Research Article

BIOMEDICAL
Journal of Scientific & Technical Research

ISSN: 2574 -1241

DOI: 10.26717/BJSTR.2021.35.005655

Associations of Humus Content and pH of Mineral Soils with Silicate Weathering Factors and Carbon Capture

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ARTICLE INFO

Received: March 22, 2021

Published: April 16, 2021

Citation: Töysä T. Associations of Humus Content and pH of Mineral Soils with Silicate Weathering Factors and Carbon Capture. Biomed J Sci & Tech Res 35(1)-2021. BJSTR. MS.ID.005655.

Keywords: Humus; Silicon Weathering; Carbon Capture; pH; Temperature; Regional; Periodical; Cropland; (Ca+Mg+K)

Abbreviations: “.68”: Period 1966-1970; ”.88”: Period 1986-1990; “.(61-90)”: 1961-1990; “.(81-10)”: 1981-2010; (Ca+Mg+K): Surrogate for Cation Exchange Capacity (CEC); coms: Coarse Mineral Soils; fims: Fine Mineral Soils (= clays+silt); Hum(us).min.(60’s); (parts in parentheses depending on space and clarity): humus content of Finnish mineral soils in 1961-1970; min: mineral soils (: coms+fims); prp: proportion; RC: Rural Center; SOC: soil organic carbon (ca. 0.58*humus); tot: total.

ABSTRACT

Silicate weathering is known to bind carbon. This study assesses associations between mineral soil humus content (1961-70) [Hum(us).min(.60’s)] (indicator of soil organic carbon - SOC), groundwater silicon [Si.gw], mineral (“.min”) soil parameters from 1966-70 (“68”) and 1986-90 (“88”): pH, (Ca+Mg+K), proportion of clays in fine mineral soils [Prp.(clays/fims], temperature [Temp] from 1961-90 (“(61-90)”) and 1981-2010 (“(81-10)”) by Rural Centers (RC) (N = 18).

Results:

	R squares (%) of regressions by [Humus.min] and [pH.min.68] with coefficient signs and significance (* = p < 0.05)	
	Humus.min	pH.min.68
Humus.min	100	9.9 (+)
Si.gw	84.4* (+)	14.1 (+)
Temp	75.3* (+)	31.5* (+)
(Ca+Mg+K).min.68	50.0*(+)	32.1* (+)

Next are represented results of combined regressions, e.g. the first one shows that combined regression of [Hum.min] was explained 79.6 % by [pH.min.68;Temp.(61-90)], p< 0.001, coefficient signs (-/+). After “cf” is difference (Δ) or “E.D.” (“explained difference”) by other “[...]” parameters in the same equation (Table 1). Supposed (given) inter-periodical 1.09-fold change in Si.gw and 0.82-fold change in [Hum.min], respectively

1) [Hum.min].E.[pH.min.68;Temp.(61-90)]_79.6_0.000.(-;+)..cf.[pH.min.88;Temp.(81-10)].Δ. (-7.2) %

2) [Humus.min].E.[1.09*Si.gw;Temp.(60-90)]_85.5_0.000.(+;+).(78;22).cf.[Si.gw;(Temp.(81-10)]..Δ.(-3.7)_%

3) [pH.min.68].E.[Hum.min.60’s;Temp.(61-90)]_43.4_0.014_(-;+)..cf.[0.82*Hum.min.60’s;Temp.(81-10)].E.D. 36 %

4) [pH.min.88].E.[0.82*Hum.min;Temp.(81-10)]_64.4_0.000_(-;+).(27;73)..cf.(Hum.min;T.(61-90)).E.D.45 %

5) [pH.min.88].E.[Si.gw;Temp.(81-10)]_65.9_0.000_(-;+).(30;70)..cf.[1.09*Si.gw;Temp.(61-90)].E.D..36 %.

Inter-periodical difference in [Humus.min] was predicted by changes in [pH.min; Temp] to be ad 7.2 %. Changes in [pH.min] was explained ad 45 %.

Conclusion: Factors indicating silicate weathering predicted regional humus content, pH and their changes in mineral soils, best humus content. Different continuous silicate weathering possibly explains the stable relative difference in regional pH values. Increase in silicate weathering rate can reduce atmospheric and increase soil carbon content.

Introduction

Silicate weathering contra carbonate weathering: Silicate weathering is known to sequestrate carbon, e.g.: CaSiO3 + 2CO2 + H2O > Ca++ + 2HCO-- +SiO2 (soluble) [1]. Importance of this process has been discovered lately: earlier “silicic” bedrock was interpreted to “promote the acidity of soils” [2]. Carbon capture via silicate weathering has been treated comprehensively e.g. in [3], including reduction of carbon loss caused by liming agents. To some extent silicate fertilizers have been known in agricultural praxis since the 19th century [4]. The decline in soil organic carbon (SOC) from mineral cropland soils estimated by data from 1974-2009 has been ca 0.4 %/ha/a, i.e. ca 220 kg/ha/a [5]. Carbon loss has generally been associated positively with annual management practices and negatively with clay soils [5]. Biogenic amorphous silica can increase water-holding capacity of soil [6], which could resist erosion and support the maintenance of carbon balance. Independently on universal guiding for cropland liming [7], relative regional differences in cropland soil pH-values have stayed stable for decades [8]. The aim of this study is to clarify associations of humus content and pH of mineral soils with silicate weathering factors: groundwater silicon (Si.gw), temperature (Temp) and sum of soil soluble (Ca+Mg+K) [(Ca+Mg+K).min.68] and soil-type (clay proportion in fine mineral soils, Prp.(clays/fims)). Inter-periodical changes are assessed by pH from periods 1966-1970 (“68”) and 1986-1990 (“88”) and by Temp values from periods 1961-1990 (“(61-90)”) and 1981-2010 (“(81-10)”).

Materials and Methods

Latitude and longitude per Rural Centers (RC) - earlier ‘Agricultural Advisory Centers’ - have been determined, as in [9], by two-phases: first by selecting visually an approximate central commune/town of each RC in the map [10] and then via internet-search [“GPS coordinates” and the name of the commune]. (Table 1), includes the data for calculations). Mean annual temperatures of RC’s are approximated by the same method by benefiting map [10] together with map [11] for period 1960-1990 and with map [12] for period 1981-2010. Data on groundwater silicon mean (Si.gw) and median (Si.gw.md) from 1999, are provided by Geological Survey of Finland [13]. Soil pH, Ca, Mg and K values by Rural Centers from period 1966-1970. (N of samples by soil-types: mineral ca 270,000, mull ca 52,000 and org ca 97,000) and pH.min values from1986-90 are provided by Viljavuuspalvelu Oy (Kurki M) [14] and Viljavuuspalvelu Eurofins Oy, (N ca 480,000), [15]. Occurrence of humus classes by RC’s and the whole country are obtained from [16], totaling 836,000 samples, 73.4 % miner. soils.

By data in [16] the mean of Regional humus content of mineral soils in 1961-70, Humus.min (60’s), by selected RC’s was 5.74 (Tabl. 1). Values from [16] are used as such, although they obviously under-estimate.

Table 1: Latitude, Longitude, Temperature in 1961-1990 and 1981-2010, mean and median of groundwater Si, pH.min (of mineral soils) in 1986-1990, pH.min, pH.mull, pH.org and proportion of clays in fine mineral soils in 1966-1970 and humus content of mineral soils in 1960-1970 by Rural Centers.

