

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 their RC values approximated by the principles as earlier presented [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 meteorological 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: Rural centers with central communes, male CHD mortality in 1964-84, THL, CHD index, Latitude, Longitude, and annual rainy days in 1981-2010, Altitude and groundwater silicon.

Regions (Rural Center)	Central Commune	CHD. (1964-84)	CHD. (2000-14)	Latitude	Longitude	Altitude	Rainy Days	Si.gw
		1/100,000	THL.index	°N	°E	(m)	d/a	mEq/L
Uusimaa (01; 02)	Järvenpää; Espoo	447	78.0	60.4	24.9	39	182	1.12
Varinais-Suomi (03;04.a)	Aura;Nauvo	386	87.4	60.6	22.5	48	170	1.12
05 Satakunnan	Noormarkku	386	91.4	61.6	21.9	44	165	0.98
06 Pirkanmaan	Ylojarvi	407	92.4	61.6	23.6	107	181	0.93
07 Hameen	Renko	414	89.1	60.9	24.3	107	190	1.12
08 Ita-Hameen	Asikkala	454	106.2	61.2	25.5	74	186	0.98
09 Kymenlaakson	Anjalankoski	511	97.0	60.7	26.8	18	195	1.14
10 Etela-Karjala	Jouseno	511	129.8	61.1	28.5	80	200	0.93
11 Mikkelin	Juva	531	124.9	61.9	27.9	98	195	0.91
12 Kuopion	Maaninka	564	135.5	63.2	27.3	88	200	0.78
13 Pohjios-Karjalan	Kontiolahti	622	122.9	62.8	29.8	138	195	0.81
14 Keski-Suomen	Saarijarvi	515	106.0	62.7	25.3	140	190	0.90
15 Etela-Pohjanmaan	Nurmo	370	100.6	62.8	22.9	47	183	1.07
16 Osterbottens Svenska	Mustasaari	370	98.3	63.1	21.7	15	160	1.78
17 Keski- Pohjanmaan	Toholampi	432	117.6	63.8	24.3	94	173	0.90
18 Oulun	Ylikiiminki	553	121.8	65.1	26.4	85	185	0.85
19 Kainuun	Ristijarvi	553	141.0	64.5	28.2	160	210	0.65
20 Lapin	Rovaniemi	529	127.8	66.5	25.7	92	195	0.70
04.b Aland	Maarianhamina	265	98.6	60.2	19.9	11	165	0.68

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 Exel by the coefficients of latitude ("c.lat") and longitude ("c.long") from the combined regressions. Because 10°E (longitude) responds only ca 5°N (latitude) in kilometers "c.long" has been divided by 2. So vector angle in radians = $\text{ATAN2}(\frac{1}{2} \cdot \text{c.long}; \text{c.lat})$. 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 ($p < 0.001$) GW hardness in the whole and continental Finland. Stronger in the whole Finland.

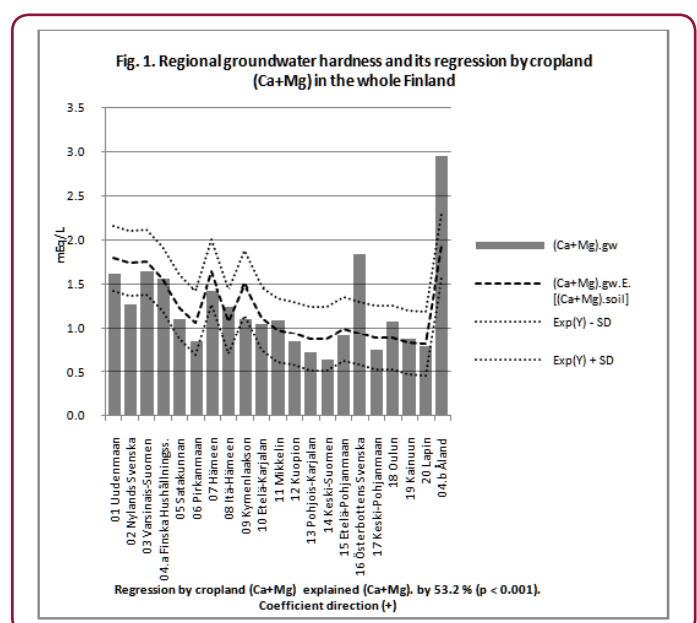


Fig. 2. Regional groundwater hardness and its regression by cropland (Ca+Mg) in the continental Finland

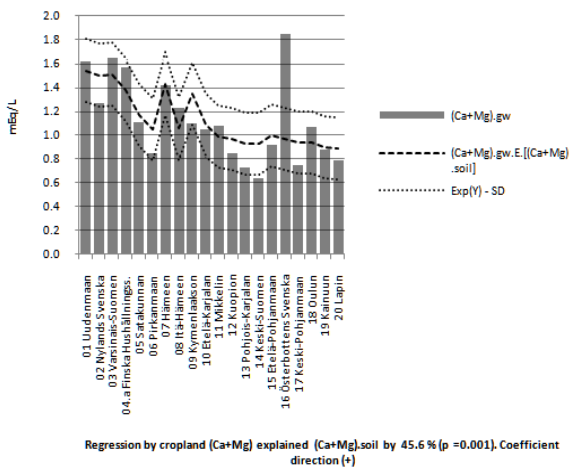


Fig.3 and Fig. 4: Regression by (Ca+Mg).gw explained gw Si variation only by 7 % (ns) in the whole Finland, but 62 % ($p < 0.001$) in the continental Finland.

