ISSN 1392-3196
Žemdirbystė=Agriculture, vol. 97, No. 3 (2010), p. 117–130
UDK 631.415.1:631.4.528.9

Spatial distribution of pH data on the digital maps as affected by different soil sampling methods

Gediminas STAUGAITIS, Jonas MAŽVILA, Donatas ŠUMSKIS

Agrochemical Research Laboratory
of the Lithuanian Research Centre for Agriculture and Forestry
Savanorių 287, Kaunas, Lithuania
E-mail: agrolab@agrolab.lt

Abstract

The aim of the current research was to determine the optimal soil sampling method and density for soil pH tests. Three different methods were applied – soil samples were collected within the boundaries of: regular grid, soil group and texture corresponding to the levels 1 and 2 of FAO soil classification, soil group and texture as well as pH group determined by the soil tests conducted during the period of 1987–1993 (previous soil test). Each soil sampling method was applied at 2, 4 and 8 ha density. There were 9 variants in total, i.e. soil samples were collected from the same field 9 times. The research was conducted in four different sites – 47, 55, 73 and 155 ha fields differing in soil group, texture and pH. These fields (objects) were representative of the regions. pH value was determined in 1M KCl extraction.

Our research evidence suggests that the calculated field pH values expressed as an arithmetic mean, median and mode do not characterize the distribution of pH values in the field precisely enough irrespective of the soil sampling method and density. The best way to evaluate the field is to use the pH value scale dividing the values into several groups (≤4.5, 4.6–5.0, 5.1–5.5, 5.6–6.0, 6.1–6.5, >6.5) and to map the spatial distribution of acid (pH ≤5.5) areas. The most optimal way of soil sampling is at 2 and 4 ha density within the boundaries of prevailing soil group and texture with/without the consideration of the boundaries of pH groups determined during previous soil tests. Data digital mapping (M 1:10000), obtained using the aforementioned approach, results in the arrays of areas to be limed, while the soil sampling using the regular grid results in scattered plots of acid soils, which is not convenient from the practical point of view. It was found that soil sampling at 8 ha density decreases the area of acid soils (pH ≤5.5) in fields where not acid soils prevail or where some eroded areas are found.

Costs of soil sampling at 2 ha density are more than twice as high as those of soil sampling at 4 ha density. Based on this, we recommend the soil sampling at 4 ha density; the transect should be drawn within the boundaries of soil group and previously determined pH group.

Key words: soil, pH, soil sampling.

Introduction

Soil sampling has a major impact on the soil agrochemical properties' test results and consequently on the chosen rates of fertiliser and lime (Kalvaitienė et al., 1976; Franzen, Cihacek, 1998). Many important factors play a role: sampling depth, size of the plot from which the soil sample is taken, soil group and texture, relief, soil cultivation degree, number of sub-samples in the composite soil sample, soil sampling transect on the field etc. (ISO 10384-1, 2002; Paulauskas, Sabienė, 2009). It has been determined that depending on the selected soil sampling method the liming and fertiliser rates, calculated for the same field, may differ by ⅓ and more (Lietuvos dirvožemių..., 1998). The pH value is strongly affected by the liming conducted in previous years – quite often pH changes take place not only in the arable layer, but in the subsoil as well (Ožeraitienė et al., 2006). Lithuanian researchers recommend collecting one composite soil sample from 4–5 ha plot in flat relief areas and from 2–3 ha plot in rolling/hilly relief areas with varying soil group and texture (Dirvožemio..., 1975; Mažvila et al., 2008). Swedish researchers suggest collecting composite soil sample from 1 ha or less than 1 ha plot in areas with highly varying soil group and texture (Hansson et al., 2002). 1–3 ha plots are recommended for taking the composite soil sample in Denmark (Vejledning..., 2003). Up to 4 ha plots are recommended in the majority of other countries, including Finland, Poland and Germany; here the results of previous soil tests are used for setting the size of plot (PN-R-04031, 1997; Markkarterings-provtagning, 2009).

First scientific research activities that addressed the soil sampling issue and developed the soil sampling methods took place in the majority of European countries in the middle of the 20th century. Research into this field and elaboration of methods have been continued till the present day. First Swedish soil maps indicating the content of plant nutrients in soil were drawn in 1920, and pH – in 1923. Since 1950 the 'spot' soil sampling method was applied: 2–4 spots were selected on 1 ha plot and soil samples were taken on the site within the circle of 3 m diameter. During that period pH and nutrient content evaluation scales were developed; red, orange, yellow, green and blue colours were used for mapping the values of pH and plant nutrients. This method was replaced by the grid method, and since 1984 the composite soil samples have been collected using transects. The 0–20 cm sampling depth was replaced by 0–25 cm. Since 1995 the location of sampling spot has been recorded using GPS and since 1997 soil test results have been displayed on interpolated maps (Linden, 2007; Wetterlind, 2009).

Composite soil sample could be collected from 8, 10 and even 20 ha plots under certain conditions: fields should be large; intensive growing techniques and large machinery should be used; not acid *Cambisols* and *Calcic Luvisols* should prevail. Agricultural producers and legislators prefer the low density soil sampling, but in Lithuania this approach has not been supported by scientific research evidence. Low density soil sampling method is used in steppe zones of Russia and Ukraine where fields are large and *Chernozems* prevail (ГОСТ 28168, 1989).

The relief and diversity of soils in the south-eastern part of the Baltic Sea basin was formed during the Ice Age. Due to the high degree of soil variation it is necessary to collect the soil samples within soil group boundaries. Soil sampling method accepted in Lithuania in 1975 stipulates that separate soil samples should be collected from carbonaceous and not carbonaceous (not carbonate saturated) soils as well as from eroded and not eroded plots. If the variation of eroded zones or soil pH is so high that it is not possible to form reasonably large separate plots, the complexes should be made and the share (%) of each complex should be indicated (Dirvožemio..., 1975). At present, the acid soil areas determined during previous soil tests are drawn on the map beforehand (Mažvila et al., 2008) and displayed on the GPS screen – this information is very important for drawing the soil sampling transect. Scale digital map (1:10000) of Lithuanian soils (data base Dirv_DB10LT) will be complete soon; this will allow transferring of the boundaries of soil group and texture from the digital map into the soil sampling plan (Grybauskas, 1998).

The developing technologies of soil sampling and data mapping open more possibilities for use of the new soil data base, the results of previous soil tests as well as the use of GPS for drawing the soil sampling transects (Buivydaitė, 1996; 2001). The aim of this research was to test these innovations on fields with different soil variation degree and to determine the optimal soil sampling method and density. Regular grid soil sampling method, soil map and the data obtained during previous soil tests were used for evaluation of variation and spatial distribution of pH data.

Research methods

Experimental design is presented in Table 1.

The field was divided into 2, 4 or 8 ha regular tetragon plots accordingly in variants 1, 2 and 3. The composite soil sample was collected using diagonal transect. Soil group and texture were not taken into consideration during the soil sampling.

Soil samples were collected within the boundaries of prevailing soil group and texture in variants 4, 5 and 6. Number of samples per tested object depended on the variant and was determined by dividing the object area into 2, 4 or 8 ha plots; error for the calculated number of samples was 1–2 samples per object. Digital map of Lithuanian data base Dirv_DB10LT contains information on boundaries of different soil group and texture corresponding to the levels 1 and 2 of FAO classification. These soil boundaries were transferred on 1:10000 scale maps before the soil sampling (Figures 1–4). Diagonal transect of soil sampling was used.

As for variants 7, 8 and 9, soil samples were collected within the boundaries of prevailing soil group and texture just like in variants 4, 5 and 6, but here the results of previous soil tests (in this case – soil pH) were considered as well. Two Lithuanian data bases were used: Dirv_DB10LT and DirvAgroch_DB10LT. Diagonal soil sampling transects were drawn in a way ensuring the collecting of soil samples within the boundaries of particular pH group determined by the previous soil tests.

