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Regional Groundwater Hardness and Silicon, Cropland Fertility and CHD in Finland

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Abstract

Abstract: The status of silicon (Si) in agriculture, veterinary and human medicine is not clear. This survey is based on old data, but groundwater (from springs and dugwells) data have been newly classified by 21 Rural Centers (RC). RC CHD has been estimated by provincial data. The aim of this paper is to clarify associations between CHD mortality, groundwater (GW) hardness (Ca+Mg), Si.gw, cropland (soil) (Ca+Mg) - a measure of soil fertility - and, pH and temperature (Temp) with regional parameters [latitude (Lat), longitude (Long)]. Regressions are given separately for the whole Finland ("21.RC") and continental Finland ("20.RC"), i.e. without Åland - the only RC with pH.soil > 6.2. Directions of trend lines of variables have been approximated.

Results: CHD regressions by Si.gw, by (Ca+Mg).gw and by (combined) [Lat; Long], (Ca+Mg).gw regressions by (Ca+Mg).soil and by [Lat; Long] and, Si.gw regressions by (Ca+Mg).gw, by [Lat; Long], by [Temp;(Ca+Mg).soil] and by [Temp;pH.soil] have been computed. In RC.20 all associations were significant ($p < 0.018$). In RC.21 all regressions without Si.gw were stronger than in RC.20, but by including Si.gw associations were weaker with one exception: [Temp; pH.soil] explained Si.gw stronger than in RC.20. The approximated CHD trend line angle was smaller than the respective angles of Si.gw and (Ca+Mg).

Conclusion: In RC.20, where soil pH was below 6.2, Si.gw and (Ca+Mg).gw were highly positively inter-correlated and soil fertility could be predicted by regional Si.gw. In RC.20 regression by Si.gw explained better CHD than by (Ca+Mg).gw. Supposedly the health effects of Si could be mediated directly through (soluble) Si in soil and via factors associated with (Ca+Mg). In regional gw analyses the effect of (mother earth) pH needs attention.

Introduction

The role of silicon as a protective mineral element against biotic and a biotic stresses is not generally known [1] in spite of increasing data. Weak plant, animal and human tissues are vulnerable to bacteria, fungi, parasites and degeneration. In the common medical practice associations of Si is in general known as an inert or harmful (by its crystals). The aim of this study is to assess associations between regional CHD mortality, cropland parameters, gw hardness and (soluble) silicon, temperature and geographic location, in order to find, whether Si could explain the "hard water effects".

Materials and Methods

Groundwater parameters are from Groundwater database © Geological Survey of Finland 2017 [2] as in my earlier publications. They are newly grouped by 21 Rural Centers (earlier Agricultural Advisory Centers). Soil values are from Viljavuuspalvelu Eurofins Oy [3] concerning only from period 1986-90. CHD mortality data of middle-aged men are from Valkonen and Martikainen (1990) [4] and their RC values are estimated as earlier in [5]. Latitude and longitude of each RC have been determined in two-phases: first by selecting approximately a central commune/town of each RC in the map [6] and then by opening its internet page, which gave the latitude and longitude of its center. Temperatures are approximated visually by the map [6] and the map of Finnish meteorogical institute [7]. Åland is in some registers a part of Finska Hushållningssällskapet. That's why "04.b" label has been given for it. The benefited data are in Table 1.

Table 1: Location, soil and groundwater Ca, Mg and soil pH of Finnish Rural Centers.

Location, soil and groundwater Ca, Mg and soil pH of Finnish Rural Centers											
	Central Commune/ Town	CHD	Latitude	Longitude	Ca.soil	Mg.soil	K.soil	Ca.gw	Mg.gw	pH.soil	Temperature