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

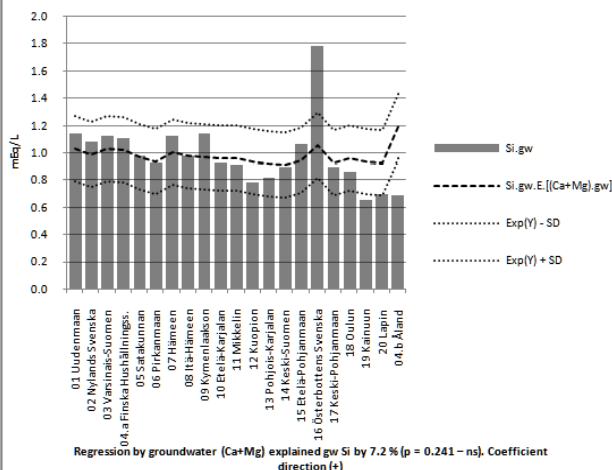


Fig. 4. Regional groundwater silicon and its regression by gw hardness in the continental Finland

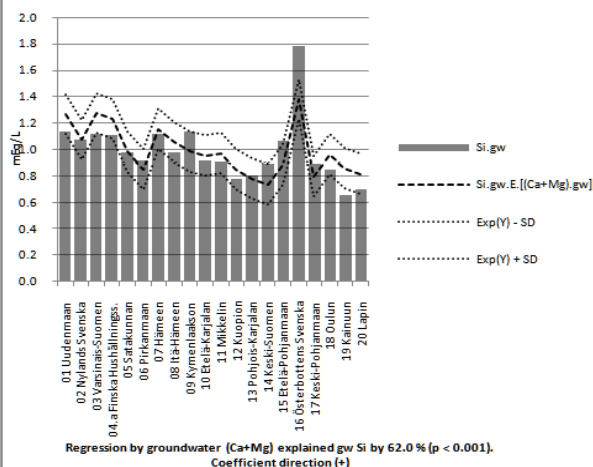


Fig. 5 and Fig. 6: Combined regression by latitude and longitude explained CHD mortality by 93 % ($p < 0.001$) in the whole Finland, respectively in continental Finland by 91 % ($p < 0.001$). CHD trend vector showed 36° towards the NE by both.

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

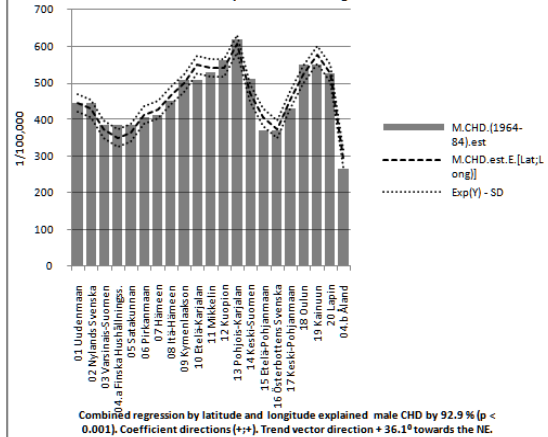


Fig. 6. Regional male CHD mortality in the continental Finland and its regression by latitude and longitude

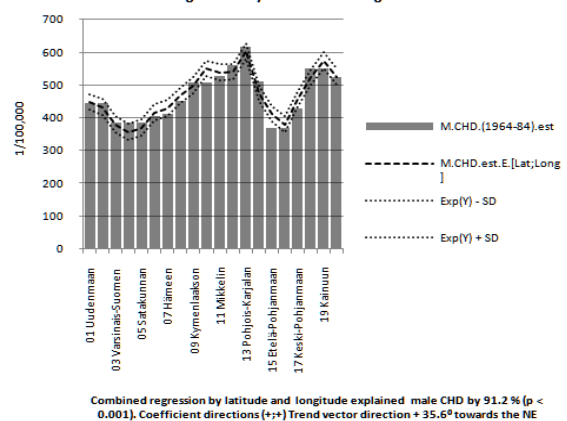
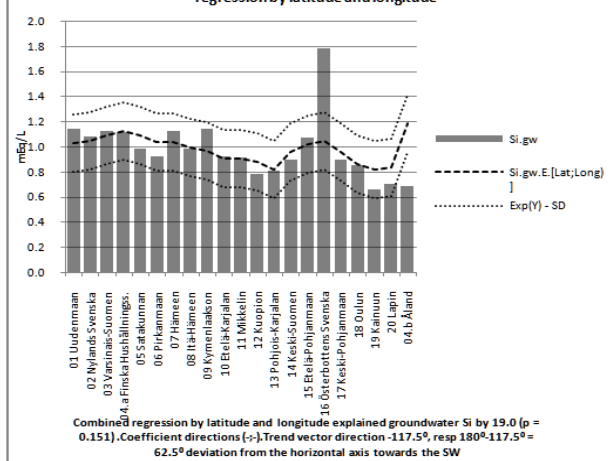