An exception was made for the object 4 – the hilly relief of this object caused a high soil group and pH variation level even in short distance. Soil samples in variants 4, 5, 6, 7, 8 and 9 in this object were collected from 10 × 10 m plots instead of transect method.

Table 1. Research scheme

Variant No.	Soil sampling density ha	Soil sampling method
1.	2	Regular grid (method 1)
2.	4	
3.	8	
4.	2	Soil sampling within the boundaries of prevailing soil group and texture (method 2)
5.	4	
6.	8	
7.	2	Soil sampling soil sampling within the boundaries of prevailing soil group and texture and in consideration of previous soil test results (method 3)
8.	4	
9.	8	

Data on the planned soil sampling transects boundaries of soil group and textures, agrochemical properties of soil were prepared and compiled in a computer before the field activities. Then the data was transferred into a GPS device *Mobile Mapper 6.52* used for precision marking of soil sampling position (LKS-94) and ensuring the correctness of actual soil sampling transect.

One composite soil sample was made of 25 sub-samples taken from 0–20 cm soil layer. The composite soil sample was collected from approximately 100 m long transect. The collected sample was thoroughly mixed and sample of 300 g was taken for the tests in laboratory. Soil pH was determined in 1M KCl extraction – 50 ml of 1M KCl solution was added to 20 g of soil and stirred for 1 hour.

pH evaluation scale developed in Lithuania is composed of the following groups: very acid soils – pH ≤4.5, acid – 4.6–5.0, slightly acid – 5.1–5.5, close to neutral – 5.6–6.0, very close to neutral – 6.1–6.5, neutral – >6.5. Soils with pH ≤5.5 are denominated as 'conditionally acid'; these soils should be limed. Areas with pH 5.6–6.0 intervening the conditionally acid areas should be limed too, but the liming rate should be not higher than the one calculated for pH 5.5 (Dirvožemio..., 1975). Object 4 contained areas of varying eroded and not eroded soils not separated by the boundaries. Often the eroded soils are not acid; therefore the spatial pH distribution was mapped using the black and white coloured complexes of acid and not acid areas expressed in percent.

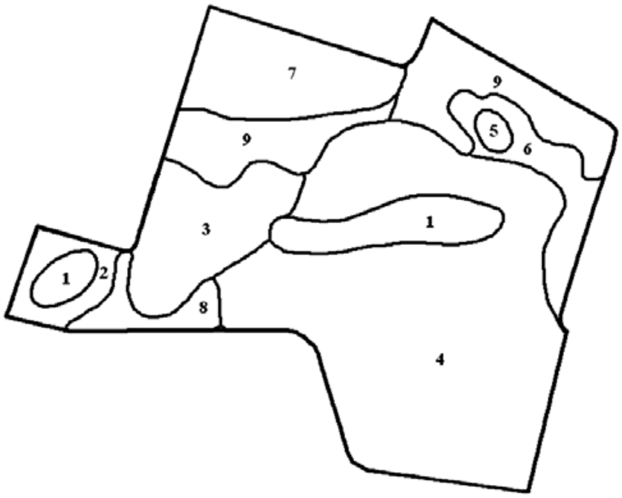
The research was conducted in Lithuania. Four representative objects were selected in different regions with the aim of representing flat and rolling reliefs where the whole area would be not acid, 1/3 of area would be acid and more than ½ of the area would be acid.

Object 1: Eglesiai. 46.7 ha object is located in Akmenė district, Eglesiai cadastral area. Relief is typical for the plain Lowland of Central Lithuania. *Gleyic Cambisols* prevail with intervening *Eutric Gleysols* and *Gleyic* and *Haplic Arenosols*. Prevailing soil texture in Ap horizon is sandy loam, some places – loam, and in subsoil – sand, sandy loam. Soil samples were collected on 26 07 2004, perennial grasses had been ploughed in recently; the field was under preparation for sowing of winter wheat.

Object 2: Elmininkai. 154.6 ha object is located in Anykščiai district, Elmininkai cadastral area. Relief is typical for the rolling plateau of Western Aukštaitija. *Gleyic* and *Calc(ar)ic Luvisols* prevail with some slightly eroded areas and intervening *Eutric Gleysols*. Prevailing soil texture in the arable horizon is sandy loam and silt loam, in the subsoil – sandy clay loam, sandy loam and clay. Soil samples were collected on 14 10 2004; the area was occupied with winter wheat.

Object 3: Daumantiškiai. 55.4 ha object is located in Ukmergė district, Daumantiškiai cadastral area. Relief is typical for the rolling plateau of Western Auk taitija. *Eutric Gleysols* and *Gleyic Luvisols* prevail. Silt loam and sandy loam prevail in the Ap horizon, and in the subsoil – clay and sandy clay loam. Soil samples were collected on 23 06 2004; the area was occupied with perennial grasses of the second year.

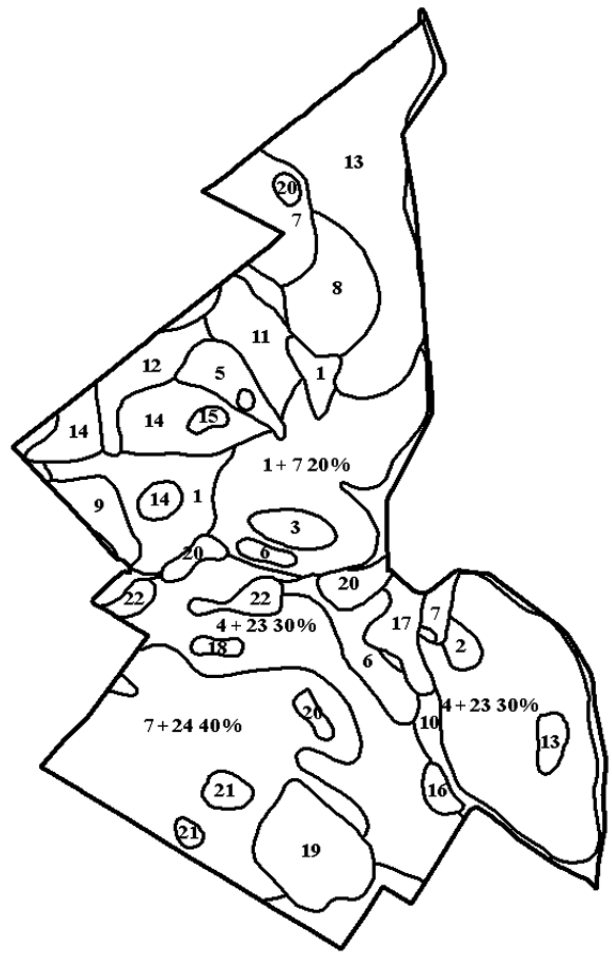
Object 4: Dapkūniškiai. 73.4 ha object is located in Molėtai district, Dapkūniškiai cadastral area. Relief is typical for the hilly Baltic uplands. *Eutric* and *Dystric Albeluvisols* prevail with intervening *slightly and moderately eroded Eutric Albeluvisols*. Soil texture in the arable layer is sandy loam with sandy clay loam, in the subsoil – loam, sandy loam and silt loam. Soil samples were collected on 12 10 2007; the area was occupied with perennial grasses of the first year.