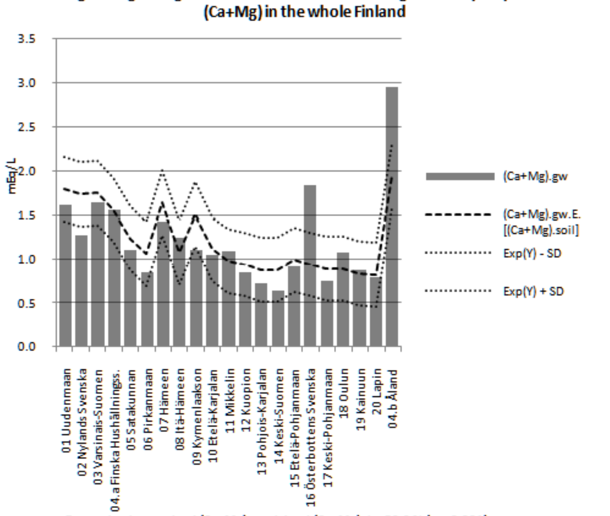
		1/100,000	(^{0}N)	(^{0}E)	mEq/L						^{0}C
01 Uudenmaan	Järvenpää	447	60.5	25.1	101	5.54	34.2	1.03	0.601	5.96	4.9
02 Nylands Svenska	Espoo	447	60.2	24.7	103	5.88	27.2	0.89	0.379	6.10	5.1
03 Varsinais-Suomen	Aura	386	60.7	22.6	104	5.52	27.6	1.05	0.601	6.13	5.0
04.a Finska Hushållningss.	Nauvo	386	60.2	21.9	100	6.06	19.3	0.97	0.601	6.19	5.3
05 Satakunnan	Noormarkku	386	61.6	21.9	79	3.98	17.6	0.82	0.288	5.92	4.5
06 Pirkanmaan	Ylöjärvi	407	61.6	23.6	69	3.31	15.7	0.59	0.263	5.94	4.1
07 Hämeen	Renko	414	60.9	24.3	95	4.83	28.3	0.89	0.543	6.01	4.6
08 Itä-Hämeen	Asikkala	454	61.2	25.5	71	4.04	14.5	0.88	0.362	5.96	4.3
09 Kymenlaakson	Anjalankoski	511	60.8	26.8	90	4.61	25.9	0.79	0.321	5.90	4.6
10 Etelä-Karjalan	Jouseno	531	61.1	28.5	75	3.78	14.3	0.76	0.296	5.86	4.1
11 Mikkelin	Juva	564	61.9	27.9	68	2.77	11.4	0.84	0.247	5.99	3.8
12 Kuopion	Maaninka	622	63.2	27.5	62	3.00	14.6	0.65	0.206	5.86	3.0
13 Pohjois-Karjalan	Kontiolahti	515	62.8	29.9	60	2.75	12.9	0.55	0.181	5.82	2.8
14 Keski-Suomen	Saarijärvi	370	62.7	25.3	59	2.65	13.1	0.49	0.156	5.89	3.2
15 Etelä-Pohjanmaan	Nurmo	370	62.8	22.9	63	3.21	16.3	0.68	0.247	5.75	3.4
16 Österbottens Svenska	Mustasaari	519	63.1	21.7	60	3.54	16.1	1.26	0.584	5.70	4.1
17 Keski-Pohjanmaan	Toholampi	553	63.8	24.3	57	2.60	16.8	0.56	0.189	5.69	2.8
18 Oulun	Ylikiiminki	529	65.0	26.2	55	2.75	18.4	0.79	0.280	5.69	1.8
19 Kainuun	Ristijärvi	265	64.5	28.2	54	2.62	15.7	0.67	0.214	5.82	1.7
20 Lapin	Rovaniemi	447	66.5	25.7	51	2.28	17.4	0.56	0.230	5.59	0.5
04.b Åland	Maarianhamina	447	60.1	19.9	135	3.85	10.9	2.74	0.222	6.31	5.3

Mean number of GW samples per RC was ca 35, SD ca 21.5. From "04.a Finska Hushållningss." were available only 2 or 3 samples, from "04.b Åland" 6 samples, from "16 Österbottens Svenska" 11 samples and from "06 Pirkanmaan" 13 samples. Low number of samples can cause big statistical error, but anyhow the RC springs and dugwells represent larger areas than single cropland samples. Number of cropland samples was ca 620,000 [8]. Regressions were calculated by IBM SPSS. Direction of geographic trend vectors for CHD, gw Si and gw (Ca+Mg) are estimated by tangent function of Excel by the coefficients of latitude ("c.lat") and longitude ("c. long") from the combined regressions. Because 10 ^{0}E (longitude) responds only ca 5 ^{0}N (latitude) in kilometers "c. long" has been divided by 2. So vector angle in radians = ATAN2 (½*c.long;c.lat). "In Fig. 5 - 8 values of angles are given in degrees."

