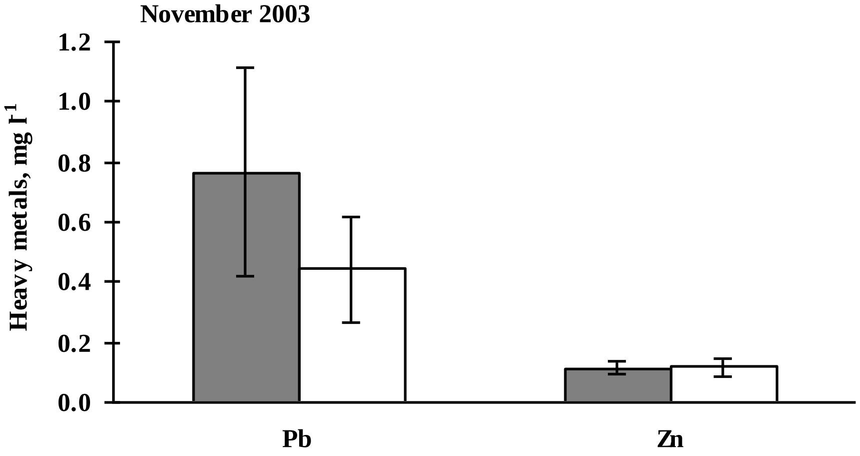
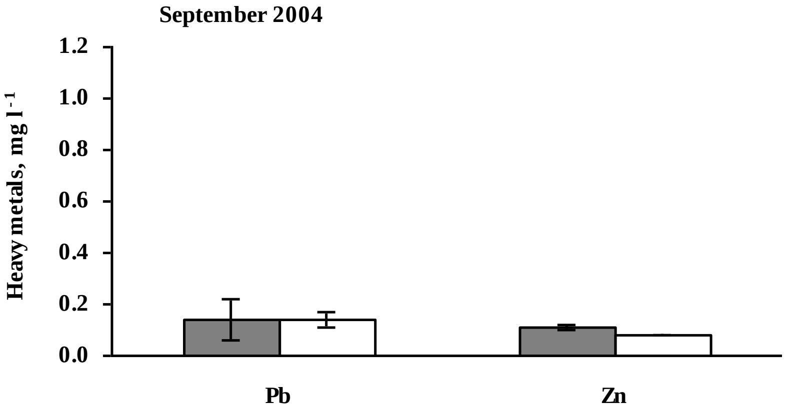
Slight leaching of Ni and Cu.

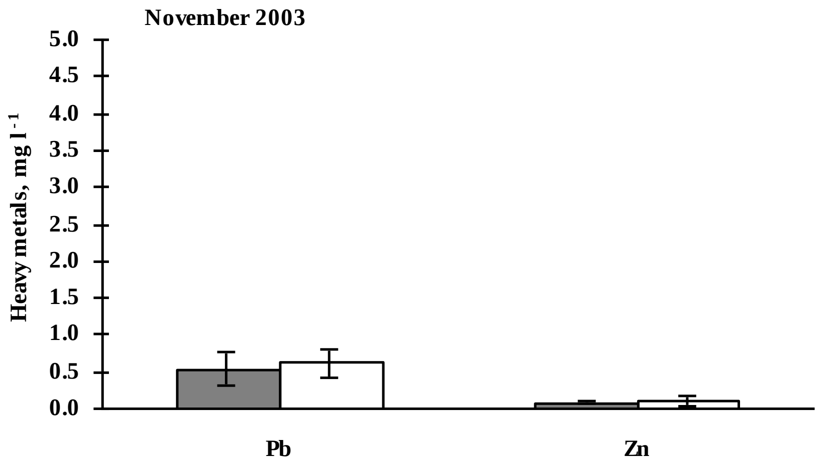
Soil solution at 20 and 50 cm depths

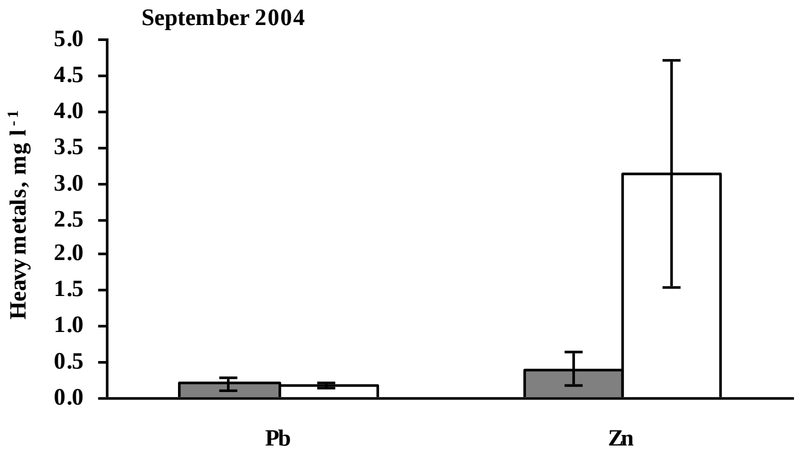
20 cm depth





50 cm depth





The concentrations of Pb and Zn in soil solution 15 months (November, 2003) and 2 years (September, 2004) after the application of wood ash.

No significant leaching of Pb and Zn.

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Soil ground vegetation

Effects of wood ash and N treatment on mean cover of bryophyte and *Pleurozium schreberi* (%). *Mean values and SE are shown for each treatment (n – the number of sample plots).*

Treatment	n	Year 2002	Year 2003	Year 2004
Mean cover of bryophyte (%)				
Control	18	96.39±1.05	96.89±0.59	92.44±2.58
WA 1.25	20	98.70±0.36	96.40±0.57	92.40±2.41*
WA 2.5	24	98.58±0.58	95.75±1.10	92.13±1.54*
WA 5.0	16	97.56±0.93	94.38±1.54	90.00±2.76**
N	23	99.04±0.46	97.78±0.67	92.00±3.04**
WA 2.5/N	20	97.20±0.76	94.95±1.10	90.65±2.73*
Mean cover of *Pleurozium schreberi* (%)				
Control	18	91.11±1.50	91.28±1.14	88.11±2.88
WA 1.25	20	90.25±1.34	90.85±1.06	87.05±2.65
WA 2.5	24	91.75±1.09	90.42±1.29	86.04±1.56*
WA 5.0	16	90.31±1.56	87.75±1.75	81.69±2.64**
N	23	93.52±1.19	94.30±1.09	87.00±3.37*
WA 2.5/N	20	93.35±1.03	92.25±1.22	87.95±2.98

Significant difference within treatment between 2002 and 2004 indicated *=p<0.05, **=p<0.01

Wood ash and N fertilizers significantly decreased the mean cover of bryophytes.