1 – *Gleyic Arenosol*, SL/S / *ps*/*s*
2 – *Eutri-Epihypogleyic Arenosol*, SL/S / *ps*/*s*
3 – *Haplic Arenosol*, SL/S / *ps*/*s*
4 – *Calcaric Cambisol*, SL/SL / *sp*/*sp*
5 – *Gleyic Cambisol*, SL/SL / *sp*/*sp*
6 – *Gleyic Cambisol*, SL/SiL/S / *ps*/*dp*/*s*
7 – *Gleyic Cambisol*, SL + L/L/SL / $sp + p_1/p_1/ps$
8 – *Eutric Gleysol*, SL/S / *ps*/*s*
9 – *Calc(ar)ic Gleysol*, SL/S / *ps*/*s*

Note. Explanation of abbreviations: S – sand, LS – loamy sand, SL – sandy loam, SCL – sandy clay loam, L – loam, CL – clay loam, SiL – silt loam, Si – silt, SiCL – silty clay loam, SC – sandy clay, SiC – silty clay, C – clay.

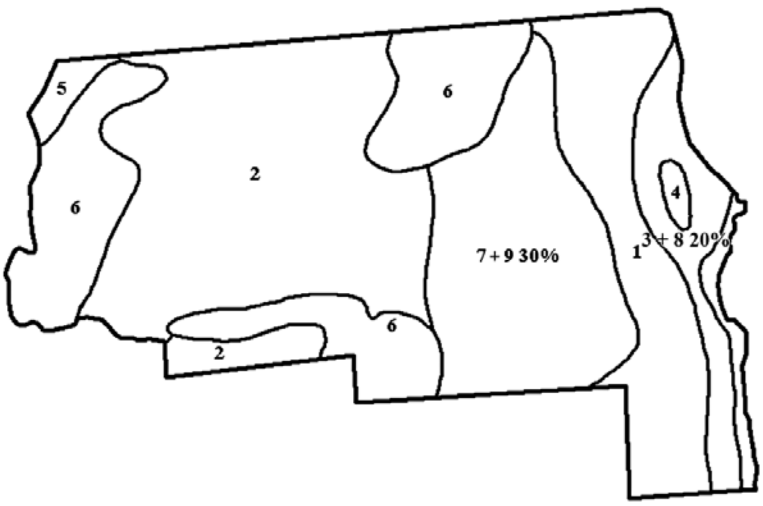
Figure 1. Boundaries of soil typological units and texture in object 1 (Eglesiai) according to the data base Dirv_DB10LT



1 – *Eutric Albeluvisol*, SL/C / *sp*/*m*
2 – *Haplic Arenosol*, SL/S / *ps*/*s*
3 – *Eutric Gleysol*, SiL/SL / *dp*/*sp*
4 – *Eutric Gleysol*, SL/SL / *sp*/*sp*
5 – *Eutric Gleysol*, SiL/SiL / *dp*/*dp*
6 – *Eutric Gleysol*, SL/SCL / sp/sp_2
7 – *Eutric Gleysol*, SL/S / *ps*/*s*
8 – *Mollic Gleysol*, SiL/SiL / *dp*/*dp*
9 – *Terric Histosol*
10 – *Gleyic Luvisol*, SL/C / *sp*/*m*
11 – *Gleyic Luvisol*, SL/SL / *sp*/*sp*
12 – *Gleyic Luvisol*, SL/SCL / sp/sp_2
12 + 23 40% – *Gleyic Luvisol*, SL/SCL / sp/sp_2 + *Gleyic Cambisol*, SL/SCL / sp/sp_2 40%
13 – *Gleyic Luvisol*, SL/SCL/SL / $sp/sp_2/sp$
14 – *Gleyic Luvisol*, SiL/C / *dp*/*m*
15 – *Gleyic Luvisol*, SiL/SiL / *dp*/*dp*
16 – *Gleyic Luvisol*, SiL/C / dp_1/m
17 – *Haplic Luvisol*, SL/SCL / sp/sp_2
18 + 24 30% – *Calc(ar)ic Luvisol*, SL/SCL / sp/sp_2 + *Calc(ar)ic Luvisol (slightly eroded)*, L/SCL / p_1/sp_2 30%
19 – *Calc(ar)ic Luvisol*, SL/SCL / sp/sp_2
19 + 12 20% – *Calc(ar)ic Luvisol*, SL/SCL / sp/sp_2 + *Gleyic Luvisol*, SL/SCL / sps/sp_2 20%
20 – *Calc(ar)ic Luvisol*, L/L / p_1/p_1
21 – *Calc(ar)ic Luvisol*, L/SL / p_1/sp
22 – *Eutric Planosol*, SL/S/SL / *ps*/*s*/*sp*

Note. Explanation of abbreviations under Figure 1.

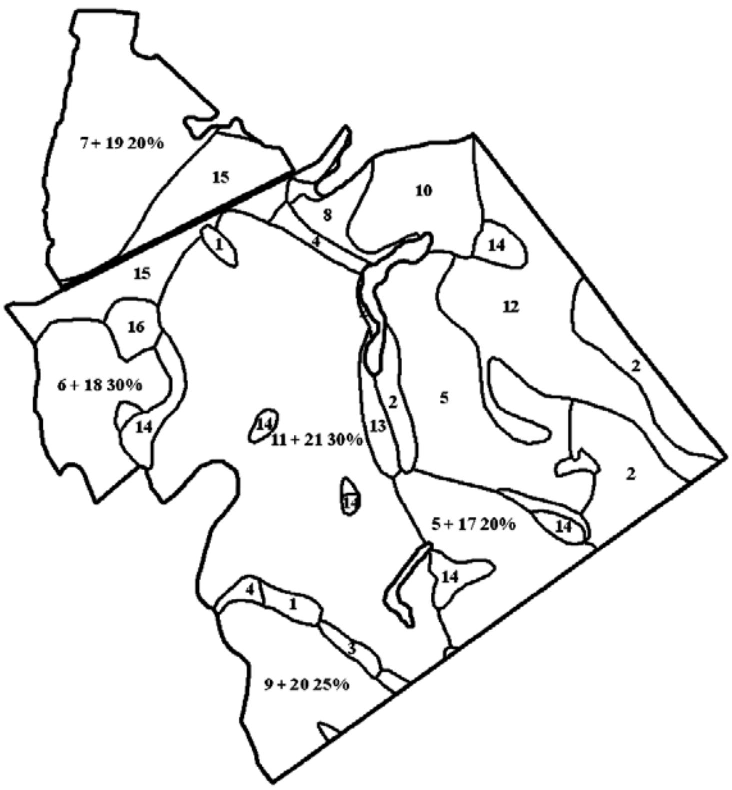
Figure 2. Boundaries of soil typological units and texture in object 2 (Elmininkai) according to the data base Dirv_DB10LT



1 – *Eutric Gleysol*, SiL/SCL / *dp*/sp_2
2 – *Eutric Gleysol*, SiL/C / *dp*/*m*
3 + 8 30% – *Eutric Gleysol*, SL/SL / *sp*/*sp* + *Gleyic Luvisol*, SL/SL / *sp*/*sp* 30%
4 – *Eutric Gleysol*, SCL/SCL / sp_2/sp_2
5 – *Gleyic Luvisol*, L/C / p_1/*m*
6 – *Gleyic Luvisol*, SiL/C / *dp*/*m*
7 + 9 20% – *Haplic Luvisol*, L/C / p_1/*m* + *Calc(ar)ic Luvisol (moderately eroded)*, L/C / p_1/*m* 20%

Note. Explanation of abbreviations under Figure 1.