Fig. 7 and Fig. 8: Combined regression by latitude and longitude explained Si gw in the whole Finland by 19 % (ns), but by 44 % ($p = 0.007$) in the continental Finland. Trend axis deviations from the horizontal line ($57-62^\circ$) were higher than by CHD.

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



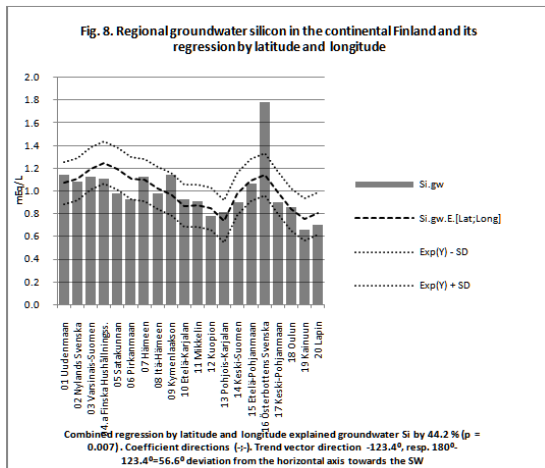


Fig. 9 and Fig. 10: Combined regression by latitude and longitude explained (Ca+Mg).gw in the whole Finland by 53 % ($p = 0.001$), respectively by 45 % ($p = 0.006$) in the continental Finland. Trend axis deviations from the horizontal line $(64-70)^\circ$ were higher than respective deviations by CHD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