	Latitude	Longitude	Temp.(61-10)	Temp.(81-10)	Si.gw	Si.gw.md	(Ca+Mg+K).min.68	pH.min.88	pH.min.68	pH.mull.68	pH.org.68	Prp.(clays/fims).68	Humus.min
	°N	°E	°C		mEq/L					%		%	
01.Uusimaa	60.5	25.1	4.9	4.1	1.14	1.11	121	6.00	5.71	5.43	5.38	87.6	6.1
02.Nyland Svenska	60.2	24.7	5.1	4.5	1.08	1.02	118	6.13	5.73	5.29	5.25	98.0	6.60
03.Varsinais-Suomi	60.7	22.6	5.0	4.4	1.12	1.14	127	6.17	5.83	5.31	5.22	98.4	6.61
05.Satakunta	61.6	21.9	4.5	4.0	0.98	1.01	89	6.04	5.75	5.23	5.16	59.9	6.53
06.Pirkanmaa	61.6	23.6	4.1	3.3	0.93	0.87	81	6.00	5.77	5.27	5.24	18.0	5.45
07.Kanta-Häme	60.9	24.3	4.6	3.7	1.12	1.10	116	6.07	5.76	5.33	5.26	71.7	6.56
08.Päijät-Häme	61.2	25.5	4.3	3.6	0.98	0.90	84	6.01	5.7	5.34	5.26	25.6	6.19
09.Kymenlaakso	60.8	26.8	4.6	4.0	1.14	1.10	119	5.95	5.73	5.38	5.31	92.0	6.44
10.South Karelia	61.1	28.5	4.1	3.5	0.93	0.81	88	5.95	5.82	5.40	5.33	60.5	5.61
11."Mikkelin läänin" RC	61.9	27.9	3.8	3.0	0.91	0.90	70	6.07	5.72	5.40	5.25	3.1	5.85
12.North Savo	63.2	27.3	3.0	2.0	0.78	0.71	65	5.93	5.64	5.29	5.23	1.7	4.95
13.North. Karelia	62.8	29.9	2.8	2.0	0.81	0.77	64	5.90	5.65	5.32	5.17	2.7	5.09
14.Central Finland RC	62.7	25.3	3.2	2.4	0.90	0.87	67	5.98	5.7	5.28	5.22	0.2	5.10
15.South Ostrobothnia	62.8	22.9	3.4	3.0	1.07	1.07	72	5.87	5.65	5.25	5.19	49.2	7.00
17.Central Ostrob.	63.8	24.3	2.8	2.3	0.90	0.83	64	5.86	5.66	5.17	5.07	1.1	5.84
18.North Ostrobothnia	65.0	26.2	1.8	1.2	0.85	0.78	64	5.85	5.68	5.24	5.18	20.0	5.34
19.Kainuu	64.5	28.2	1.6	0.7	0.65	0.57	59	5.97	5.78	5.36	5.24	0.0	4.09

20.Lapland	66.5	25.7	0.5	0.0	0.70	0.64	55	5.81	5.59	5.23	5.16	0.0	4.02
Mean	62.3	25.6	3.6	2.9	0.94	0.90	85	5.98	5.72	5.31	5.23	38	5.74
SD	1.8	2.2	1.3	1.3	0.15	0.17	25	0.10	0.06	0.07	0.07	39	0.86

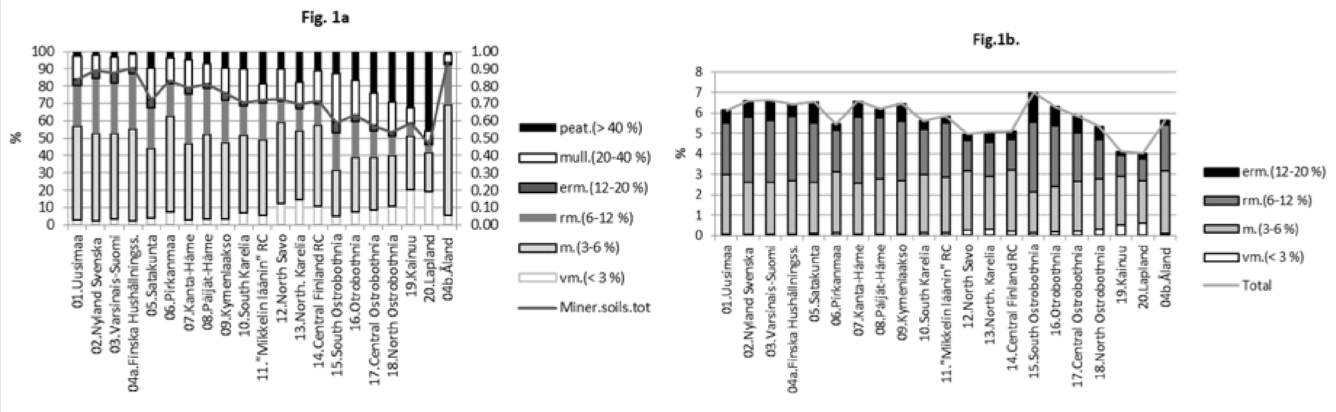

Figure 1:
a. Ditribution of soiltypes in Finnish Rural Centers
b. Humus content in Finnish mineral soils by humus clases and by Rural Centers in 1960-1970.

Humus content of mineral soils, [Humus.min], for $RC_{.x}$ is attained by multiplying the proportion, occurrence ($o_{.ix}$) (%) (Figure 1a) of each humus class by its humus class content ($c_{.i}$) (%) (approximated by the mean of the limits, i.e. 1.5; 4.5; 9 and 16, respectively), as a result ($o_{.ix}*c_{.i}$). After that each result in each humus class is divided by the sum of occurrences $\Sigma o_{.ix}$. The sum $\Sigma[\Sigma(o_{.ix}*c_{.i})/\Sigma o_{.ix}]$ gives the humus content of mineral soils in $RC_{.x}$. The same procedure is reiterated for each RC and the whole country (Figure 1a & 1b). Because of the scanty number of groundwater samples Finska Hushållningss. (N 3) and Åland (N 6) [13] are excluded. Ostrobothnia is excluded because of its high deviation between mean and median Si.gw [18] and additionally because its soil acidity, which is obviously regulated not only by silicates and humus, but by sulfur and iron compounds [19]. In Finnish experimental stations between 1960 and 1981 agricultural humus content was reduced in 13 fields and increased in 2 fields, on an average the humus content was reduced from 7.4 to 6.0 %, i.e. annually 9 % [20]. By data in [16] the mean of Regional humus content of Finnish mineral soils in 1961-70 (was (Table 1), by selected RC's 5.74. Values from [16] although they obviously under-estimate, are used as such.

Approximates for soil organic carbon content [SOC] can be attained by multiplying humus-% by 0.58 [21] (Table 1). For clarity sometimes postfix "60's" is added to [Humus.min]: [Humus.min.60's]. Latitude [Lat] and longitude [Long] are given for further discussions. [Lat] is given as a reference for [Temp]. Regressions are performed by IBM SPSS Statistics 27. (Figure 1a) shows distribution (proportions, occurrence o) of soil-types in Finnish Rural Centers (RC), all RC's included. (Figure 1b) shows humus contents of Finnish mineral soils by soil classes and by Rural Centers [15], including all RC's. Values are calculated for each humus class (i) in $RC_{.x}$ by proportions, occurence ($o_{.ix}$) (%) and humus content ($c_{.i}$) (%) e.g. value for "m" in Uusimaa = $o_{.m.Uusimaa}*4.5/\Sigma o_{i.Uusimaa}$. (Here, for clarity of the (Figure 1b), occurrence sum does not include organic soils). (Table 2) represents R squares of single regressions by [Humus.min] and [Si.gw]. For normally distributed variables the significance level of ($p = 0.05$) of the R square for 18 pairs of observations is ca 0.22. R square (%) values above 22 are interpreted as significant for rapid survey. Signs in parentheses are directions of the regression coefficients.

Results

(Table 2) represents R squares of single regressions by [Humus.min] and [Si.gw]. For normally distributed variables the significance level of ($p = 0.05$) of the R square for 18 pairs of observations is ca 0.22. R square (%) values above 22 are interpreted as significant for rapid survey. Signs in parentheses are directions of the regression coefficients. All represented associations were positive. All associations with Humus.min were significant. pH associated significantly with Temp, (Ca+Mg+K) and Prp.(clays/fims), but insignificantly with Humus.min and Si.gw.

Table 2: R squares (%) of regressions by [Humus.min] and [pH.min.68] with coefficient signs and significance (* = $p < 0.05$).

	Humus.min	pH.min.68
Humus.min	100	9.9 (+)
Si.gw	84.4* (+)	14.1 (+)
Temp	75.3* (+)	31.5* (+)
(Ca+Mg+K).min.68	50.0* (+)	32.1* (+)
Prp.(clays/fims).68	62.2* (+)	27.0* (+)

Associations of Humus.min, Si.gw and pH.min.68 with Each Other

In compliance figures RC's are arranged by [Temp] in increasing order

Associations of [Humus.min] with Parameters of Weathering Rate in Mineral Soils

Regressions of [Humus.min] are represented in (Figures 2-5). In parentheses are represented significances, signs of coefficients and possible proportions of Beta coefficients. Thin dotted lines show the limits of standard deviation. (Figure 6) shows [Humus.min] and its regression by ("E.by.") [(Ca+Mg+K).min.68]. Regression by [(Ca+Mg+K).min.68], explained [Humus.min] positively by 49.6 % (p = 0.001). Geographic factors latitude and longitude explained [humus.min] by 73.5 % (p < 0.001). Compactly: [Humus.min].60's.E.(Lat; Long)_73.5_0.000.(-;-).(61;39). In (Figure 2) distribution of [Humus-%.min] is like a mirror image of the distribution of Male CHD in 1964-1984, e.g. (Figure 2) in [18]. (Figure 3) shows [Humus.min] and its regression by [Prp.(clays/fims).68]. Regression by [Prp.(clays/fims).68]. explained positively [Humus.min] by 55.6 % (p < 0.001).