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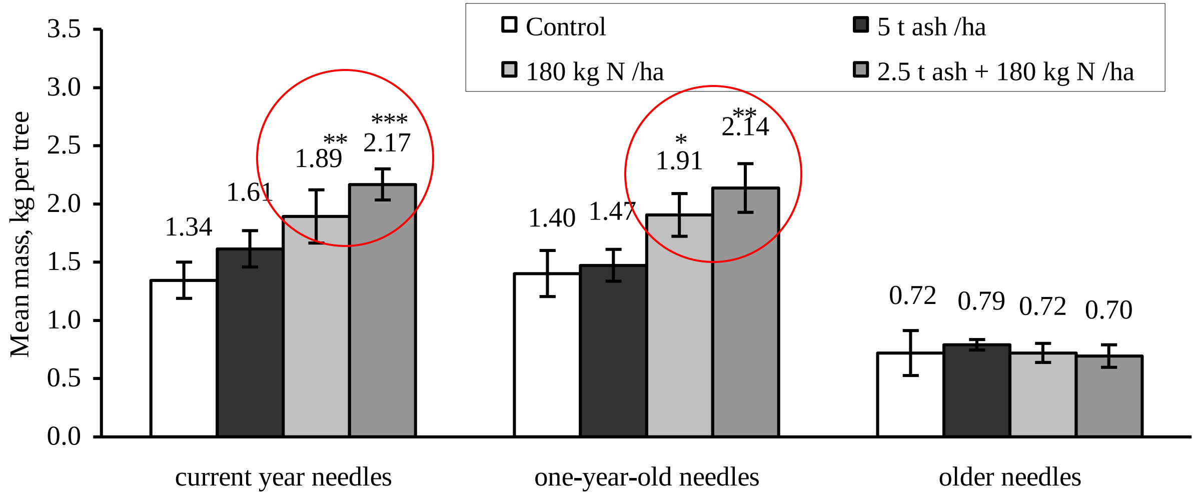
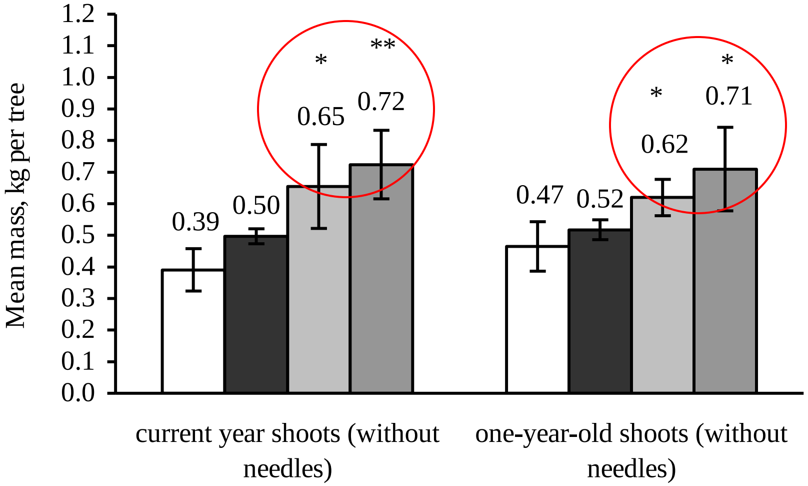
Current and first year needle

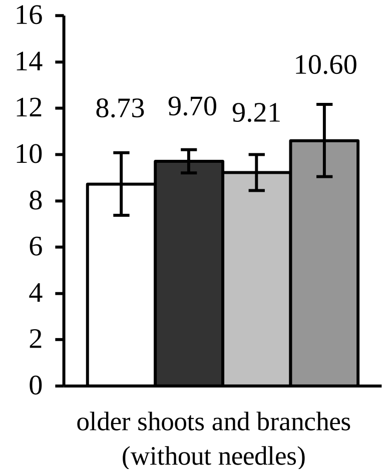


No ash effect on needle mass.

N fertilizers and ash applied in complex with N increased the current and one-year-old needle mass by 1.4-1.6 fold.

No treatment effects on the older needle mass.





Only the complex treatment (ash+N) gave a stronger response on tree growth after 2-3 years (in average DBH increment increased by 40%, stand volume – by 16%).

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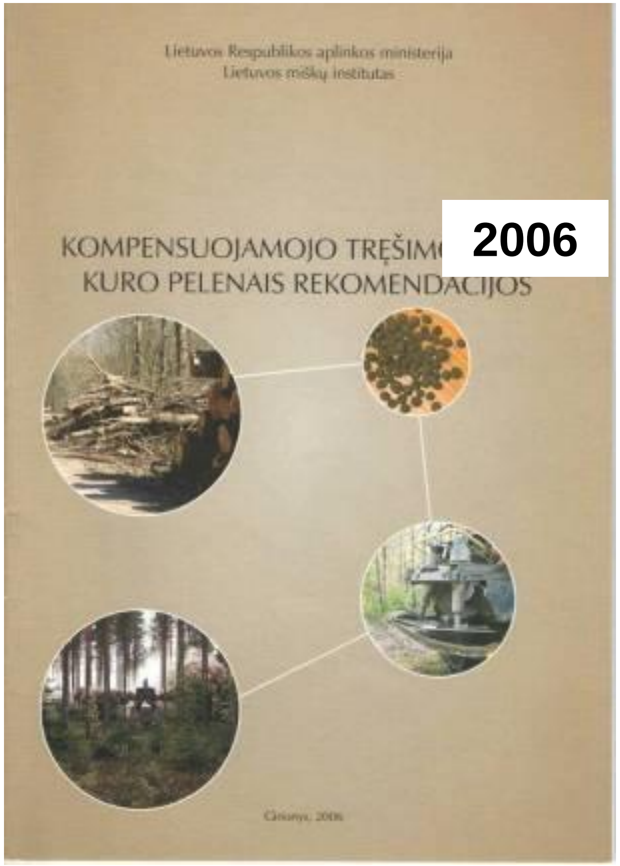

Ozolinčius R., Armolaitis K., Mikšys V., Varnagirytė-Kabašinskienė I. 2006; 2011. **Recommendations for compensating wood ash fertilization.** Kaunas-Girionys: Ministry of Environment of the Republic of Lithuania / Institute of Forestry of Lithuanian Research Centre for Agriculture and Forestry. – p. 17. [in Lithuanian with English summary].