Figure 3. Boundaries of soil typological units and texture in object 3 (Daumanti kiai) according to the data base Dirv_DB10LT



1 + 17 30% – *Dystric Albeluvisol*, SL/L / *ps*/p_1 + *Eutric Albeluvisol* (*slightly eroded*), SL/SL / *sp*/*sp* 30%
2 – *Dystric Albeluvisol*, SL/SL / *sp*/*sp*
3 – *Eutric Albeluvisol*, SL/SL / *sp*/*sp*
3 + 18 20% – *Eutric Albeluvisol*, SL/SL / *sp*/*sp* + *Eutric Albeluvisol (slightly eroded)*, SL/SL / *sp*/*sp* 20%
4 + 19 20% – *Eutric Albeluvisol*, SCL/L / sp_2/p_1 + *Eutric Albeluvisol (slightly eroded)*, SCL/L / sp_2/p_1 20%
5 + 20 30% – *Eutric Albeluvisol*, SL/L / *ps*/p_1 + *Eutric Albeluvisol (slightly eroded)*, L/CL / p_1/p_2 30%
6 – *Eutric Albeluvisol (moderately eroded)*, SCL/SCL / sp_2/sp_2
7 + 21 25% – *Eutric Albeluvisol (moderately eroded)*, L/L / p_1/p_1 + *Calc(ar)ic Luvisol (slightly eroded)*, SCL/SCL / sp_2/sp_2 25%
8 – *Gleyic Albeluvisol*, L/CL / p_1/p_2
9 – *Eutric Fluvisol*, SL + SCL/SL + SCL / *ps* + sp_2/*ps* + sp_2
10 – *Eutric Fluvisol*, SiL/SiL / *dp*/dp_1
11 – *Eutric Gleysol*, SiL/SiL / *dp*/*dp*
12 – *Bathiterric Histosol*
13 – *Gleyic Luvisol*, SCL/SiL / sp_2/dp_1
14 – *Gleyic Luvisol*, SiL/SiL / *dp*/*dp*
15 – *Calc(ar)ic Luvisol*, L/L / p_1/p_1
16 – *Eutric Regosol*, SCL/L / sp_2/p_1

Note. Explanation of abbreviations under Figure 1.

Figure 4. Boundaries of soil typological units and texture in object 4 (Dapkūniškiai) according to the data base Dirv_DB10LT

Previous soil test results indicate different acidity of soils in the selected objects (Table 2). Neutral soils prevail in object 1; soils of various acidity dominate in other tested objects. More than half of soils in object 3 were conditionally acid.

Table 2. Area distribution according to pH (%) in selected objects based on the results of previous soil tests

Object	Year of test	pH_{KCl}						Acid area ≤5.5	
		≤4.5	4.6–5.0	5.1–5.5	5.6–6.0	6.1–6.5	>6.5	%	ha
1.	1987	–	–	–	10.1	6.3	83.6	–	–
2.	1993	–	4.8	15.2	21.3	18.8	39.9	20.0	30.9
3.	1992	–	19.6	32.8	27.9	19.7	–	52.4	29.0
4.	1991	7.0	4.6	16.6	23.8	39.0	9.0	28.2	20.7

The following statistical indices were used for the general evaluation of soil pH in selected objects: arithmetic mean ($\bar{x}$), standard deviation (s), coefficient of variation (V), mode (*Mode*), median (M_e), standard error of the mean ($s_{\bar{x}}$). *ArcGIS 9* programme was used for drawing the digital maps.

The actual soil sampling density was calculated after the soil sampling; it was close to the planned density. On the average for all objects, the actual result for the planned 2 ha soil sampling density was 1.97 ± 0.05 ha, for 4 ha – 3.89 ± 0.25 ha and for 8 ha – 7.44 ± 0.40 ha.

Results and discussion

At first we assessed the effect of soil sampling density and method on the average, minimal and maximal values of pH and on variation of pH (Table 3).

Differences between the pH arithmetic means and medians in the variants of object 1, dominated by the neutral soils, was 0.6 and 0.5 pH units, respectively. Higher pH values were obtained in the variants where soil samples were collected using regular grid at 8 ha density. This is reflected by arithmetic means, medians and especially in minimal values. Application of 8 ha soil sampling density resulted also in smaller differences between the minimal and maximal values, therefore the values of square deviations and variations in these variants were lower. Thus the application of regular grid and low sampling density in neutral soils increased the obtained pH values.

According to the arithmetic means and medians of pH values in object 2, close to neutral pH values prevailed on the field. Minimal and maximal pH values varied strongly, from 4.4 to 7.2. pH differences between the variants (arithmetic mean, mode and mean were compared) were not significant. The same trends were noticed in object 3, where slightly acid soils prevailed; pH variation span was approximately the same.

Soils with a pH reaction close to neutral prevailed in object 4, hilly relief with a few eroded areas. Minimal and maximal pH values – 4.6 and 7.1. The effect of soil sampling density and methods on mean values and variation of pH was similar to that observed in objects 2 and 3.

Thus the pH mean values determined in slightly acid and close to neutral fields of 47–115 ha in area and expressed as arithmetic means, medians or modes were not tangibly affected by the sampling density and method. Characterisation of the trends in pH changes by these indicators was not precise enough.

The second phase of our research comprised investigation of the impact of soil sampling density and method on distribution of pH groups in the objects (Figure 5).

Object 1 is dominated by the not acid soils; 2 and 4 ha soil sampling density, applied in this object, brought out more of small acid plots than 8 ha sampling density. The following shares of pH ≤6.0 areas were detected using methods 1, 2 and 3: 2 ha sampling density – 2.7%, 10.1% and 10% respectively; 4 ha sampling density – 11.1% , 10.1% and 10.0% respectively; 8 ha sampling density – no pH ≤6.0 areas were detected, the lowest determined pH value was 6.5. It should be noted that there were no significant differences in distribution of areas of pH groups in this object – both at 2 ha and at 4 ha sampling density.

Table 3. Soil pH values and variation as affected by the different soil sampling methods and density

Variant	n	$\bar{x}$	s	V	*Mode*	M_e	Min/max	$s_{\bar{x}}$
Object 1: Eglesiai								
1.	23	7.24	0.41	5.66	7.1	7.3	6.0/7.8	0.09
2.	11	7.31	0.52	7.11	7.5	7.5	5.8/7.6	0.16
3.	6	7.53	0.05	0.66	7.5	7.5	7.5/7.6	0.02
4.	23	7.02	0.55	7.83	7.1	7.1	5.3/7.6	0.11
5.	11	6.91	0.48	6.95	7.0	7.0	5.5/7.2	0.15
6.	6	7.05	0.10	1.42	7.0	7.1	6.9/7.2	0.04
7.	23	7.06	0.48	6.80	7.2	7.2	5.4/7.6	0.10
8.	11	7.07	0.44	6.22	7.2	7.2	5.8/7.4	0.13
9.	6	7.13	0.22	3.09	7.2	7.2	6.7/7.3	0.09
Object 2: Elmininkai								
1.	80	5.89	0.47	7.98	6.1	6.0	4.5/6.9	0.05
2.	41	6.13	0.40	6.53	6.4	6.2	5.0/7.0	0.06
3.	20	5.87	0.42	7.16	5.5	6.0	5.2/6.6	0.09
4.	80	5.93	0.56	9.44	6.1	6.1	4.5/7.2	0.06
5.	41	5.81	0.60	10.33	5.4	5.7	4.6/7.2	0.09
6.	20	5.75	0.38	6.61	5.8	5.8	4.9/6.5	0.09
7.	80	5.78	0.53	9.17	5.9	5.9	4.4/6.9	0.06
8.	41	5.94	0.49	8.25	6.0	6.0	4.4/6.5	0.08
9.	20	5.65	0.49	8.67	6.1	5.8	4.7/6.3	0.11
Object 3: Daumantiškiai								
1.	28	5.57	0.52	9.34	5.3	5.5	4.8/7.1	0.10
2.	15	5.55	0.57	10.27	5.3	5.4	5.0/7.3	0.15
3.	8	5.60	0.52	9.28	-	5.6	4.9/6.5	0.18
4.	28	5.30	0.37	6.98	5.3	5.3	4.5/6.4	0.07
5.	15	5.23	0.43	8.22	4.7	5.3	4.4/5.9	0.11
6.	8	5.45	0.24	4.40	-	5.5	5.1/5.8	0.09
7.	28	5.33	0.49	9.19	5.0	5.2	4.7/6.9	0.09
8.	15	5.42	0.49	9.04	5.1	5.4	4.9/6.9	0.13
9.	8	5.38	0.42	7.81	5.2	5.3	4.9/6.3	0.15
Object 4: Dapkūniškiai								
1.	38	5.93	0.58	9.78	5.6	5.8	4.6/7.1	0.09
2.	19	6.08	0.49	8.06	6.1	6.1	5.1/7.1	0.11
3.	10	5.89	0.47	7.98	5.6	5.8	5.1/6.6	0.15
4.	38	6.03	0.62	10.28	6.1	6.1	4.8/7.1	0.10
5.	19	6.07	0.53	8.73	5.3	6.0	5.3/7.1	0.12
6.	10	5.92	0.42	7.09	5.7	6.0	5.0/6.5	0.13
7.	38	6.07	0.75	12.36	6.3	6.0	4.6/7.4	0.12
8.	19	5.96	0.65	10.91	6.6	5.9	4.7/7.0	0.15
9.	10	5.85	0.59	10.09	5.7	5.8	5.0/6.9	0.19