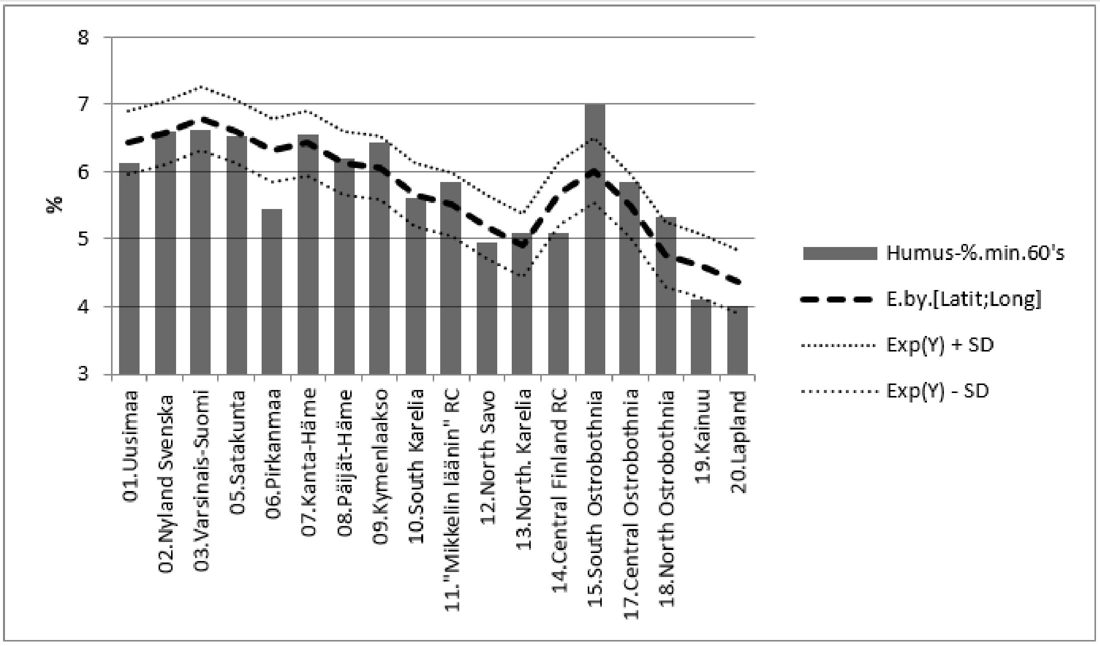

Figure 2: Regression of [Humus.min] by [Latit;Long].

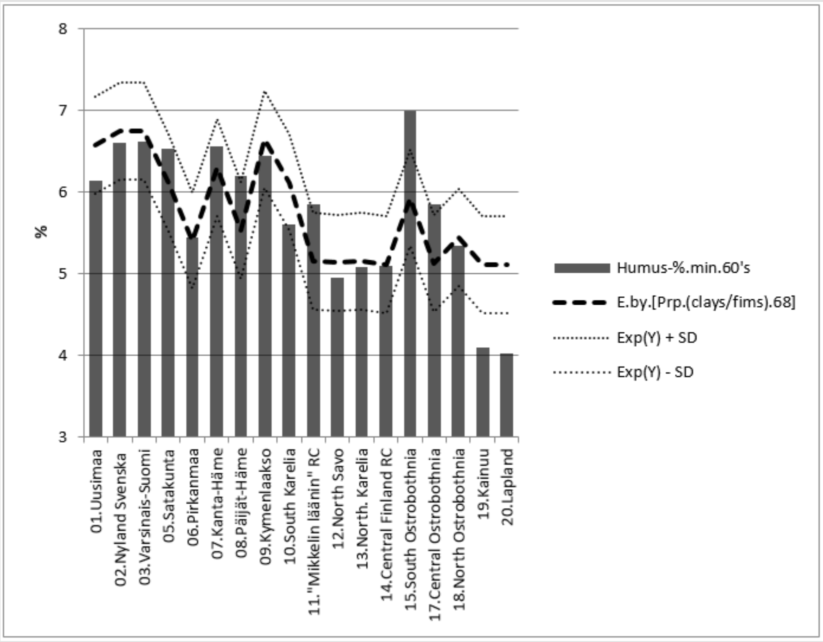

Figure 3: [Humus.min] and its regression by [Prp.(clays/fims).68].

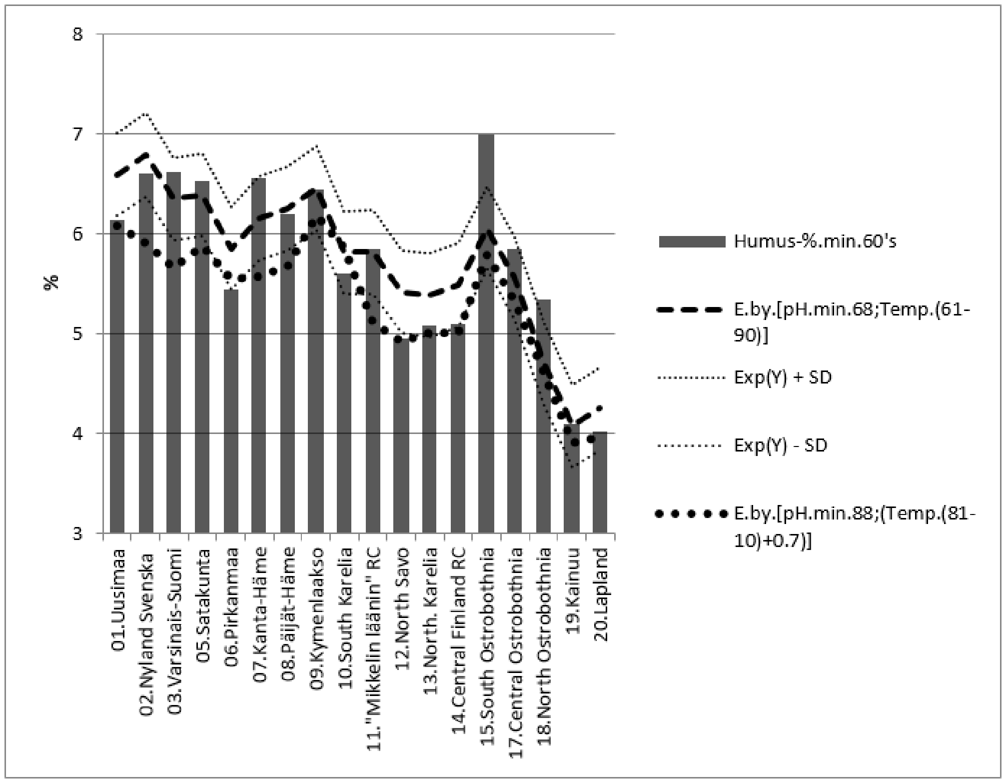

Figure 4: [Humus.min] and its regression by [pH.min.68; Temp.(61-90)], and curve by the same equation with parameters from the 1980's.

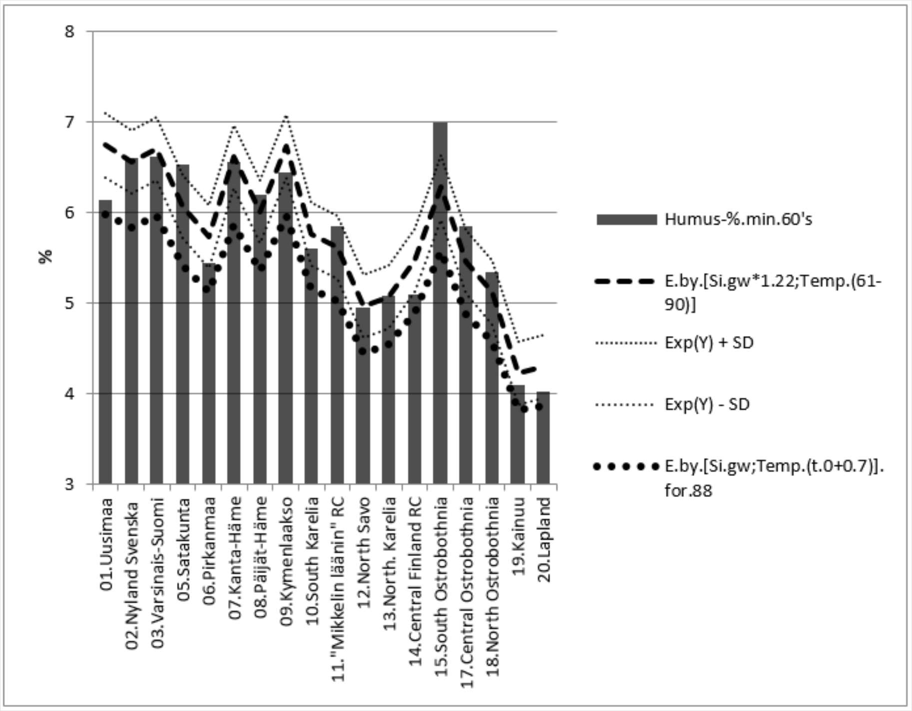

Figure 5: [Humus.min] and its regression by [1.22*Si.gw;Temp.(61-90)], and curve by the same equation with respective parameters from the 1980's.