- **Use of biomass fuels requires recycling of nutrients in sustainable forest management.**
- **Removal of nutrients could be by *forest fuel* or *wood* ash recycling.**

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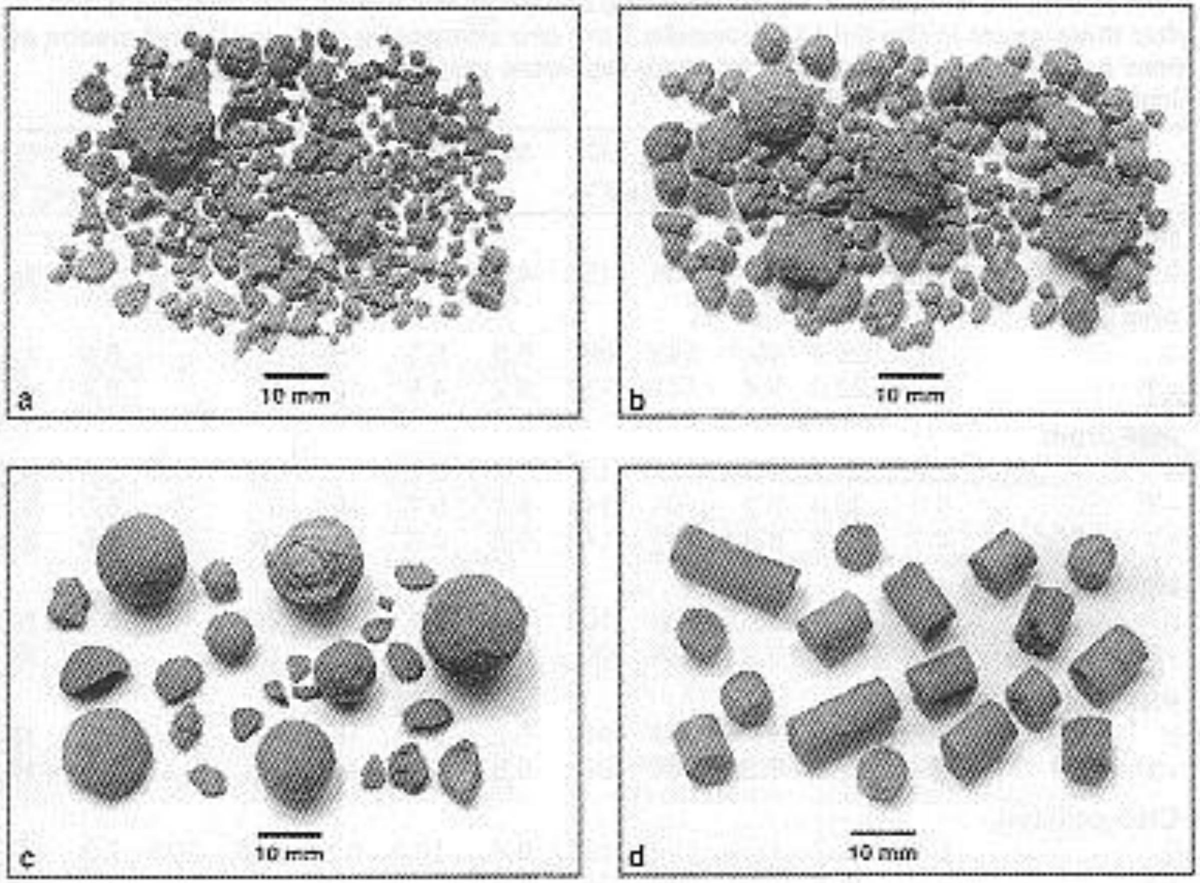
a
10 mm
b
10 mm
c
10 mm
d
10 mm

*For the compensation of the essential plant macronutrients in Scots pine stands, the content of macronutrients was calculated by **nutritional balance method**.*

Application rates of wood ash for the macronutrients compensation in Scots pine stand.

The wood ash was taken from Lithuanian burners.

Macroelements	Wood ash dose, t ha^{-1}	
P	3.3-6.9	~ 3-7 t
K	5.3-6.9	~ 5-7 t
Ca	0.9-1.0	~ 1 t
Mg	2.0-4.6	~ 2-5 t

For the compensation of each nutrient, different amount of wood ash should be applied.

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Doses of forest fuel ash and nitrogen for fertilization of Lithuanian commercial (IV group) forests

Forest site*	Forest fuel ash doses, t ha^{-1}**	N doses, kg ha^{-1}***
Nae, Na	1.5-2.0	70
Nb	2.5-3.0	90
Nc, Nd	3.0-3.5	120
P^na, P^nb	2.0-2.5	70
P^nc	2.5-3.0	90

* N – mineral soils of normal moisture; P^n – peat drained soils; ae – degraded (erosion. fires); a – very oligotrophic/very infertile; b – oligotrophic/infertile; c – mesoeutrophic/fertile, and d – eutrophic/very fertile soils (according to the Lithuanian forest site classification).

** Ash doses are spreaded twice: (1) in complex with thinnings when the net for the haul timber is established; (2) in middle-aged and premature stands together with N fertilizers. Wood ash fertilization is performed in clear cuts if there were no ash fertilization in the former stand.

*** No N fertilization in the clear-cuts.

For the forest fertilization, the most suitable is **stabilized ash**, which dissolve in 5–25 years.

Raw ash could be used in re-cultivated quarries or fresh clear-cuts before soil preparation for forest planting.

The application of ash should be performed **in two treatment operations per stand rotation**:

- first time - during the stand thinnings,
- second time - in the middle-aged stands.