One fourth of the tested object 2 area was acid (pH ≤5.5). Application of the regular grid method in this object resulted in more significant variations of acid areas determined using different soil sampling densities. 10.2–35.8% (depending on soil sampling density) of the total area was determined as pH ≤5.5 using method 1, 21.9–36.5% – using method 2, 27.6–28.5% – using method 3. Thus application of method 3 (sampling within the soil group and texture boundaries in consideration of the data on pH obtained during the previous soil tests) resulted in about the same size of determined acid area irrespective of the sampling density applied.

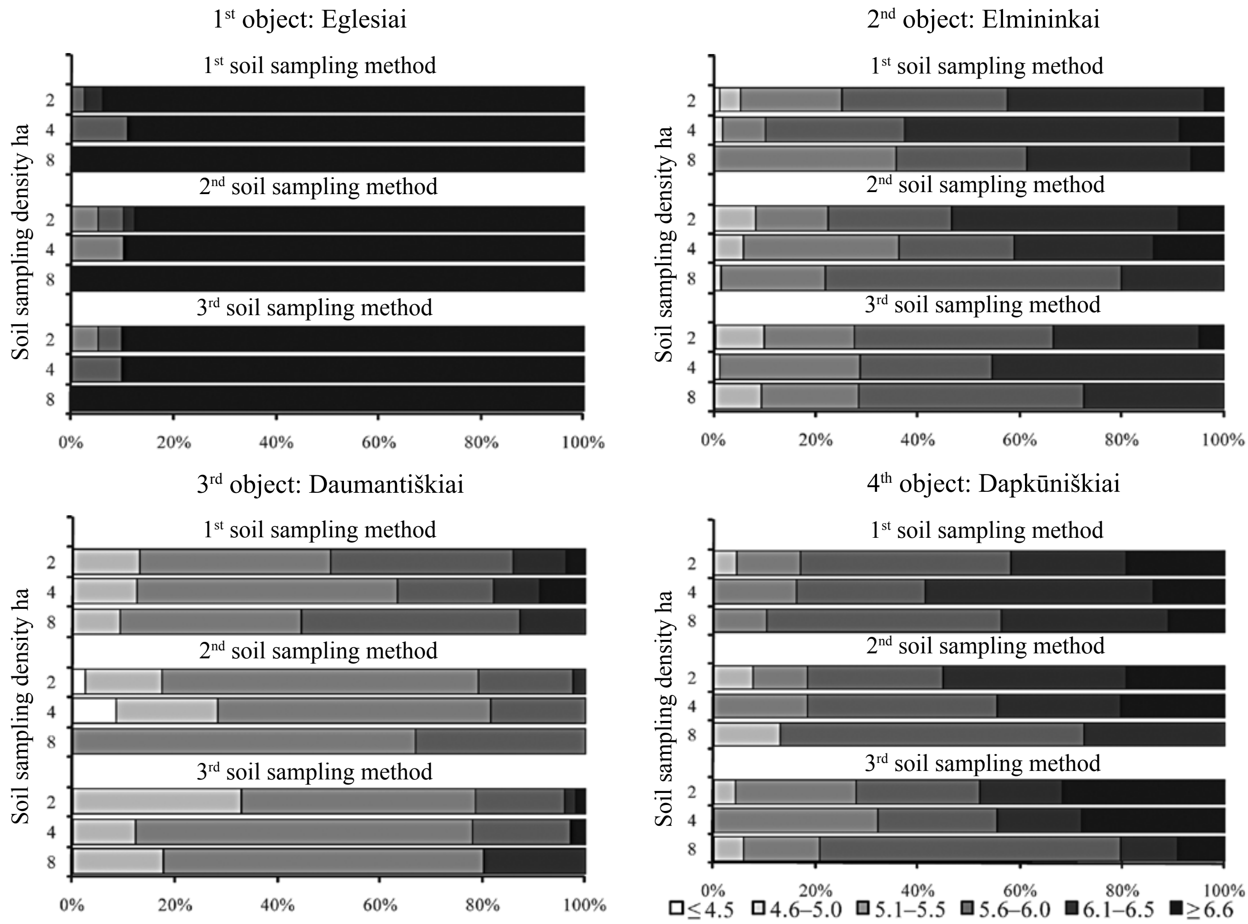


Figure 5. Distribution of areas of soil pH groups (%) as affected by different soil sampling methods and densities

One third of the tested object 3 area was acid. Soil sampling using regular grid (method 1) revealed smaller area of acid soils than methods 2 and 3: according to the results obtained using method 1, regardless of soil sampling density, 24.8–35.2% of total area of object 3 was acid, method 2 – 37.1–45.2%, method 3 – 43.3–44.5%. Thus irrespective of soil sampling density, the results of soil sampling methods 2 and 3 (especially) were rather uniform. Smaller acid areas were determined using methods 1 and 2 at 8 ha soil sampling density.

Object 4 relief is irregular; not acid eroded soils intervene the acid areas. Larger areas of acid and neutral (>6.5) soils were determined using the soil sampling method 3. 10.9–19.2% of object area was determined as acid when method 1 was applied, method 2 – 13.1–18.4%, method 3 – 20.9–32.1%. Application of methods 1 and 2 resulted in creation of several intermediate pH groups, i.e. close to neutral (5.6–6.0) and very close to neutral (6.1–6.5); this is not good for the planning of liming. Smaller acid areas were determined when soil samples were collected at 8 ha density.

Soil sampling at 2 ha and 4 ha density resulted in similar distribution of pH groups on the field map. Soil sampling at 8 ha density decreased the determined acid (pH ≤5.5) area in fields dominated by not acid (object 1) soils and fields with eroded areas (object 4). Irrespective of soil sampling density the obtained variation of acid area is less when soil samples are collected within the soil group and texture boundaries or within the soil group and texture boundaries and the boundaries of pH groups determined by the previous soil tests.

Spatial display of acid areas (pH ≤5.5) on the digital map is as important as distinguishing of different soil pH groups on the field. We have drawn the digital maps of acid (pH ≤5.5) zones for objects 2, 3 and 4 characterized by larger acid areas. Acid soils on these maps are coloured in black.