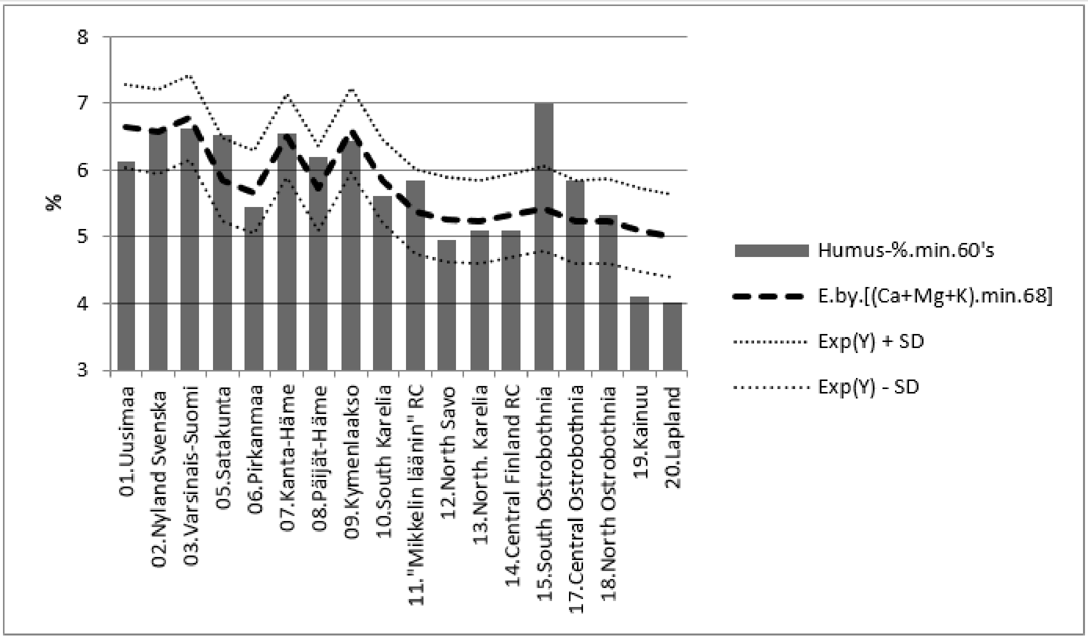

Figure 6: [Humus.min] and its regression by [(Ca+Mg+K).min.68].

Predicting of Periodical Humus.min

(Figure 4) represents [Humus.min] and its regression by [pH.min;Temp.(61-90)]. [Humus.min] was explained 80 % ($p < 0.001$) by this regression. The same equation with parameters: [pH.min.88;Temp.($t_{.0}$ +0.7 °C)] explained average change in [Humus.min] by 7.2 %. (Inter-periodical difference in mean Temp was 0.7 °C).

Compact:[Hum.min.60's].E.[pH.min.68;Temp.(61-90)]_79.6_0.000.(-;+).(20;80).cf.[pH.min.88;Temp.(81-10)].Δ. -7.2 %.

If proposed that Si.gw (or Si availability to plants) had been 22 % higher in period (66-70), than in (86-90), combined correlation of Si.gw and Temp could explain average decrease in Humus.min by 10.8 %. If Si.gw change had been 9 %, the average change in Humus.min had been 3.1 %.

Compact:Humus.min.60's.E.(Si.gw*1.22;Temp.(60-90))_85.6_0.000.(+;+).(78;22).cf.(Si.gw;T.(t.0+0.7).Diff..(-10.8)_%Humus.min.60's.E.(Si.gw*1.09;Temp.(60-90))_85.5_0.000.(+;+).(78;22).cf.(Si.gw;(Temp.(t.0+0.7)).E..(-3.7).

(Figure 7) shows that the pH in of mineral soils is higher than that of organic soils (including mull).

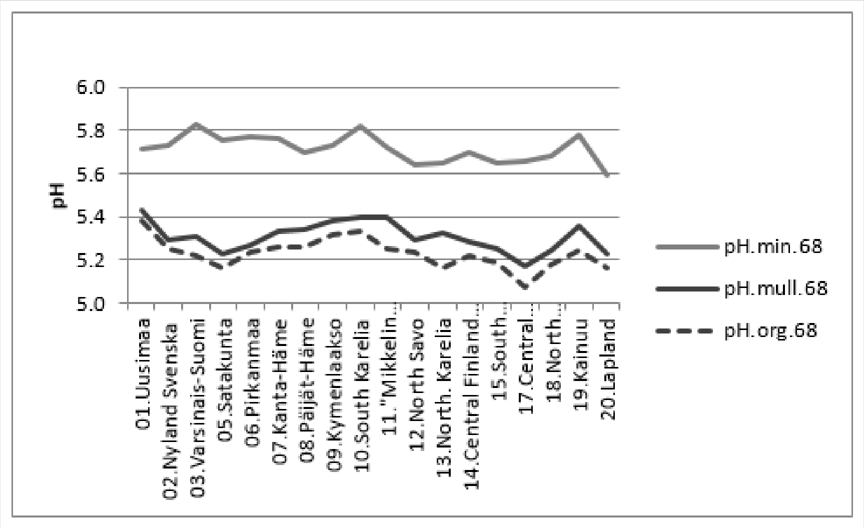

Figure 7: The pH in of mineral soils is higher than that of organic soils (including mull).

pH.min and Its Predicting

(Figure 8) suggests that similar successive pH values could have some explaining rules. (Figure 8) shows changes in [pH.min] between periods "68" and "88". Next are represented regressions of [pH.min.68]. In parentheses are given significances, signs of coefficients and possible proportions of Beta coefficients. In (Figure 9). [pH.min] is explained 43.4 % ($p = 0.014$) by [Humus.min;Temp.(61-90)]. When supposed that inter-periodical decrease in Humus.min was 18 %, this gives coefficient 0.82 for Humus.min in the 1980's. Mean inter-periodical difference (0.7°C) was added for the parameters of 1980's. Parameters [0.82*Humus.min;Temp.(t.0+0.7)] in the same equation explained 36 % of the observed average difference in inter-periodical pH.

Compactly:[pH.min.68].E.[Hum.min.60's;Temp.(61-90)]_43.4_0.014_(-;+).(37;63).cf.[0.82*Hum.min;Temp.(81-10)].E.(+36).%.

In (Figures 10&11) has been used supposed value 0.82* Humus min for Humus value in "88". First was calculated regression for "88", then "predicted" value for "68". The average difference in inter-periodical pH was explained by 45 %.

Compactly:[pH.min.88].E.[0.82*Hum.min;Temp.(81-10)]_64.4_0.000_(-;+).(27;73)..cf.[Hum.min;Temp.(61-90)].E.D.45 %Supposed relative inter-periodical change in Si.gw (and/or Si availability), i.e. Si availability was 9 % higher in "68" than in "88". Supposed Si.gw change with Temp increase, explained together 36 % of the average difference in inter-periodical pH.

Compactly**:**[pH.min.88].E.[Si.gw;Temp.(81-10)]_65.9_0.000_(-;+).(30;70)..cf.[1.09*Si.gw;Temp.(61-90)].E.D.36 %.

In (Figure 12) are calculated [pH.min.88] regressions by [Si.gw;Temp.(81-10)]. For Si.gw was given supposed value, which is 1.6-fold to measure in 1999 (and especially for "88"). This could explain 99 % of the observed average difference in inter-periodical pH.

Compact**:**[pH.min.88].E.[Si.gw;Temp.(81-10)]_65.9_0.000_(-;+).(30;70)..cf.[1.6*Si;Temp.(t.0-0.7)].E.Diff..99 %.

(Figure 13) shows [Si.gw] and its regression by [Humus.min;Temp.(61-90)]. Regression by [Humus.min;Temp.(61-90)] explained [Si.gw] by 88.3 % ($p < 0.001$), coeff. signs (+;+). Proportions of Beta coefficients: (59;41). Temperature seems to fortify the "Si.gw effect on Humus".