In order to avoid negative stress effects on forest ecosystems, **onetime dosage of wood ash should not exceed 2–3.5 t ha^{-1}, applying it in growing stands.**

In clear-cuts, ash fertilizing with 2.5–3 t ash ha^{-1} could be carried out only in the cases when there were no any treatment operations in former stands.

The best time for fertilizing is **autumn** or early spring before an active vegetative period.

Some environmental restrictions

Compensating wood ash fertilizing could be carried out **only in the commercial forests in forest sites of normal moisture, first of all in the stands or clear cuts where all logging residues were removed**;

- Wood ash **could be applied in drained or self-drained peatland soils**;
- Wood ash fertilizing **is not recommended in 20%** of mentioned forest areas in order to **preserve biological diversity**;
- Wood ash **could not be applied in the places nearer than 50 meters to surface waters** (streams, melioration ditches, etc.) or waterlogged plots;
- Ash fertilizing **could not be carried out on snow cover** in winter because of leaching risk of chemical ash particles.

Recommended orientate contents of the nutrients (K, P, Ca and Mg,) and allowable maximum concentrations of trace metals and micronutrients (B, V, Cr, Cd, Pb, Cu, Zn, Hg and As), 137Cs, and polyaromatic hydrocarbons in dry wood ash (Skogsstyrelsen, 2002)

Elements	Limits (critical values)
Phosphorus (P), g kg^{-1}	10 (minimum)
Potassium (K), g kg^{-1}	30 (minimum)
Calcium (Ca), g kg^{-1}	125 (minimum)
Magnesium (Mg), g kg^{-1}	20 (minimum)
Boron (B), mg kg^{-1}	500 (maximum)
Vanadium (V), mg kg^{-1}	70 (maximum)
Chromium (Cr), mg kg^{-1}	100 (maximum)
Cadmium (Cd), mg kg^{-1}	30 (maximum)
Lead (Pb), mg kg^{-1}	300 (maximum)
Copper (Cu), mg kg^{-1}	400 (maximum)
Zinc (Zn), mg kg^{-1}	1000-7000 (minimum - maximum)
Mercury (Hg), mg kg^{-1}	3 (maximum)
Arsenic (As), mg kg^{-1}	30 (maximum)
^{137}Caezium (^{137}Cs), kBq kg^{-1}	5 (maximum)
Polyaromatic hydrocarbons (PAH), mg kg^{-1}	2 (maximum)

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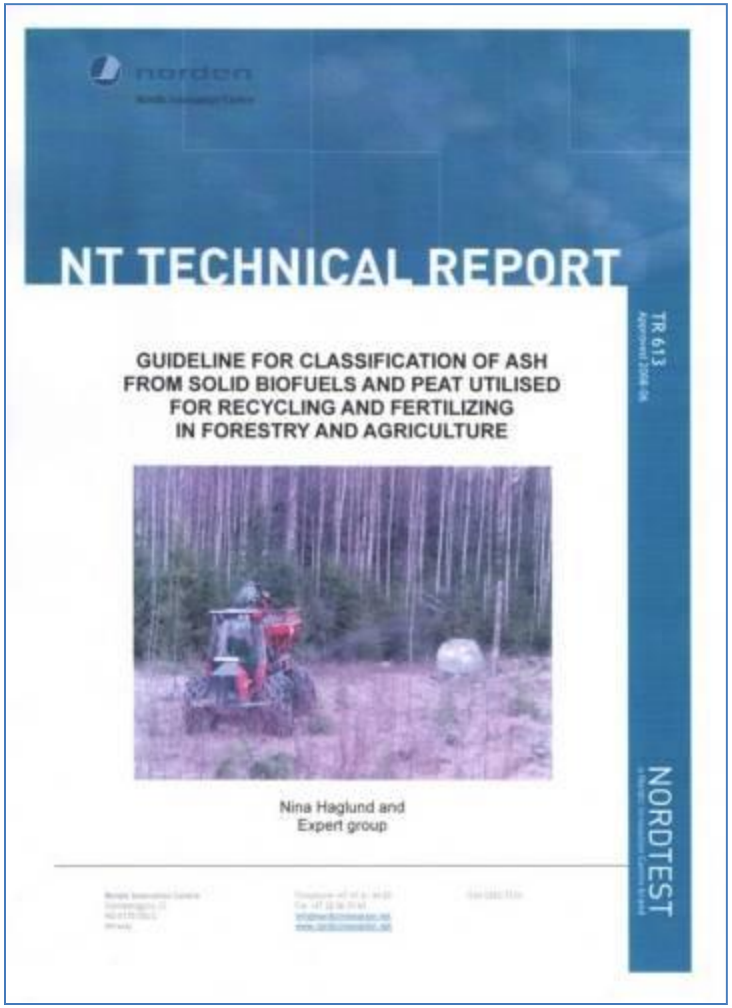
metals / minor elements



"Guidelines for classification of ash..." (Nordic Innovation Centre, 2008)