Application of regular grid soil sampling method in object 2 (Figure 6) resulted in scattered small plots of acid areas instead of a single acid array, especially when the soil samples were collected at 2 ha and 4 ha density. Such result is not satisfactory from the practical point of view, when planning liming. Separate arrays of acid soils were obtained using the soil sampling methods 2 and 3. The size and spatial position of these arrays depended little on soil sampling density. Based on the distribution of acid areas on the digital map the soil sampling methods 2 and 3 at 4 ha sampling density were selected as the optimal ones.

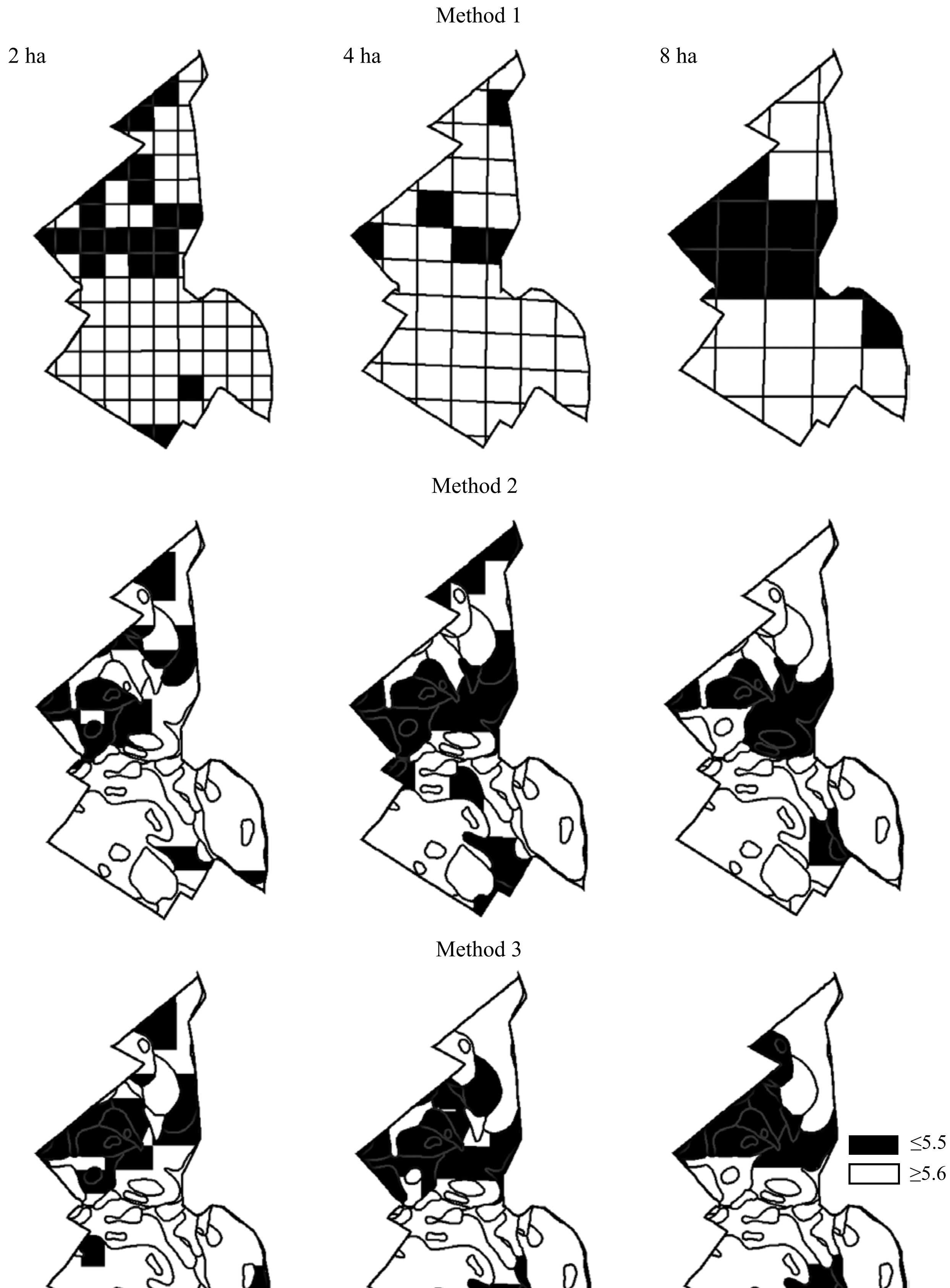


Figure 6. Spatial distribution of acid areas (pH ≤5.5) in object 2 (Elmininkai) as affected by different soil sampling methods and densities

Results of application of method 1 in object 3 (Figure 7) were similar to those obtained in object 2. Soil sampling methods 2 and 3 were the most suitable ones for object 3 – similar arrays of acid soils were obtained. The results obtained using methods 2 and 3 in object 3 depended little on the soil sampling density.

Object 4 (Figure 8) was the most complicated one for the spatial display of acid areas. Each variant yielded a different map of acid areas. Undoubtedly the reason for that was high variation of pH even in small area combined with the distribution of soil sampling spots. The closest to reality display of acid areas was obtained using the methods 2 and 3 at 2 ha and 4 ha soil sampling density.

Based on the research results presented above we can conclude that soil sampling at 2 ha and 4 ha density within the soil group and texture boundaries with or without the use of information on the boundaries of pH groups obtained during previous soil tests is the best approach for evaluation of distribution of pH groups and spatial distribution of acid areas in the tested objects. This approach yielded similar arrays of acid areas on the map. Application of regular grid soil sampling method resulted in scattered small acid areas instead of a single array.

On the other hand, soil sampling at 2 ha density costs more than twice as much as the 4 ha density soil sampling. Number of samples to be analysed in the lab is doubled, soil sampling time is increased by 1.6 times. Thus the cost-wise 4 ha soil sampling density is the optimal one.