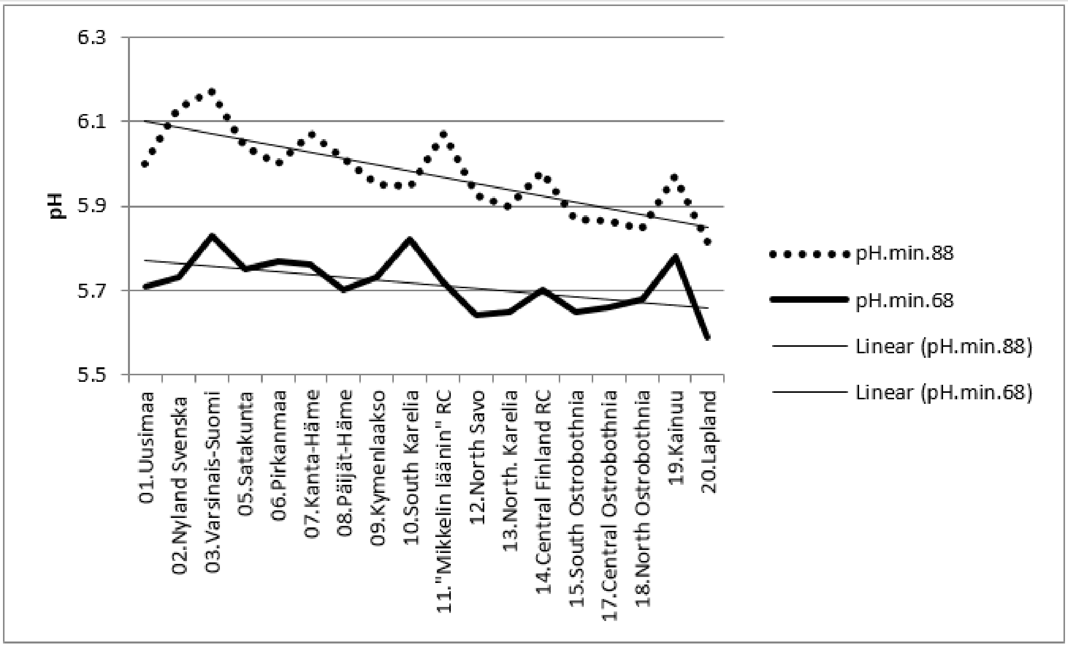

Figure 8: Changes in pH of mineral soils during two decades.

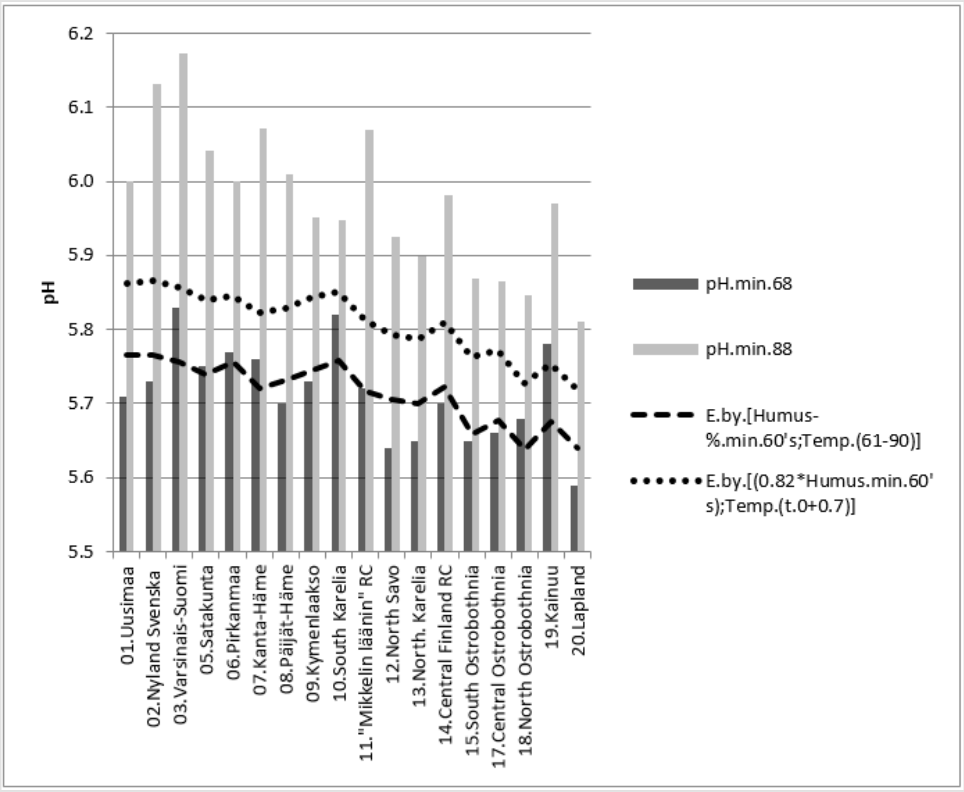

Figure 9: [pH.min.68] and its regression by [Humus.min;Temp.(61-90)], and curve by the same equation with respective parameters from the 1980's.

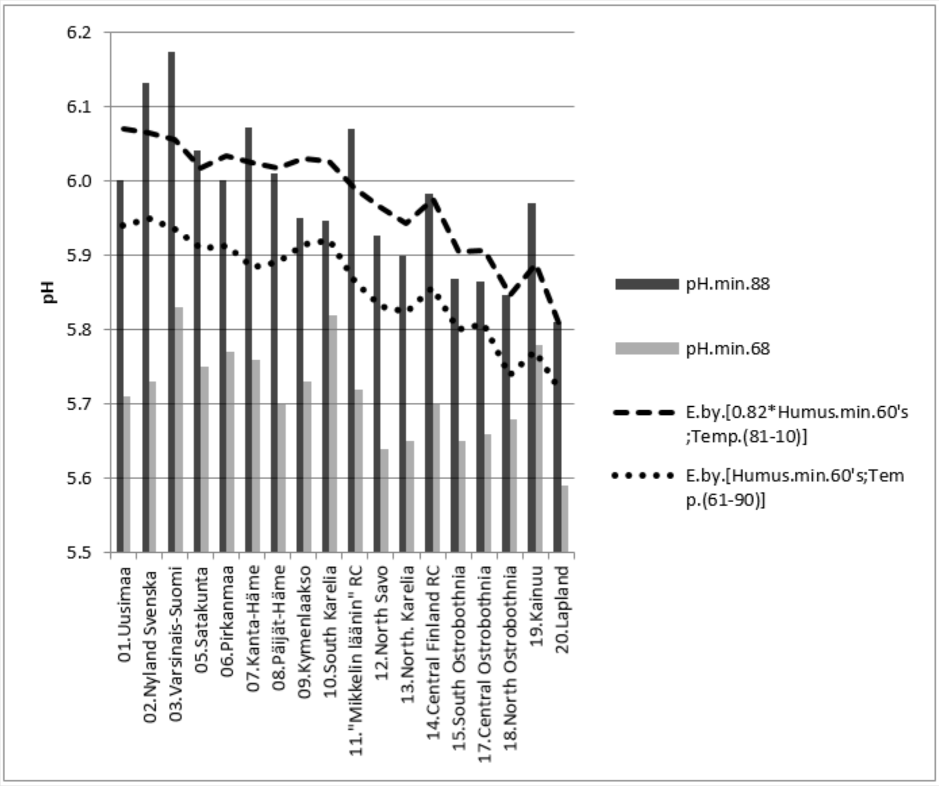

Figure 10: [pH.min.88] and its regression by [0.82*Humus.min;Temp.(81-10)] and a curve by the same equation with respective parameters from the 1960's.

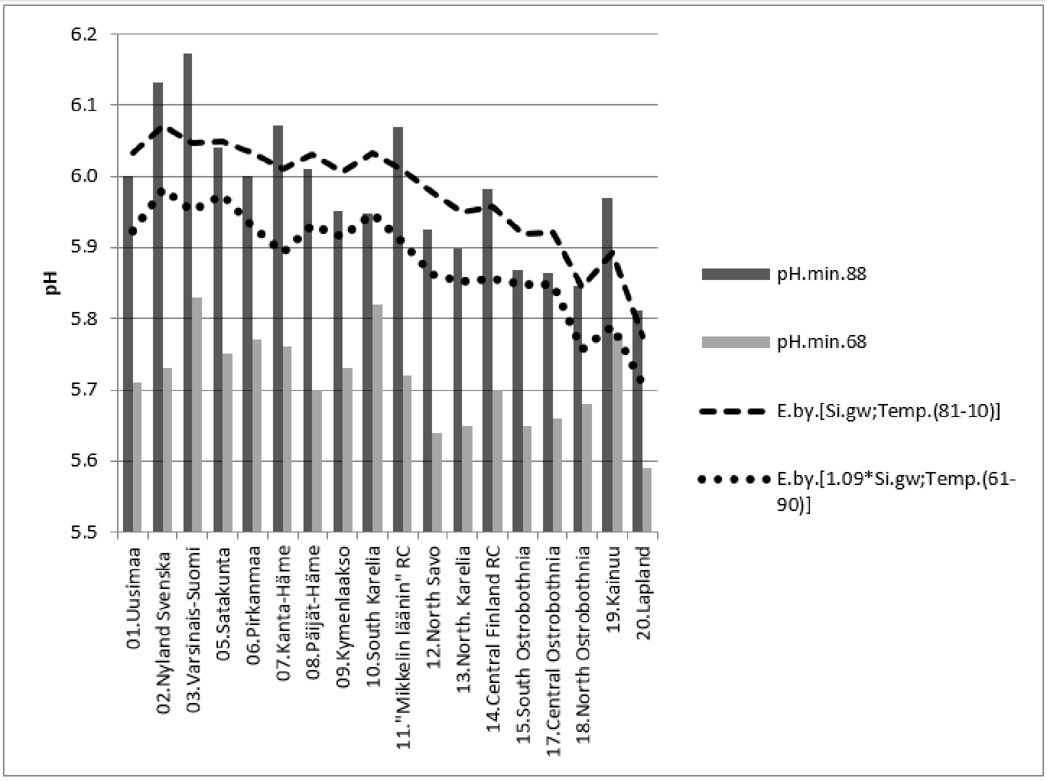

Figure 11: [pH.min.88] and its regression by [Si.gw;Temp.(81-10)] and a curve by the same equation with respective parameters from the 1960's.