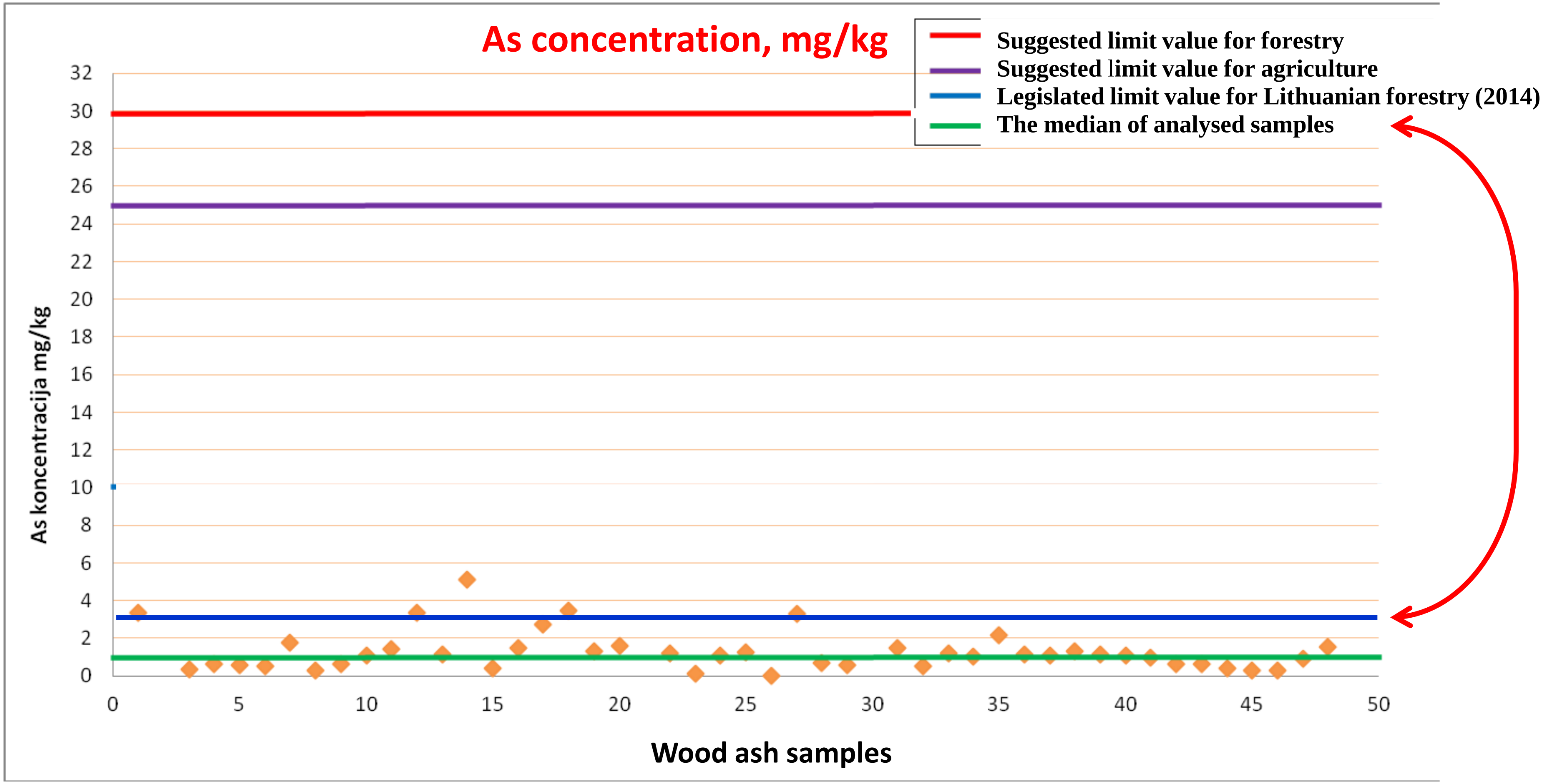
metals / minor elements

Limit values for minor elements (mg kg^{-1}) in wood ash

Values in the Nordic countries according to the "Guidelines for classification of ash...", p. 8. (Nordic Innovation Centre, 2008)

COUNTRY	DENMARK	FINLAND	FINLAND	SWEDEN	LITHUANIA, *maximal conc*	LITHUANIA
Status	Legislation, 2006	Legislation, 2007	Legislation, 2007	Recommendations draft, 2007	Agrochemical Research Lab (LRCAF)*	Regulations for wood ash disposal & use, 2014
Application	Agriculture / Forestry	Agriculture	Forestry	Forestry		Agriculture / Forestry
Arsen (As)	-	25	30	30	~4	3/3
Cadmium (Cd)	5/15	1.5	17.5	30	9-11	5/3
Chromium (Cr)	100	300	300	100	-	30/20
Copper (Cu)	-	600	700	400	200-250	200/100
Mercury (Hg)	0.8	1.0	1.0	3	< 0.5	0.2/0.2
Nickel (Ni)	30/60	100	150	70	30-35	30/20
Lead (Pb)	120	100	150	300	~ 60	50/40
Zinc (Zn)	-	1500	4500	7000	2500-3500	1500/1000

*** Obtained maximal values based on databases of the Agrochemical Research Laboratory of LRCAF**



The limit values of As and As concentrations in wood ash samples. – *The values obtained at the Agrochemical Research Laboratory, LRCAF (2013-2014)*