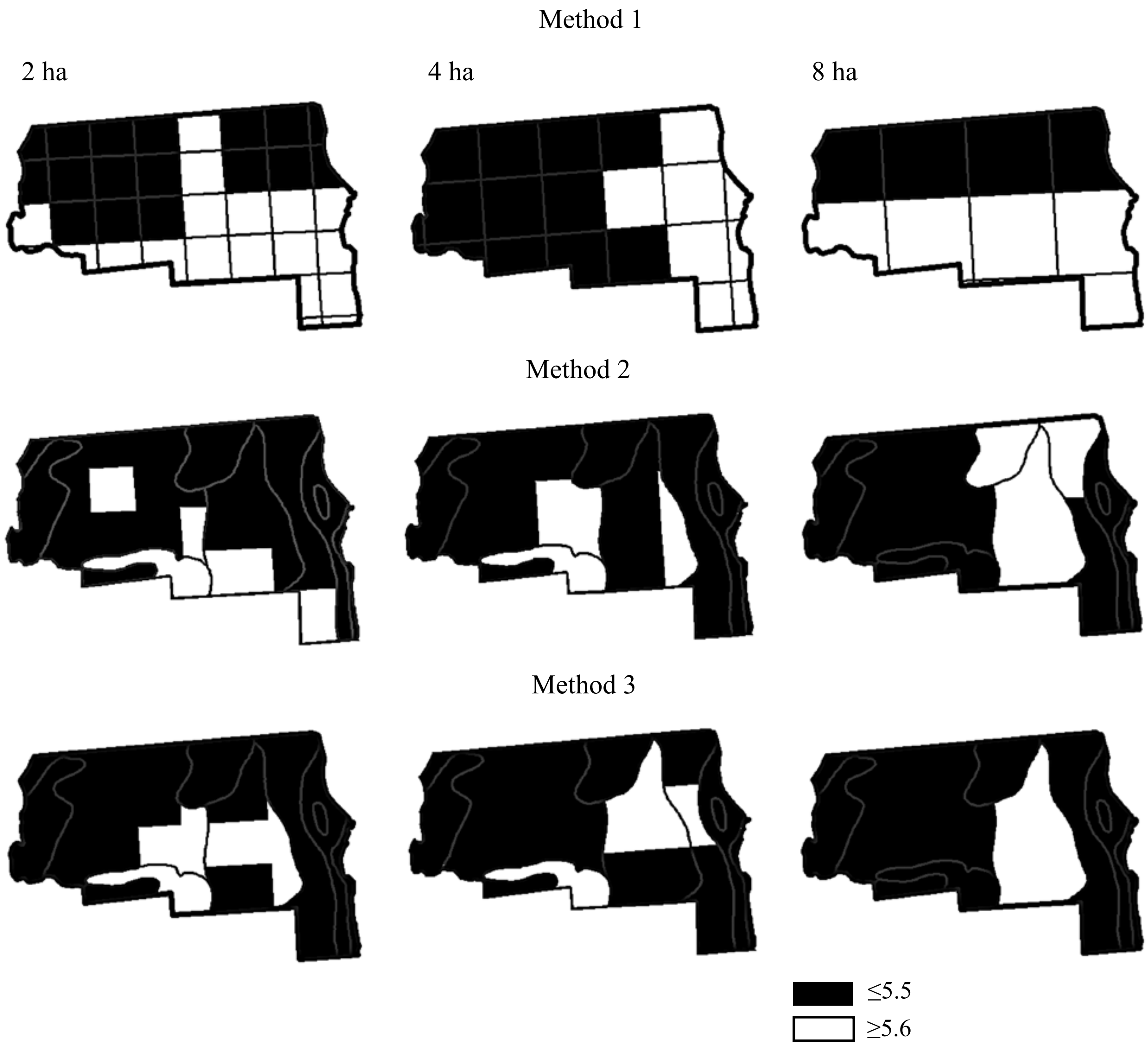


Figure 7. Spatial distribution of acid areas (pH ≤5.5) in object 3 (Daumantiškiai) as affected by different soil sampling methods and densities

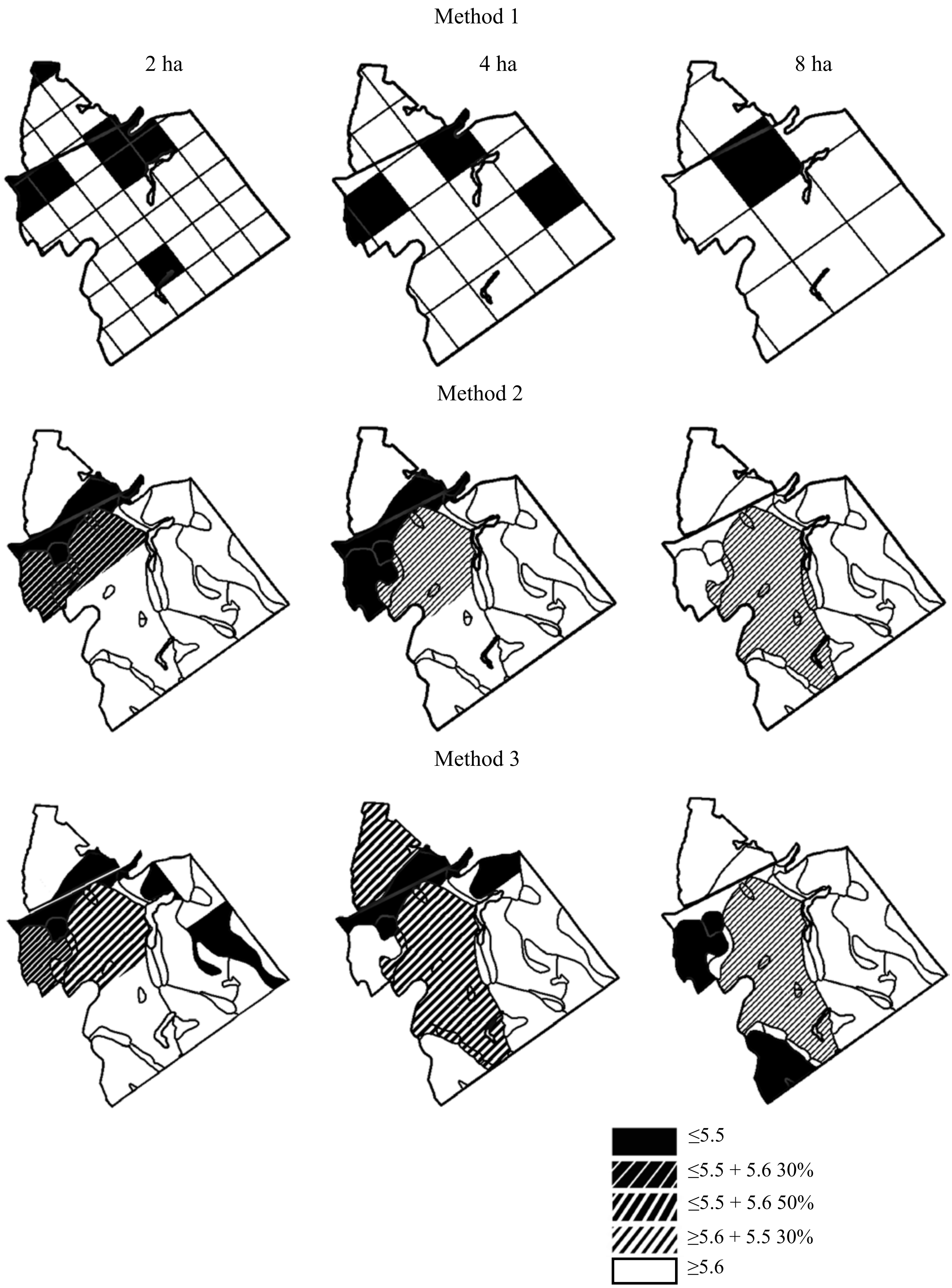


Figure 8. Spatial distribution of acid areas (pH ≤5.5) in object 4 (Dapkūniškiai) as affected by different soil sampling methods and densities

Conclusions

1. The determined pH values expressed as arithmetic means, medians or modes do not characterize accurately enough the consistent patterns of pH distribution in 50–150 ha fields with diverse soil group and varying soil acidity. Soil sampling density and method have no significant effect on the mean values of pH in slightly acid and close to neutral soils (including the eroded areas). pH values in neutral soils are higher when the soil sampling density decreases and when the regular grid soil sampling method is used.

2. Soil sampling at 2 ha and 4 ha density gives similar displays of distribution of pH groups on the map. Soil sampling at 8 ha density in fields dominated by not acid soils or containing some eroded zones decreases the determined area of acid soils (pH ≤5.5). Irrespective of the soil sampling density the obtained variation of acid areas is less when soil samples are collected within the soil group and texture boundaries with/without consideration of information on the boundaries of pH groups obtained during previous soil tests.

3. Considering the spatial distribution of acid (pH ≤5.5) areas on the digital maps of fields of different acidity the best approach is to sample the soil at 2 and 4 ha density within the boundaries of prevailing soil group and texture with/without consideration of information on the boundaries of pH groups obtained during previous soil tests. It gives similar arrays of acid areas and simplifies the marking of areas to be limed. When soil samples are collected using regular grid the determined acid areas do not make a single array, they are scattered throughout the field as small plots.

4. The costs of soil sampling at 2 ha density are more than twice as high as those of 4 ha density soil sampling, therefore it is recommended sampling the soil at 4 ha density within the boundaries of prevailing soil group and texture and within the boundaries of pH groups determined during previous soil tests.