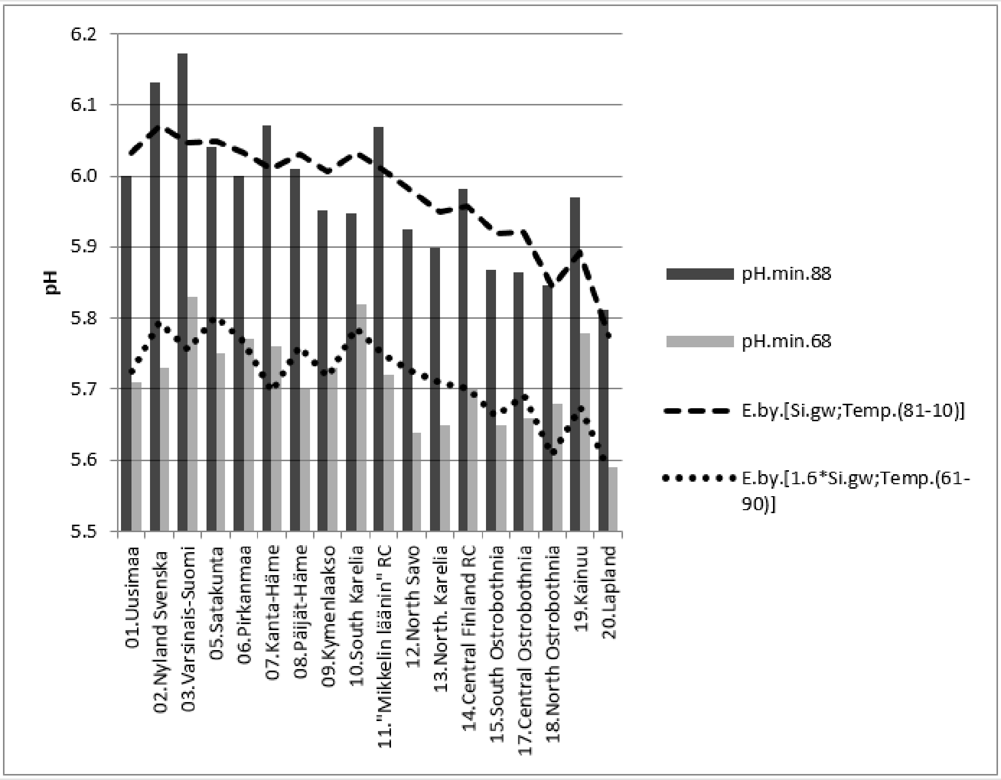

Figure 12: [pH.min.88] and its regression by [Si.gw;Temp.(81-10)] and a curve by the same equation with respective (supposed) parameters from the 1960's.

DOI: 10.26717/BJSTR.2021.35.005655

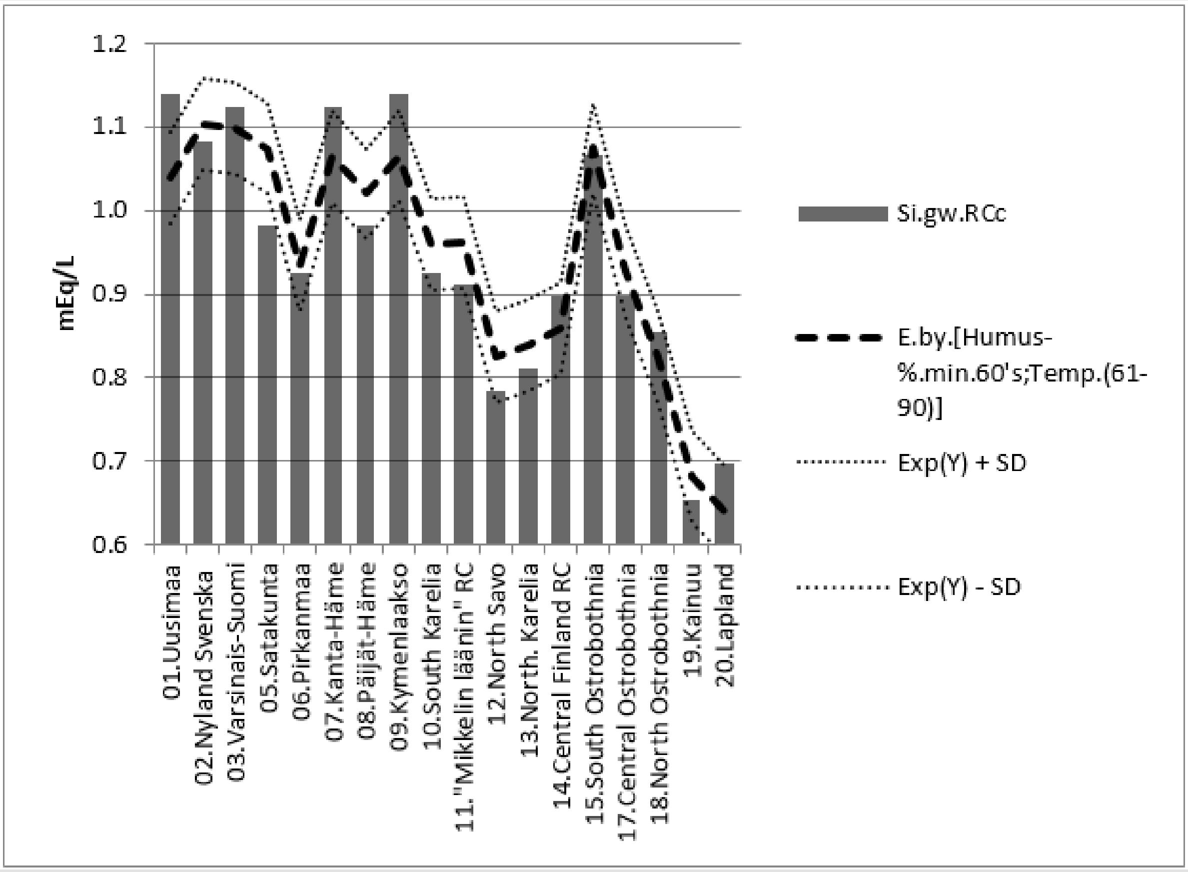

Figure 13: Si.gw and its regression by [Humus.min;Temp.(61-90)].

Associations between Weathering Factors

Rural Centers are arranged in next (Figures 14 - 17) by increasing annual Temp (Figure 14) shows compliance between [Temp] and [Humus.min]. [Temp] explained [Humus.min] by 75.3 % ($p < 0.001$). N.B. prediction by plain Temp suggests 7 % increase in humus content between periods “68” and “88”!

Compliance of Humus.min with Si.gw

(Figure 15) shows compliance between [Humus.min] and [Si.gw]. [Humus.min] was explained 84.4 % by [Si.gw] and 85.4 % by [Si.gw;Temp.(61-90)].

Compliance of Humus.min with pH.min.68

(Figure 16) shows compliance between [Humus.min] and [pH.min68]. [Humus.min] was explained 9.9 % by [pH.min.68] alone, but 79.6 % by [pH.min.68;Temp.(61-90)].

Compliance of Si.gw with pH.min.68

(Figure 17) shows compliance between[pH.min] and [Si.gw]. [pH.min] was explained positively 14.1 % ($p = 0.125$) by [Si.gw], but 39.7 % ($p = 0.023$) by [Si.gw;Temp.(61-90)].

Compact**:** [pH.min.68].E.[Si.gw;Temp.(61-90)]_39.7_0.023_(-;+).(36;64). cf. (Figure 2) in [24].