Results

Fig. 1 and Fig. 2: Regression by cropland (Ca+Mg) explained about equally (46-63 %) and very significantly (p < or = 0.001) GW hardness in the whole and continental Finland. Stronger in the whole Finland.

Fig. 1. Regional groundwater hardness and its regression by cropland (Ca+Mg) in the whole Finland



Regression by cropland (Ca+Mg) explained (Ca+Mg). by 53.2 % (p < 0.001). Coefficient direction (+)

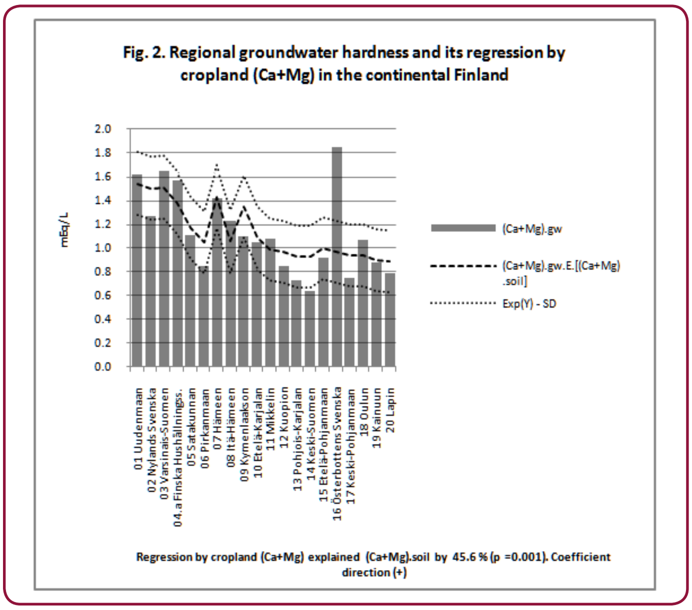


Fig. 2. Regional groundwater hardness and its regression by cropland (Ca+Mg) in the continental Finland

Regression by cropland (Ca+Mg) explained (Ca+Mg).soil by 45.6 % (p =0.001). Coefficient direction (+)

Fig.3 and Fig. 4: Regression by (Ca+Mg).gw explained gw Si variation only by 7 % (ns) in the whole Finland, but 62 % ($p < 0.001$) in the continental Finland.

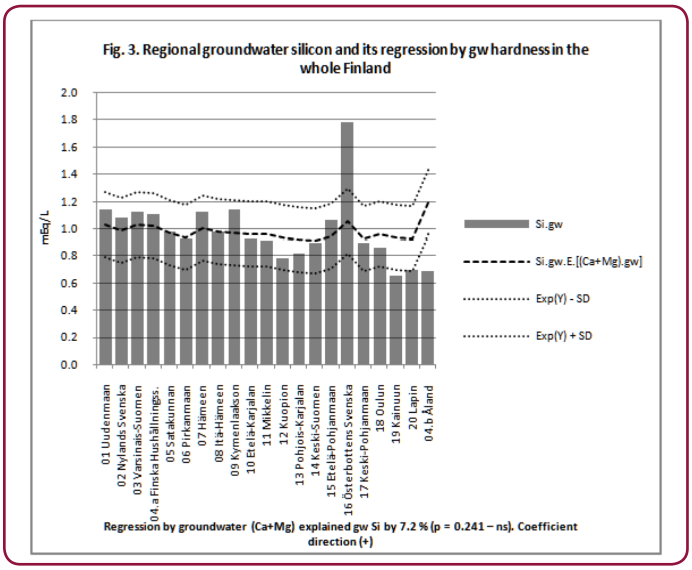


Fig. 3. Regional groundwater silicon and its regression by gw hardness in the whole Finland

Regression by groundwater (Ca+Mg) explained gw Si by 7.2 % (p = 0.241 – ns). Coefficient direction (+)