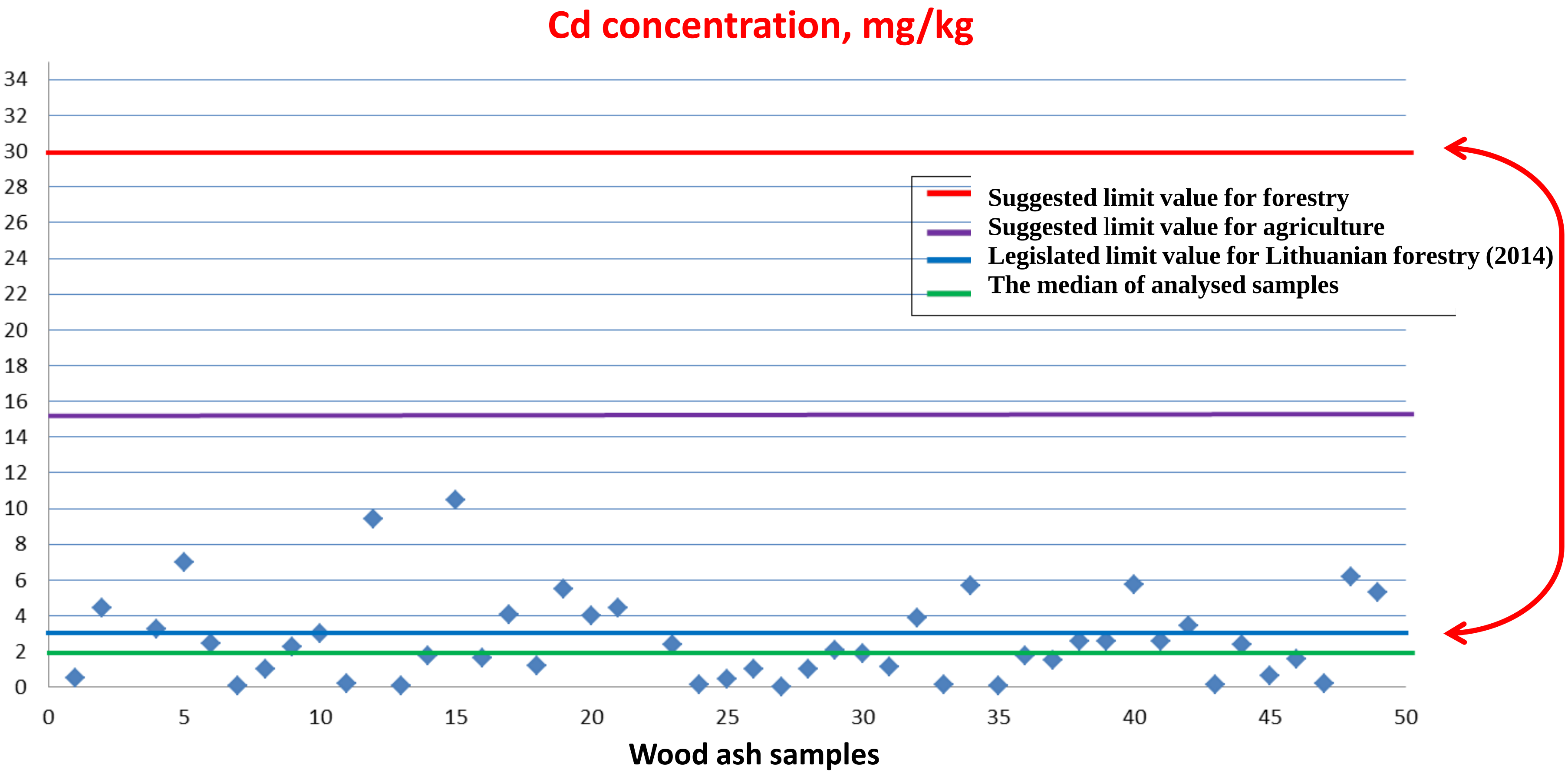


***Fig. 4*. The limit values of Cd and Cd concentrations in wood ash samples.**

The values obtained at the Agrochemical Research Laboratory, LRCAF (2013-2014)

Suggested limit value of Cd *(red line)* for forestry was by ~ 3 times higher than <u>maximal Cd concentrations</u> in wood ash (Lithuanian case)

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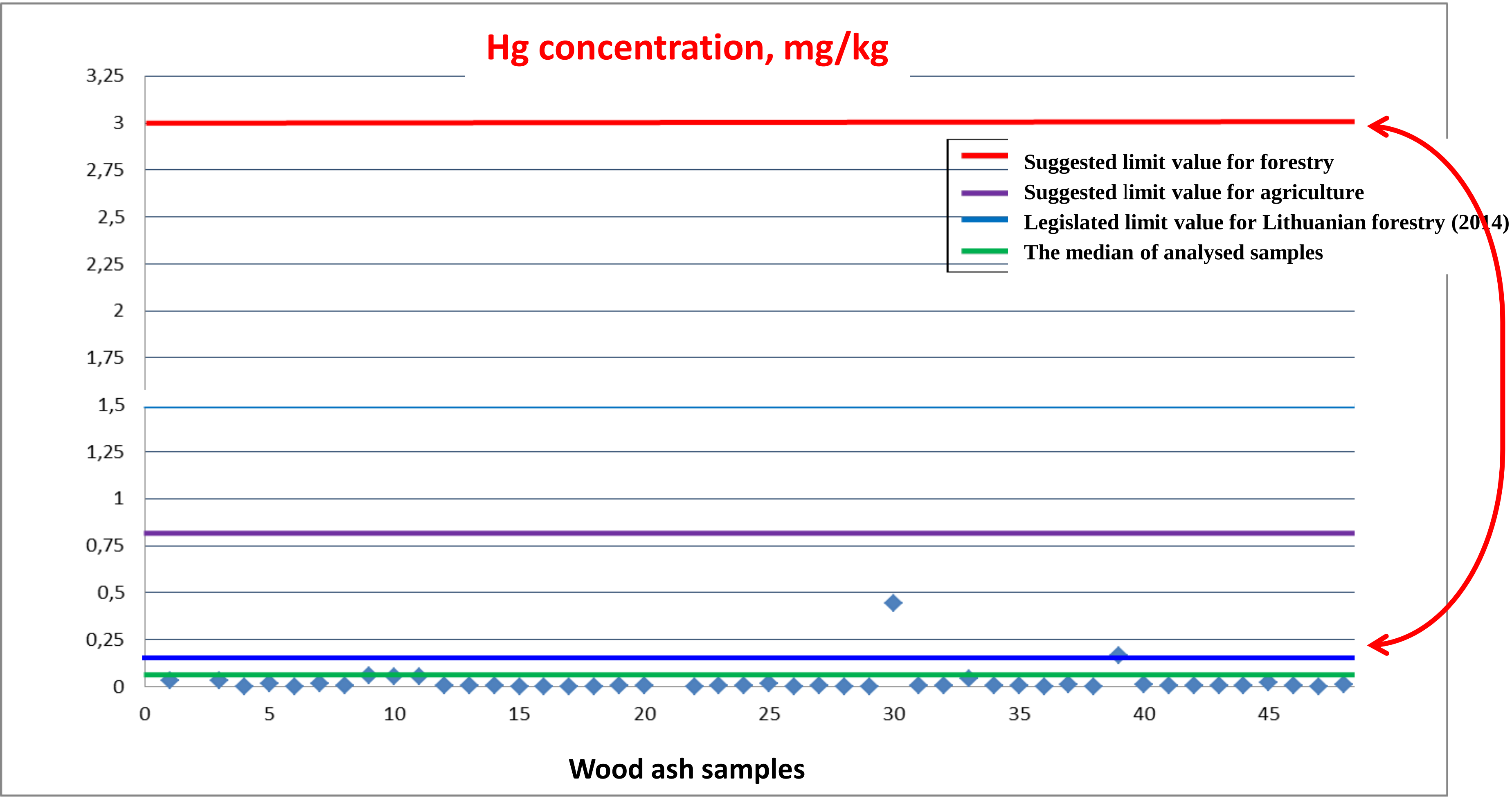
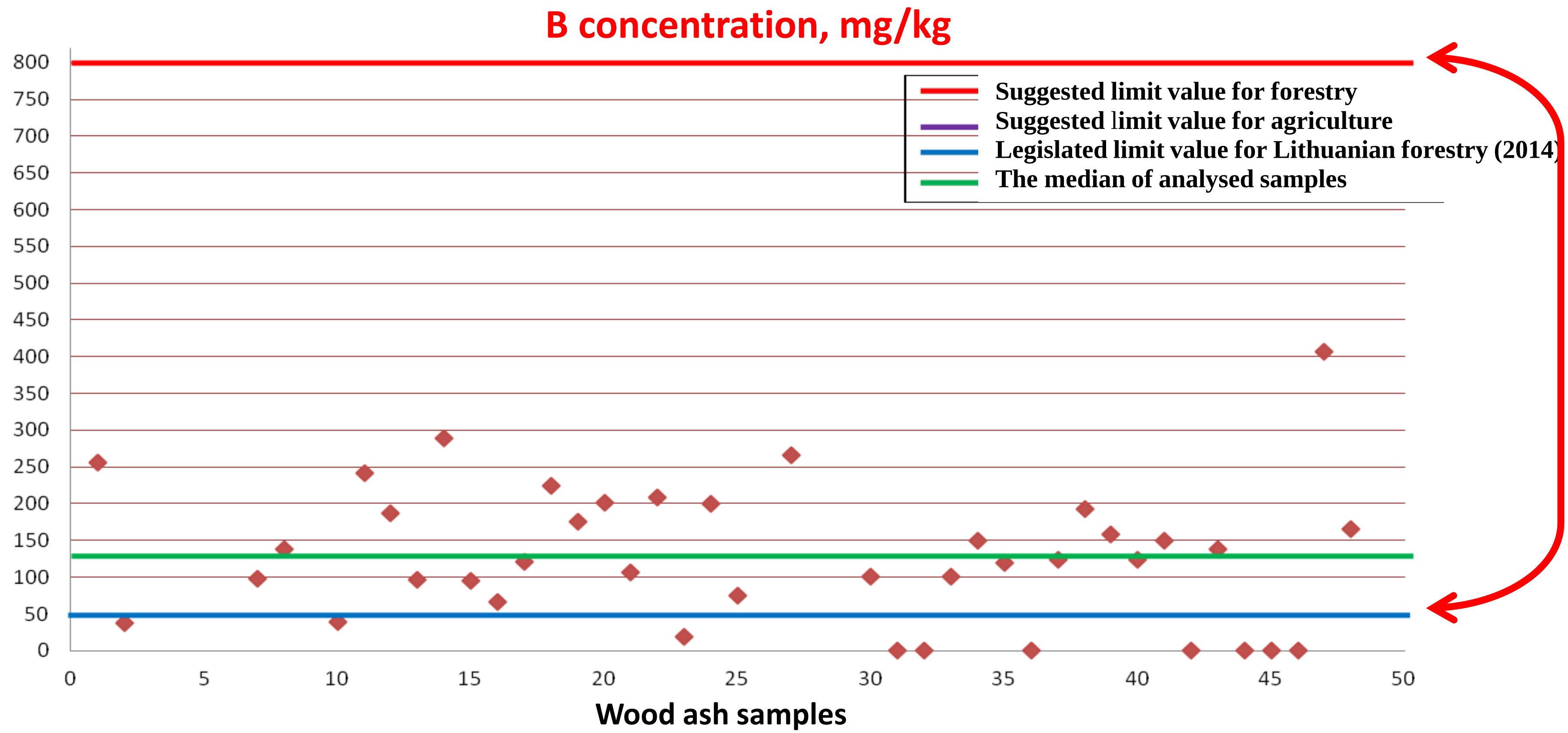