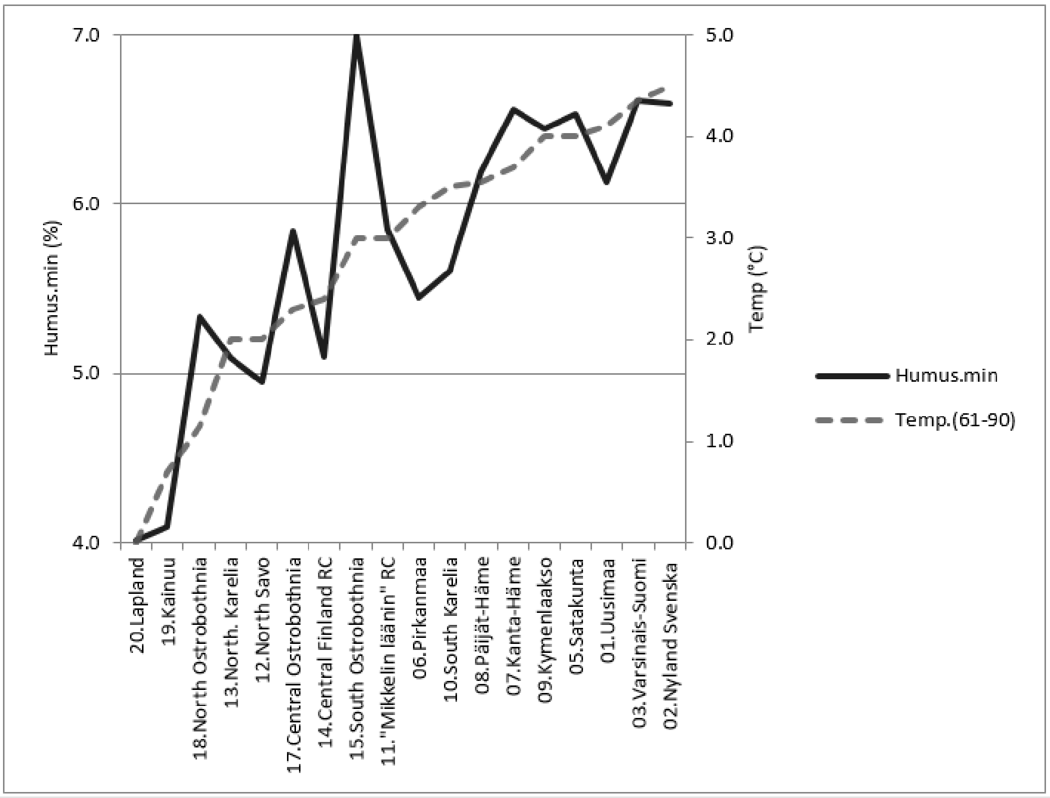

Figure 14: [Humus.min.60's] and Temp.(61-90).

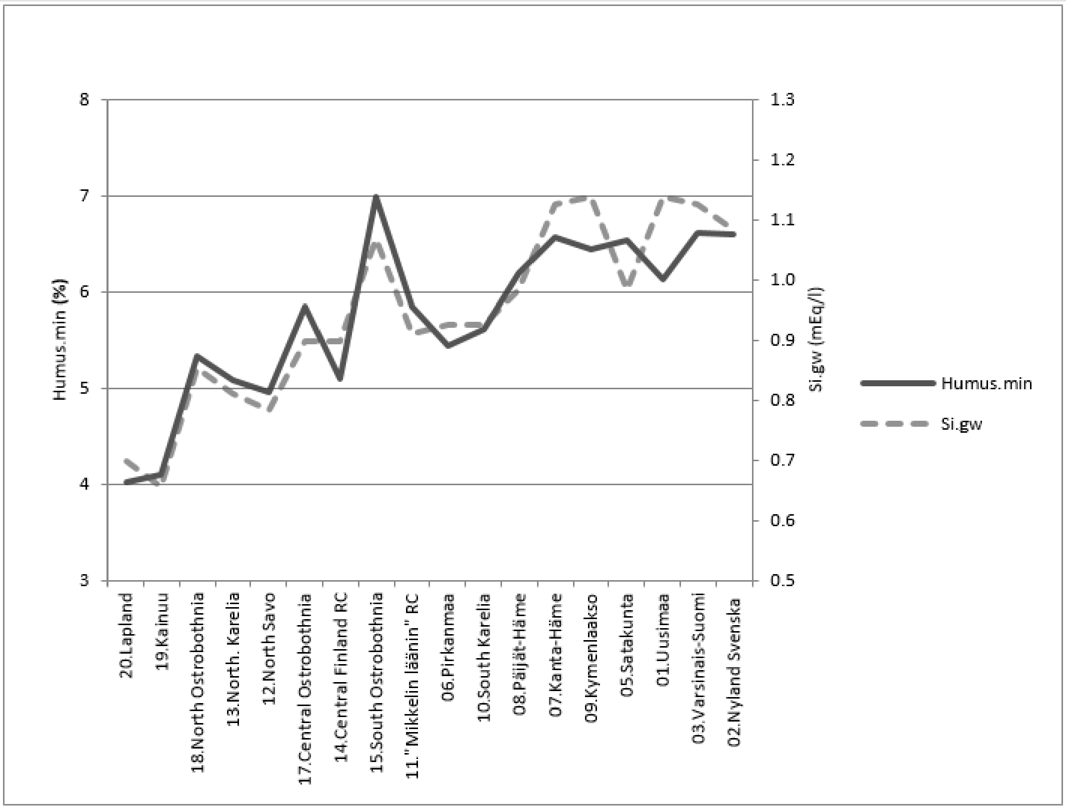

Figure 15: Association between [Humus.min] and [Si.gw].

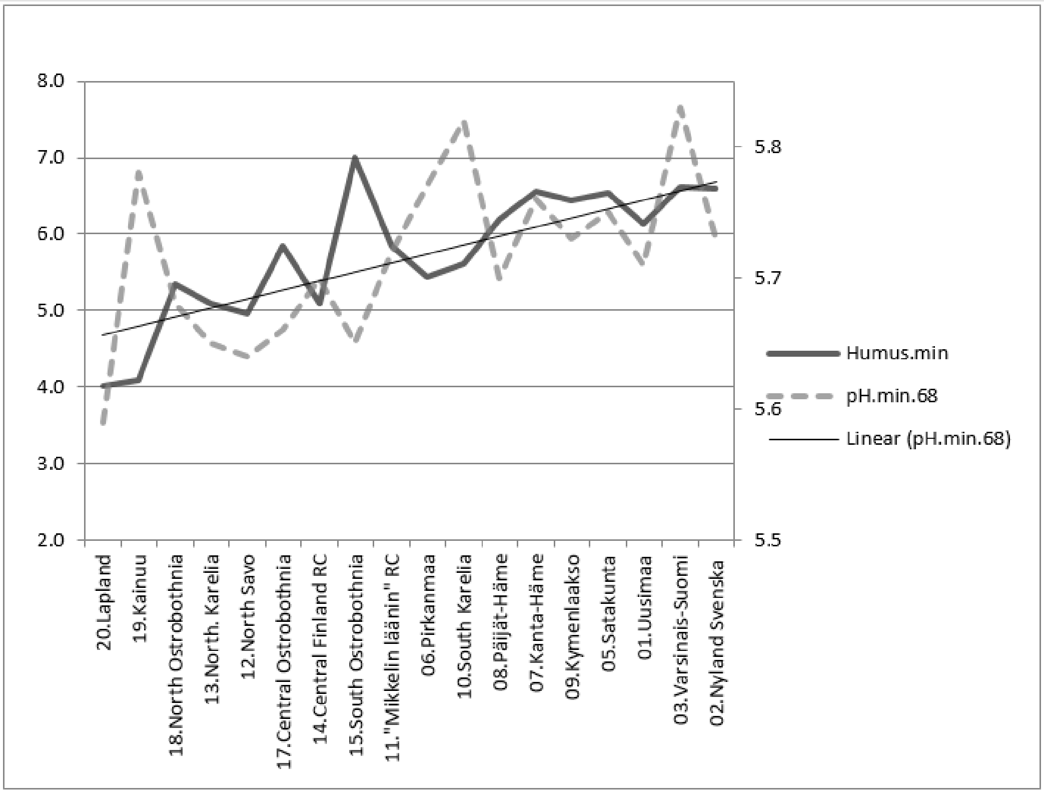

Figure 16: Association between [Humus.min] and [pH.min.68].