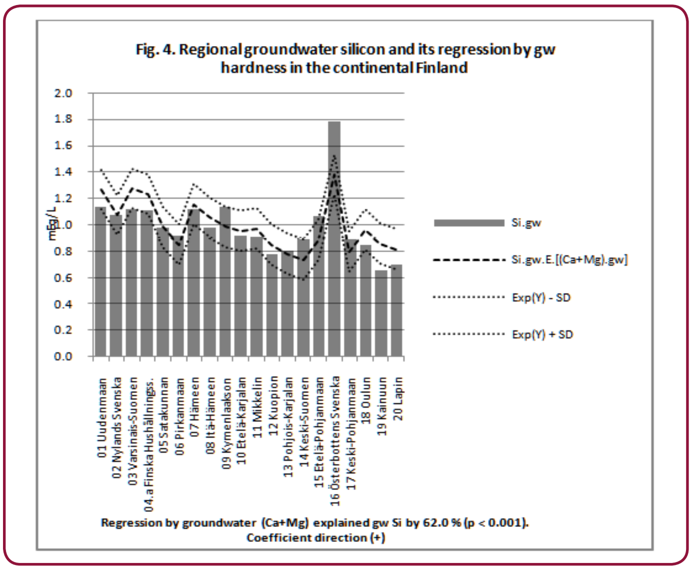


Fig. 4. Regional groundwater silicon and its regression by gw hardness in the continental Finland

Regression by groundwater (Ca+Mg) explained gw Si by 62.0 % (p < 0.001). Coefficient direction (+)

Fig. 5 and Fig. 6: Combined regression by latitude and longitude explained CHD mortality by 93 % ($p < 0.001$) in the whole Finland, respectively in continental Finland by 91 % ($p < 0.001$). CHD trend vector showed 36^0 towards the NE by both.

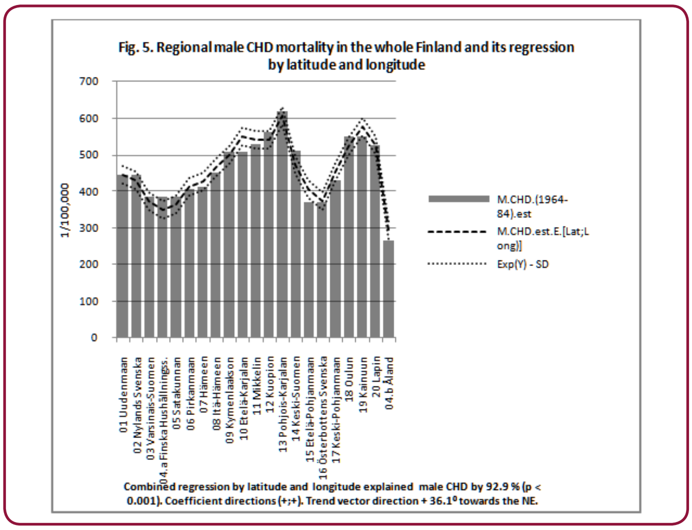


Fig. 5. Regional male CHD mortality in the whole Finland and its regression by latitude and longitude

Combined regression by latitude and longitude explained male CHD by 92.9 % (p < 0.001). Coefficient directions (+;+). Trend vector direction + 36.1⁰ towards the NE.

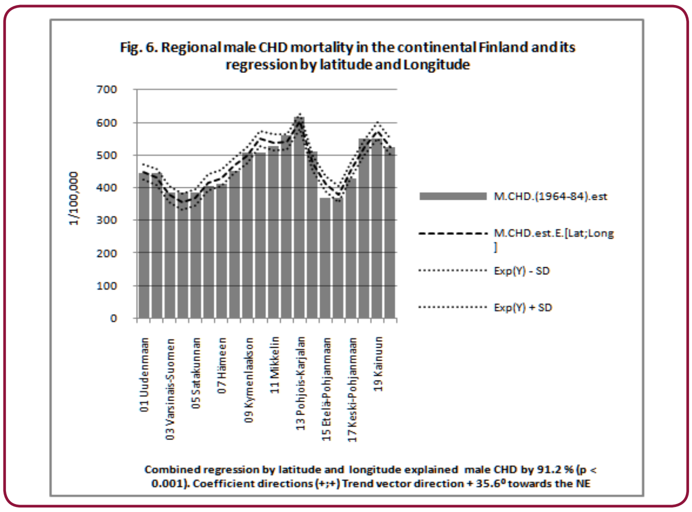


Fig. 6. Regional male CHD mortality in the continental Finland and its regression by latitude and Longitude

Combined regression by latitude and longitude explained male CHD by 91.2 % (p < 0.001). Coefficient directions (+;+) Trend vector direction + 35.6⁰ towards the NE

Fig. 7 and Fig. 8: Combined regression by latitude and longitude explained Si gw in the whole Finland by 19 % (ns), but by 44 % (p = 0.007) in the continental Finland. Trend axis deviations from the horizontal line ($57\text{-}62^0$) were higher than by CHD.