The limit values of Hg and Hg concentrations in wood ash samples. –
The values obtained at the Agrochemical Research Laboratory, LRCAF (2013-2014)



The limit values of B and B concentrations in wood ash samples. –
The values obtained at the Agrochemical Research Laboratory, LRCAF (2013-2014)

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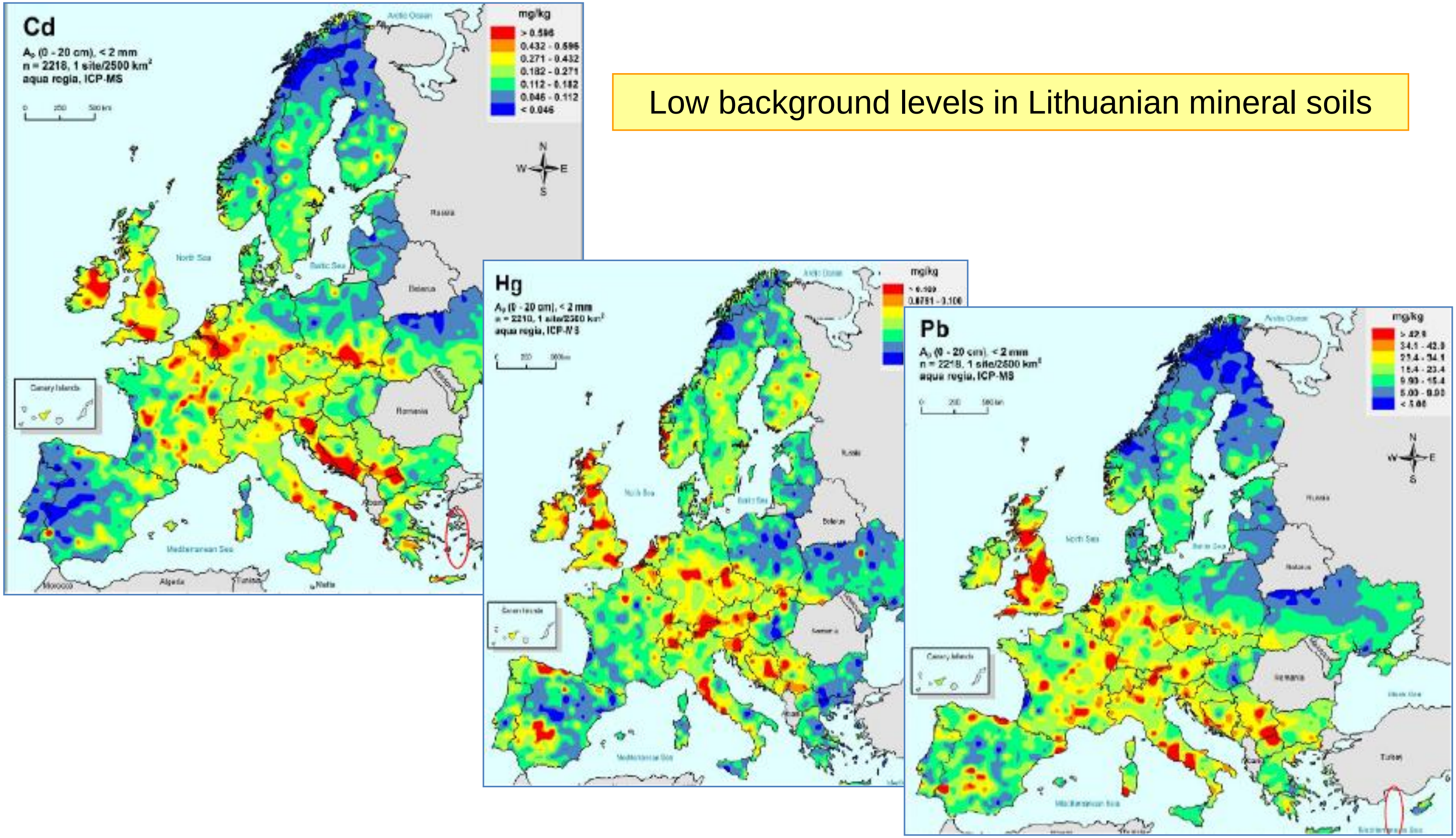
metals