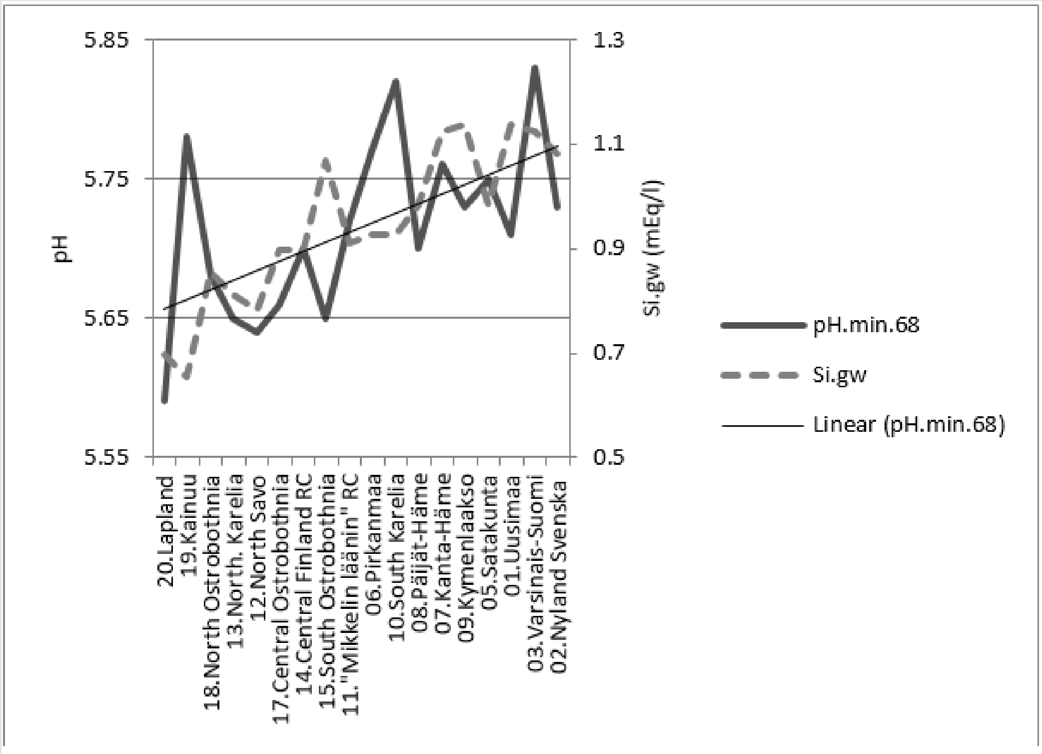

Figure 17: Association between [pH.min] and [Si.gw].

Discussion

[Humus.min] (SOC) was significantly explained by factors associated with weathering (Table 2), (Figures 3-6). [Humus.min] was best explained by [Si.gw] (84 %). Changes in [pH.min] and [Temp] predicted 7.3 % reduction in [Humus.min] for 20 years. [pH.min.68] was explained significantly positively by weathering factors [Temp], [Prp.(clays/fims).68] and [(Ca+Mg+K).min.68]. Prerequisites for antacid production [1], maintenance of pH, in non-carbonate soils are - as generally in chemical reactions - temperature and proper substrates: Silicates are the real natural liming agents - with pH ad 9.5 [22]. [(Ca+Mg+K).min] and [Si.gw] are obviously mainly signs of preceding chemical reaction. Anyhow some oligomers of Si.gw, [= $H4SiO4$, $Si(OH)4$], with pK 6.8 [23,24] can work as buffers and liming agents in Finnish cropland soils where pH was and is below 6.8 [13,14,25]. (Figures 9-12) represent combined pH regressions by [Humus.min], [Temp] and/or [Si.gw]. Figures represent experiments for predicting pH-value for two different decades by the same equation. Agricultural soil gets acids not only via atmospheric CO2: plant roots [26] and many micro-organisms excrete acids [27], which can promote silicate weathering and carbon capture.

Humus contains even humic acids [28], with can have buffer abilities [29]. Possibly silicon/silicon compounds work as matrix for formation of humic acids [30]. By maintenance of soil humidity [6] the soluble silicates can protect soil against erosion. (Obviously too effective ditching could promote erosion and via humus loss elevate pH (Figure 9). Significant association of [Prp.(fims/min).68] with [Humus.min] (Figure 6) is in concordance with Heikkinen, et al. [5] who found that clay soils resisted best carbon loss or even could increase carbon binding independently on soil management [5]. Relative periodical stability in inter-regional pH values (Figure 11) is not fully explained. The data above suggests that it could be dependent on different regional speed of weathering: high values in weathering factors (low values in Lat) suggest on moderately fast weathering of solid silicates, associated with [Si.gw] and [(Ca+Mg+K)] formation. If the relative difference in weathering factors remains for decades the same, so the relative difference is expected to be the same in humus content and Si.gw. Anyhow, as old farmers said: the soil can get “tired”, which suggests that methods in represented in [3] are obviously worth trying. Inter-periodical difference in [Humus.min] was explained 7 % by changes in temperature and pH (Figure 4).

Other predictions (Figures 6 & 9-12) are made by suppositions. Prediction of pH seems to need additional factors as: changes in soil liming and changes in structural and biological humus characteristics, possibly changes in acid rain, although it is not supported by the approximated linear reduction [5]. Inter-dependence of [Temp], [Humus.min], [Si.gw] and [pH] are represented in (Figures 14-17). Although humus content increases soil pH, in the micro-milieu of the roots, where the carbon capture occurs, the pH can be above the general level. The scanty examples suggest that predicting [pH.min.68] by [pH.min.88] and the average inter-periodical difference gives better estimates than via predicting [pH.min.88] by [pH.min.68], possibly depending on higher number of samples from “88” and shorter time to 1999 (time point, when groundwater samples were collected). Possibly plant available Si was changed inter-periodically, too.

Lower humus contents in [16] (to [20]) can be dependent on lower temperature in carbon determination (“hehkutuskevennys”-“glow lightening”): “not over 550 °C” (Virpi Saksa, Eurofins, personal communication), contra 1370 °C in [20].

The original data [16], which includes data on mull (mm) and peat (tm) soil samples and excluded RC’s (Finska Hushållningss., Österbottens Sv., and Åland) is attached by courtesy of Eurofins Viljavuuspalvelu Oy, for clarity. In 1960’s parts of nowadays Lapland (Peräpohjola and Lappi) were separate. Humus.min for Lapland has been calculated by weighting the occurence values by the number of samples (Table 3).

Table 3: Soil ratios by region based on 1961-1970 fertility surveys. Percentage of different soil categories. The humic acid content is determined in Gegenden. Der Anteil der Humusgehaltskalassen in Prozent.

Alue Gebiet	Nayueita probem	vm	m	rm	crm	mm	tm
Uudenmaan MK	53839	2.6	54.5	23.5	3.4	13.4	2.6
Nylands Sv. LBS	29982	2.1	50.9	31.6	4.4	8.7	2.3
Varsinais-Suomen MK	69209	3.2	49.4	29.3	5.4	9.4	3.3
Finska Hushallningss	7348	2.1	53.4	31.8	3.3	7.6	1.8
Satakunnan MK	80375	3.9	40.4	23.2	4.7	18.4	9.4
Pirkanmaan MK	39927	7.7	55.3	18.5	1.6	13.1	3.8
Hämeen I. MK	53072	3.0	43.9	28.6	3.8	15.7	5.0
Itä- Hämeen MK	40156	3.2	49.0	26.8	2.3	11.8	6.9
Kymenlaakso	25486	3.1	44.5	24.4	4.1	14.5	9.4
Etelä-Karjala	38161	6.8	43.6	17.1	1.9	19.3	9.9

Mikkelin I. MK	49082	5.6	43.6	21.0	1.7	9.5	18.6
Kuopion I. MK	71107	12.4	46.8	12.0	1.4	17.6	9.8
Pohjois- Karjalan MK	41437	14.3	40.2	12.7	2.3	13.0	17.5
Keski- Suomen MK	60463	10.7	47.0	12.1	1.8	17.4	11.0
Etelä- Pohjanmaan MK	56489	5.0	26.3	22.2	5.4	28.2	12.9
Osterbottena Sv. LBS	22071	7.5	31.5	20.9	3.7	19.8	16.6
Keski- Pohjanmaan Mk	24874	8.4	30.7	15.3	2.9	18.8	23.9
Oulu	40171	10.5	29.3	11.3	2.2	17.6	29.1
Kainuun Mk	13687	20.5	30.8	6.6	0.7	8.9	32.5
Peräpohjola	9599	18.2	22.7	6.1	0.9	8.2	43.9
Lappi	2021	23.7	21.7	3.3	0.2	2.2	48.9
Aland	4987	5.2	63.9	23.3	1.3	4.7	1.6
Koko maa	833543	6.9	43.1	20.3	3.1	15.4	11.2

Conclusion

Factors indicating silicate weathering predicted regional humus content, pH and their changes in mineral soils, best humus content. Different continuous silicate weathering possibly explains the stable relative difference in regional pH values. Increase in silicate weathering rate can reduce atmospheric and increase soil carbon content.

Acknowledgement

I am grateful to Professor Osmo Hänninen and late veterinary surgeon Seppo Haaranen for several discussions.

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ISSN: 2574-1241

DOI: 10.26717/BJSTR.2021.35.005655

Töysä T. Biomed J Sci & Tech Res

Submission Link: https://biomedres.us/submit-manuscript.php