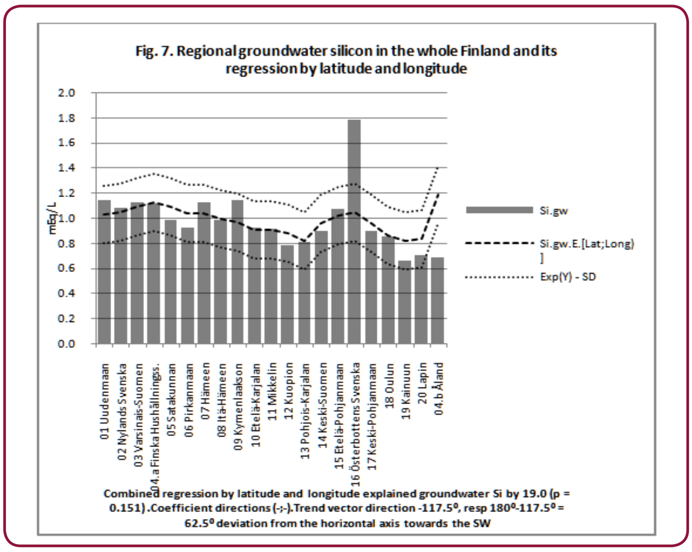


Fig. 7. Regional groundwater silicon in the whole Finland and its regression by latitude and longitude

Combined regression by latitude and longitude explained groundwater Si by 19.0 (p = 0.151) .Coefficient directions (-;-).Trend vector direction -117.5⁰, resp 180⁰-117.5⁰ = 62.5⁰ deviation from the horizontal axis towards the SW

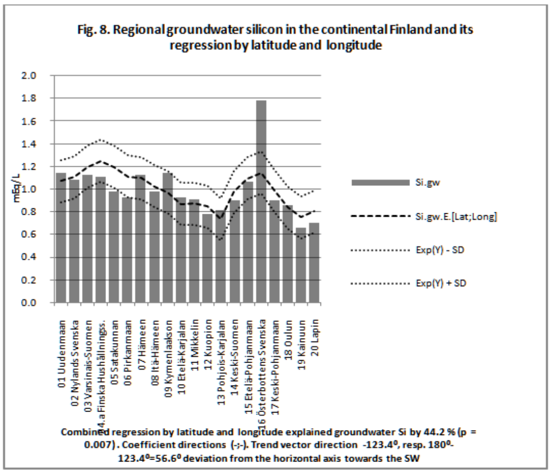


Fig. 8. Regional groundwater silicon in the continental Finland and its regression by latitude and longitude

Combined regression by latitude and longitude explained groundwater Si by 44.2 % (p = 0.007). Coefficient directions (-;-). Trend vector direction -123.4^0, resp. 180^0-123.4^0=56.6^0 deviation from the horizontal axis towards the SW

Fig. 9 and Fig. 10: Combined regression by latitude and longitude explained (Ca+Mg).gw in the whole Finland by 53 % (p = 0.001), respectively by 45 % (p = 0.006) in the continental Finland. Trend axis deviations from the horizontal line (64-70)^0 were higher than respective deviations by CHD and Si.