Low background levels in Lithuanian mineral soils

Distribution of cadmium (Cd), mercury (Hg) and lead (Pb) in the agricultural soil (Ap horizon, 0-20 cm) in Europe (GEMAS, 2013)

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radioactive compounds – potential risk ?

Группа	Степень радиоэкологической напряженности территории	Диапазон баллов	Всего районов	В том числе по областям					
				Брестская	Витебская	Гомельская	Гроднейская	Минская	Могилевская
I	Низкая	1-4	29	4	1	3	5	10	6
II	Средняя	5-8	9	1	-	4	-	1	3
III	Высокая	9-12	12	1	-	6	-	-	5
IV	Очень высокая	13 и более	7	-	-	7	-	-	-
Всего			**57**	**6**	**1**	**20**	**5**	**11**	**14**

I группа ; II группа ; III группа ; IV группа

Рисунок 1. – Синтезированная картодиаграмма группировки районов по радиоэкологической напряженности

Distribution of $^{137}Cs + ^{90}Sr$ in Belorussian soils

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Tsybulko, N. 2016. Usage optimisation of the radionuclide-contaminated agricultural lands and agrochemical protection events in the remote period of the Chernobyl accident. ***PhD thesis***

III. Forest fertilization perspectives.

Wood/forest fuel ash fertilization, as well as an addition of dried sewage sludge should be applied mainly in former agricultural land afforested with forest plantations and, especially, with willow and short rotation woody plants energy plantations.

To produce wood ash fertilizers:

- **the granulated ash;**
- **the liquid fertilizer (wood ash in complex with weak nitric acid);**
- **the granulated ash in complex with the manure of avifauna…**

LITHUANIAN RESEARCH CENTRE FOR AGRICULTURE AND FORESTRY

Main publications

PhD thesis, defended in 2006

- **Varnagirytė-Kabašinskienė I. 2006. Initial effects of compensatory wood ash fertilization: nitrogen, phosphorus, potassium and heavy metals in soil and plants of Scots pine stands *(Pinetum vacciniosum* forest type). Prepared at Lithuanian Forest Research Institute jointly with Vytautas Magnus University; supervised by Prof. R.Ozolinčius.**

Scientific papers

- **Ozolincius R., Varnagiryte I., Armolaitis K., Karltun E. 2005. Initial effects of wood ash fertilization on soil, needle and litterfall chemistry in Scots pine stands. *Baltic Forestry* 11 (2), p. 59–67.**
- **Ozolinčius R., Varnagirytė I. 2005. Effects of wood ash application on heavy metal concentrations in soil, soil solution and vegetation in a Lithuanian Scots pine stand. *Metsanduslikud uurimused/Forestry Studies* 42, p. 66–73.**
- **Ozolinčius R., Armolaitis K., Raguotis A., Varnagirytė I., Zenkovaitė J. 2006. Influence of wood ash recycling on chemical and biological condition of forest arenosols. *Journal of Forest Science* 52 (*Special issue*), p. 79–86.**
- **Ozolinčius R., Varnagirytė-Kabašinskienė I., Armolaitis K., Gaitnieks T., et al. 2007. Initial influence of compensatory wood ash fertilization on soil, ground vegetation and tree foliage in Scots pine stands. *Baltic Forestry* 13(2), p. 158–168.**
- **Ozolinčius R., Buožytė R., Varnagirytė-Kabašinskienė I. 2007. Wood ash and nitrogen influence on ground vegetation cover and chemical composition. *Biomass&Bioenergy* 31, p. 710–716.**
- **Mikšys V., Varnagirytė-Kabašinskienė I., Møller I.S., Armolaitis K., Kukkola M., Wójcik J. 2007. Above-ground biomass functions for Scots pine in Lithuania. *Biomass&Bioenergy* 31, p. 685–692.**
- **Ozolinčius R., Varnagirytė-Kabašinskienė I., Stakėnas V., Mikšys V. 2007. Effects of wood ash and nitrogen fertilization on Scots pine crown biomass. *Biomass&Bioenergy* 31, p. 700-709.**
- **Ozolinčius R., Varnagirytė-Kabašinskienė I., Armolaitis K. 2010. Compensations of nutrients removed through extraction of forest fuel. In: Contraction for a Sustainable Environment (Sarsby & Meggyes (eds.)). London, Taylor & Francis Group, p. 493–500.**
- **Armolaitis K., Varnagirytė-Kabašinskienė I., Stupak I., Mikšys V., Kukkola M., Wójcik J. 2013. Carbon and nutrients of Scots pine stands on sandy soils in Lithuania in relation to bioenergy sustainability. *Biomass&Bioenergy* 54, p. 250–259.**
- **Varnagirytė-Kabašinskienė I., Armolaitis K., Stupak I., Kukkola M., Wójcik J., Mikšys V. 2014. Some metals in aboveground biomass of Scots pine stands in Lithuania. *Biomass&Bioenergy* 66, p. 434–441.**

Thank you for your attention!