Received 02 08 2010
Accepted 08 09 2010

References

Buivydaitė V. Lietuvos dirvožemių duomenų bazė [Lithuanian soil data base] / Lietuvos dirvožemiai // Lietuvos mokslų akademija. – Vilnius, 2001, p. 1063–1084 (in Lithuanian)

Buivydaitė V. Lietuvos dirvožemių tyrimo duomenų bazė [Lithuanian soil research data base] // Agronomijos ir gyvulininkystės mokslo aktualijos. – Akademija, Kauno r., 1996, p. 299–308 (in Lithuanian)

Dirvožemio, organinių trąšų, durpių ir šiltnamių žemių pavyzdžių paėmimo metodiniai nurodymai [Methodical guidelines on sampling of agricultural soil, organic fertilizers, peat and greenhouse substrate]. – Vilnius, 1975, p. 3–15 (in Lithuanian)

Franzen D. W., Cihacek L. J. Soil sampling as a basis for fertilizer application // North Dakota State University. – 1998. <http://www.ag.ndsu.edu/pubs/plantsci/soilfert/sf-990.htm#Index> [accessed 01 12 2009]

Grybauskas J. Lietuvos Respublikos dirvožemių skaitmeninės duomenų bazės programos parengimas [Lithuanian soil digital data base program preparation]. – Kaunas, 1998. – 31 p. (in Lithuanian)

Hansson G., Olofsson S., Albertsson B. Markkartering-jordprovtagning-analyser [Mapping the results of agricultural soil analyses] // The Swedish Board of Agriculture. – 2002. <http://www2.jordbruksverket.se/webdav/ files/SJV/trycksaker/Pdf_jo/JO02_6.pdf> [accessed 12 03 2010] (in Swedish)

ISO 10384-1:2002. Soil quality. Sampling. Part 1: Guidance on the design of sampling programmes

Kalvaitienė M., Knašys V., Kuzmickas B., Grybauskas J. Dirvų kalkinimas [Soil liming]. – Vilnius, 1976, p. 5–17 (in Lithuanian)

Lietuvos dirvožemių agrocheminės savybės ir jų kaita [Agrochemical properties of Lithuanian soils and their change (summary)] / sudaryt. J. Mažvila. – Kaunas, 1998, p. 21–34 (in Lithuanian)

Linden B. Bibliografiska uppgifter för Markkartering-shistoria [Bibliographic notice for soil mapping history] // VäxtEko [EcoPlant]. – 2007. <http://chaos.bibul.slu.se/sll/slu/utan_serietitel_slu/UST07-12/UST07-12D.PDF> [accessed 25 02 2010] (In Swedish)

Markkarterings-provtagning: Utrustning och anvisningar [Soil sampling and mapping: equipment and precautions] // Markkarteringstjänst [Soil Mapping Service]. – 2009. <http://www.markkartering-stjanst.fi/user_files/files/ oppaat/markkartering-sprov.pdf> [accessed 20 02 2010] (in Swedish)

Mažvila J., Staugaitis G., Adomaitis T. et al. Agrochemical properties of Lithuanian soils and their changes after regaining independence // Žemės ūkio mokslai. – 2008, vol. 15, No. 3, p. 13–21
Ožeraitienė D., Plesevičienė A. K., Gipiškis V. Skirtingų kalkinių trąšų veikimo trukmė ir poveikis dirvožemio savybėms bei sėjomainos augalų derliui [Duration of action of different lime fertilizers and their effect on soil properties and yield of crop rotation crops (summary)] // Žemdirbystė=Agriculture. – 2006, vol. 93, No. 1, p. 3–21 (in Lithuanian)
Paulauskas V., Sabienė N. Dirvožemio ėminių paėmimo planas, ėminių ėmimas ir mėginių paruošimas [Soil sampling scheme, sampling and sample preparation (summary)]. – Akademija, Kauno r., 2009. – 60 p. (in Lithuanian)
PN-R-04031:1997. Analiza chemiczno-rolnicza gleby. Pobieranie próbek [Analysis of the chemical-agricultural land. Sampling] (in Polish)
Vejledning i udtagning af jordprøver på landbrugsjord [Instruction for taking soil samples on farmland] // Landbrugsinfo [Agriculture information]. – 2003. <http://www.lr.dk/planteavl/diverse/Goed_jordproever.htm> [accessed 18 02 2010] (in Danish)
Wetterlind J. Improved farm soil mapping using near infrared reflection spectroscopy: doctor thesis. – Skara, Sweden, 2009. – 73 p.
ГОСТ 28168:89. Почвы. Отбор проб [Soil sampling] (in Russian)

ISSN 1392-3196
Žemdirbystė=Agriculture, t. 97, Nr. 3 (2010), p. 117–130
UDK 631.415.1:631.4.528.9

Dirvožemio ėminių skirtingų paėmimo būdų įtaka pH duomenų erdviniam pasiskirstymui skaitmeniniuose žemėlapiuose

G. Staugaitis, J. Mažvila, D. Šumskis
Lietuvos agrarinių ir miškų mokslų centro Agrocheminių tyrimų laboratorija

Santrauka

Tyrimų tikslas – nustatyti optimalų dirvožemio ėminių paėmimo pH tyrimams būdą ir tankumą. Dirvožemio ėminiai paimti trimis būdais: pagal sudarytą taisyklingą tinklelį, atsižvelgus į dirvožemio kontūrus pagal FAO 1 bei 2 lygius, pagal dirvožemio grupių ir ankstesnių tyrimų metu nustatytų pH grupių ribas. Šiais būdais ėminiai paimti iš 2, 4 ir 8 ha. Iš viso tirti 9 variantai, t. y. iš to paties lauko dirvožemio ėminiai paimti 9 kartus. Tyrimai atlikti keturiose skirtingose Lietuvos vietovėse, esančiose 47, 55, 73 ir 155 ha dydžio laukuose, kurių dirvožemis ir pH skyrėsi. Objektų laukai buvo tipingi esamoms vietovėms. pH nustatytas 1 M KCl ištraukoje.
Tyrimai parodė, jog, nepriklausomai nuo dirvožemio ėminių paėmimo būdo ir tankumo, apskaičiuotos laukų dirvožemių pH reikšmės, išreikštos aritmetiniu vidurkiu, mediana arba moda, tiksliai neatskleidė lauko dirvožemio pH pasiskirstymo dėsningumų. Lauko dirvožemių rūgštumą geriausia vertinti pagal pH grupes (≤4,5, 4,6–5,0, 5,1–5,5, 5,6–6,0, 6,1–6,5, >6,5) ir pagal rūgščių (pH ≤5,5) plotų erdvinį išsidėstymą. Pagal tai ėminius geriausiai imti iš 2 ir 4 ha, atsižvelgus į dirvožemio vyraujantį tipą bei granuliometrinę sudėtį arba į tai ir į ankstesnių agrocheminių tyrimų metu nustatytas pH grupes. Tuomet skaitmeniniuose žemėlapiuose (M 1:10000) susidaro panašūs rūgščių plotų masyvai, kuriuose patogu išskirti kalkintinus plotus. Kai ėminiai imami pagal taisyklingą tinklelį, rūgštūs plotai būna labiau išsibarstę atskirais ploteliais, o ne viename masyve. Nustatyta, kad kai laukuose vyrauja nerūgštūs arba pasitaiko eroduotų plotų, ėminių paėmimas iš 8 ha sumažina rūgščių (pH ≤5,5) dirvožemių plotą.
Kadangi dirvožemio ėminius imant iš 2 ha išlaidos esti daugiau nei dvigubai didesnės nei imant iš 4 ha, rekomenduojama ėminius imti iš 4 ha, o sudarant ėminių paėmimo maršrutą atsižvelgti į dirvožemio kontūrus ir ankstesnių tyrimų metu nustatytas pH grupių ribas.

Reikšminiai žodžiai: dirvožemis, pH, ėminio paėmimas, skaitmeniniai žemėlapiai.