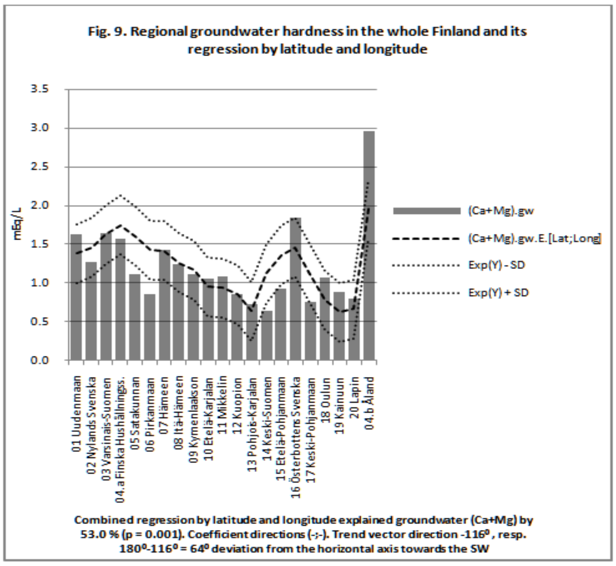


Fig. 9. Regional groundwater hardness in the whole Finland and its regression by latitude and longitude

Combined regression by latitude and longitude explained groundwater (Ca+Mg) by 53.0 % (p = 0.001). Coefficient directions (-;-). Trend vector direction -116^0, resp. 180^0-116^0 = 64^0 deviation from the horizontal axis towards the SW

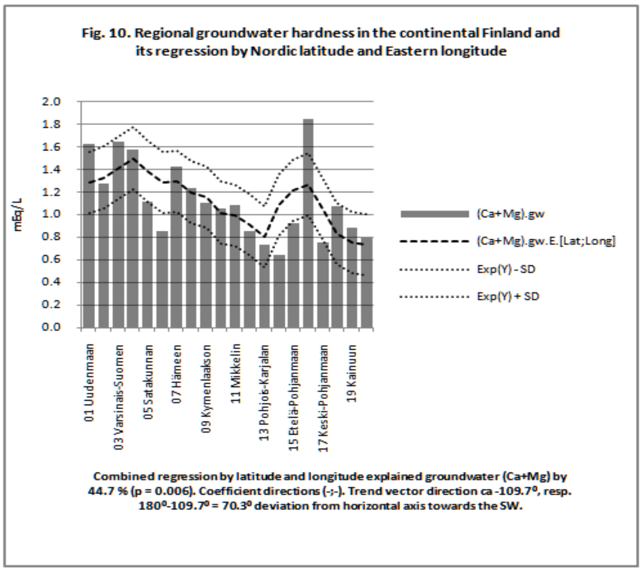


Fig. 10. Regional groundwater hardness in the continental Finland and its regression by Nordic latitude and Eastern longitude

Combined regression by latitude and longitude explained groundwater (Ca+Mg) by 44.7 % (p = 0.006). Coefficient directions (-;-). Trend vector direction ca -109.7^0, resp. 180^0-109.7^0 = 70.3^0 deviation from horizontal axis towards the SW.

Fig. 11 and Fig. 12: Combined regression by Temp and cropland pH explained gw Si about equally (by 66-68 %, p < 0.001 or p = 0.001) in the whole and continental Finland. Coefficient directions (+;-).

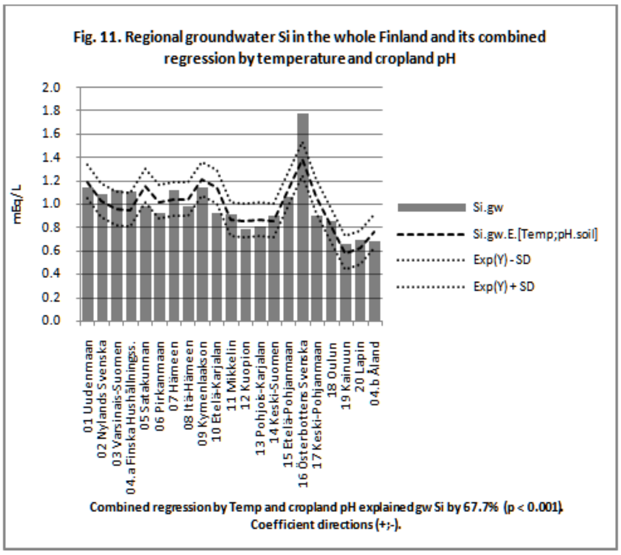


Fig. 11. Regional groundwater Si in the whole Finland and its combined regression by temperature and cropland pH

Combined regression by Temp and cropland pH explained gw Si by 67.7% (p < 0.001). Coefficient directions (+;-).

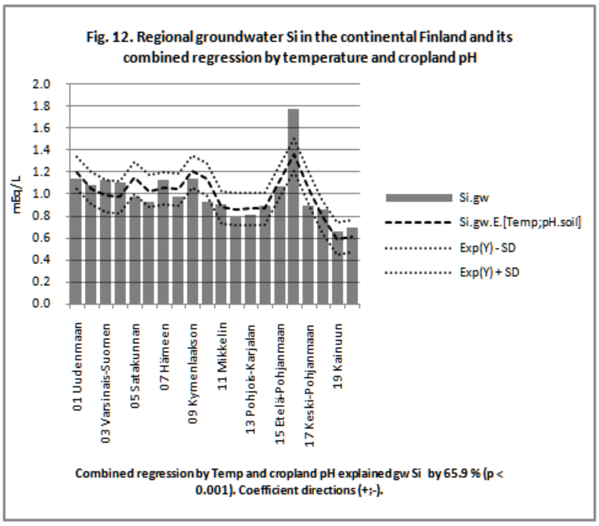


Fig. 12. Regional groundwater Si in the continental Finland and its combined regression by temperature and cropland pH

Combined regression by Temp and cropland pH explained gw Si by 65.9 % (p < 0.001). Coefficient directions (+;-).

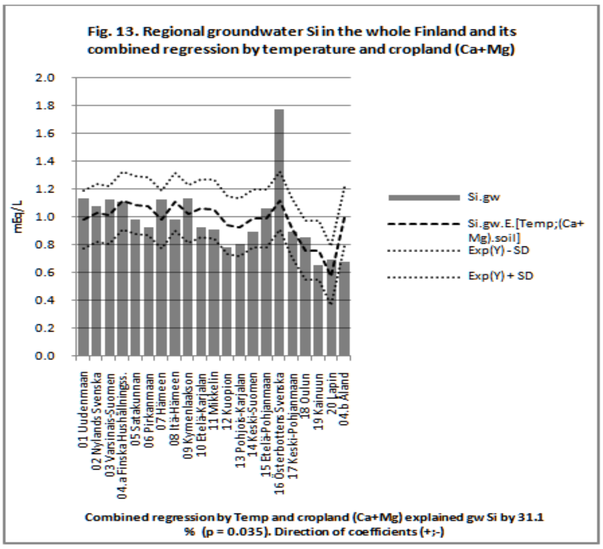


Fig. 13. Regional groundwater Si in the whole Finland and its combined regression by temperature and cropland (Ca+Mg)

Combined regression by Temp and cropland (Ca+Mg) explained gw Si by 31.1 % (p = 0.035). Direction of coefficients (+;-)

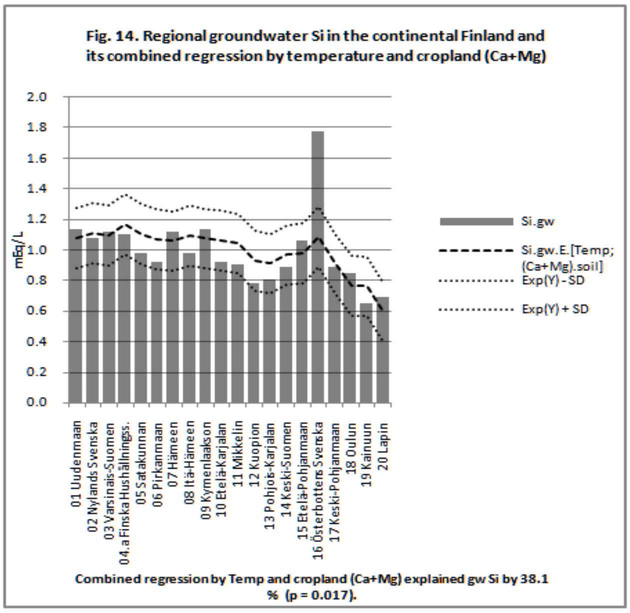


Fig. 13 and Fig. 14: Combined regression by Temp and cropland (Ca+Mg) explained Si.gw in the whole Finland by 31.1 % ($p < 0.035$), respectively in the continental Finland by Si by 38.1 % ($p < 0.017$).

Discussion

(Ca+Mg) of cropland can be seen as a measure of soil fertility, because cropland (Ca+Mg) and (Ca+Mg+K) are generally highly associated (R square > 0.95, from Table 1). Åland was the only RC, where mean (Ca+Mg).gw (1,48 mmol/L) (Table 1) exceeded the lower limit of "hard water" (1.21 mmol/L, i.e. = 2.42 mEq/L) [9]. In Åland CHD mortality was the lowest in Finland (Table 1). Only in Åland the mean soil pH (6.31) (Tabl.1) was within the carbonate buffer range (over 6.2) [10] (Table 2). This could explain low "soluble" Si, possibly without indicating as low Si availability to plants. The soil pH in the immediate vicinity of the plant roots can be different to those from soil analyses. It can be in silicate buffer range, although macroscopic pH is in the carbonate buffer range. In combined regression by [Temp; pH.soil] pH increase indicated decrease in Si.gw, too (Table 3).

Table 2: Summary of essential results.

Summary of Essential Results						
		Whole Finland			Continental Finland	
Dependent variables	Independent variables	R square	Sign	R square comparison	R square	Sign
CHD.est	Si.gw	0.15	0.082	<	0.43	0.002
CHD.est	(Ca+Mg).gw	0.52	< 0.001	>	0.35	0.006
CHD.est	[Lat;Long]	0.93	< 0.001	"="	0.91	< 0.001
Si.gw	[Lat;Long]	0.19	0.151	<	0.44	0.007
(Ca+Mg).gw	[Lat;Long]	0.53	0.001	>	0.45	0.006
[(Ca+Mg).gw]	(Ca+Mg).soil	0.53	< 0.001	>	0.46	0.001
Si.gw	(Ca+Mg).gw	0.07	0.241	<	0.62	< 0.001
Si.gw	[Temp;pH.soil]	0.68	< 0.001	>	0.66	< 0.001
Si.gw	[Temp;(Ca+Mg).soil]	0.31	0.035	<	0.38	0.017

Table 3

	pH
Silicate buffer	5.0 – 6.2
Carbonate buffer	6.2 – 8.0

In Åland Ca/Mg equivalent ratio of cropland was the highest (12.4), about the same as in GW (12.3) From Table 1. (In the UK hard water Ca/Mg equivalent ratio was ca 7, about 3-fold to respective value of soft water [11]. Possibly because of mother soil included clay soil-types, too. Anyhow Mg deficiency is known to be very uncommon on carbonate soils [12], possibly because of different micro-milieu of roots. In Åland GW Si content (0.68 mEq/L) was below the inter-RC mean (0.98) (Table1). In the UK hard water Si (1.15 mEq/L) was 2.3-fold to the soft water content [11]. This can be dependent on e.g. statistical error (in Finland) and/or mixture of different mother soil-types in the UK. Post-glacial earth elevation [13,14] (Figure 15) can partially explain the soil juvenility of the western Finnish regions. Lower Nordic values can additively be explained by lower temperature, which is associated not only with weathering activity, but some more rapid inorganic phenomenons, too (Figure 15). 10,000 years erosion, temperature and soil history can explain mortality and mineral element gradient towards north-east (Figure 15) is skizze from [13].

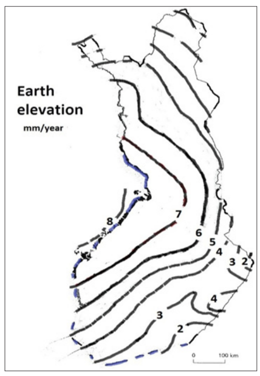


Figure 15: shows the speed of post-glacial earth elevation in different parts of Finland.

Conclusion

In RC.20, where soil pH was below 6.2, Si.gw and (Ca+Mg).gw were highly positively inter-correlated and soil fertility could be predicted by regional Si.gw. In RC.20 regression by Si.gw explained better CHD than by (Ca+Mg).gw. Supposedly the health effects of Si could be mediated directly through (soluble) Si in soil and via factors associated with (Ca+Mg). In regional gw analyses the effect of (mother earth) pH needs attention.

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   Ca: ”http://www.viljavuuspalvelu.fi/index.php?id=107-> Taulukko 5.

   K: ”http://www.viljavuuspalvelu.fi/index.php?id=107-> Taulukko 6.

   Mg: ”http://www.viljavuuspalvelu.fi/index.php?id=107-> Taulukko 8.

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