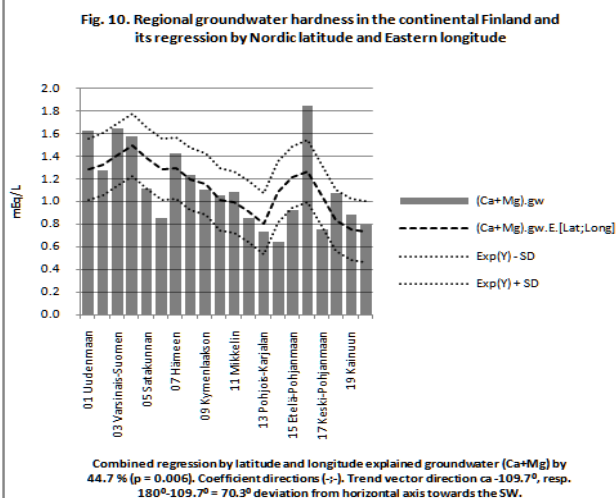
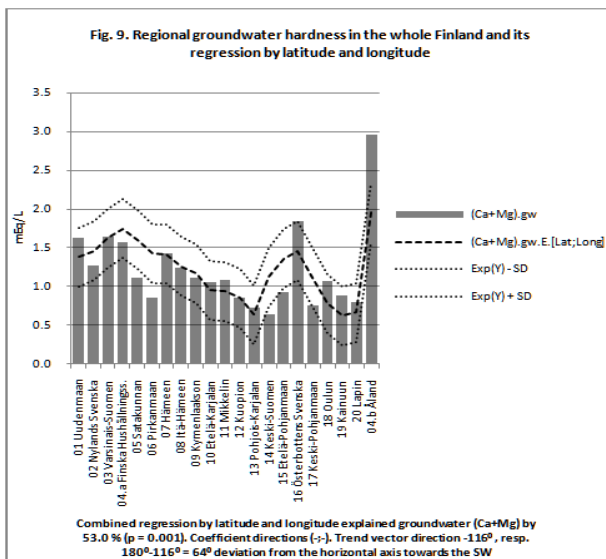
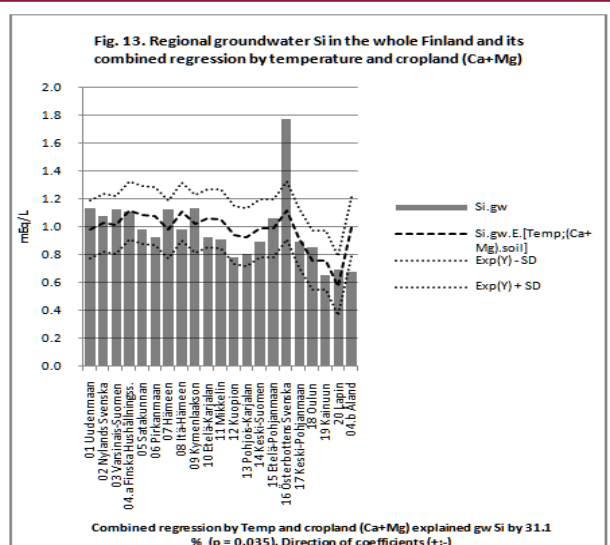
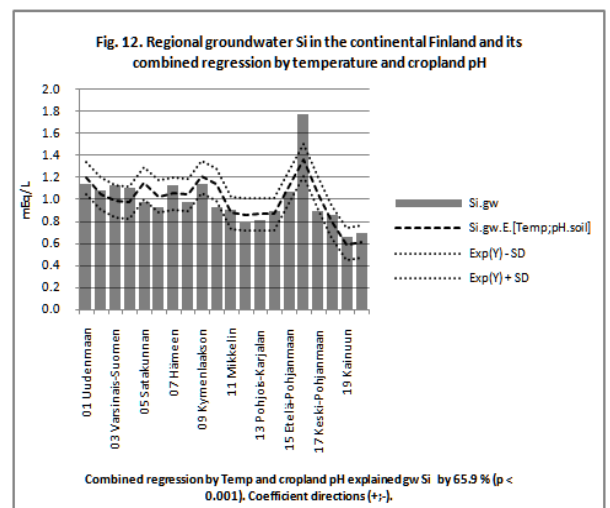
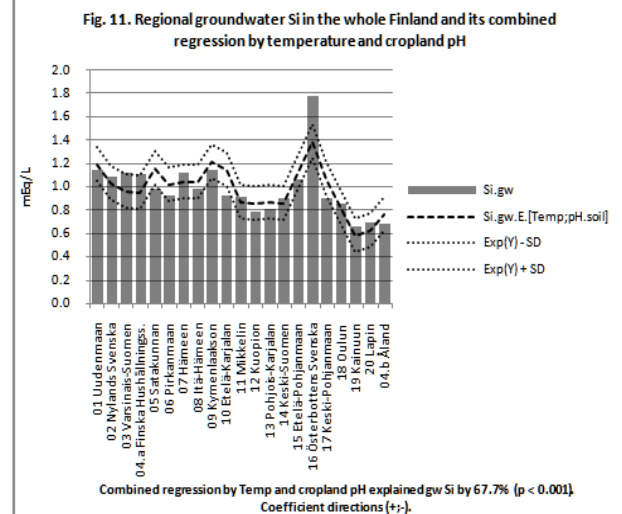


Fig. 11 and Fig. 12: Combined regression by Temp and cropland pH explained gw Si about equally (by 66-68 %, $p < 0.001$ or $p = 0.001$) in the whole and continental Finland. Coefficient directions (+;-).



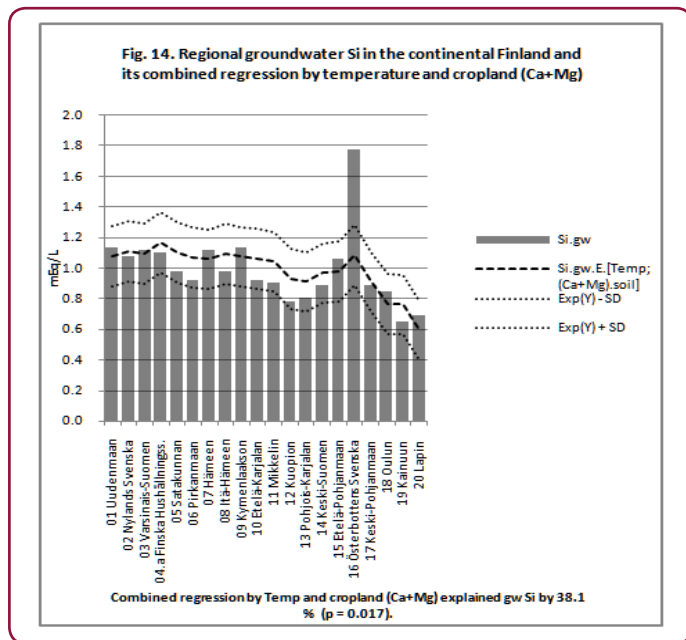


Table 2: Summary of essential results.

Summary of Essential Results						
Dependent variables	Independent variables	Whole Finland		R square comparison	Continental Finland	
		R square	Sign		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

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).

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].

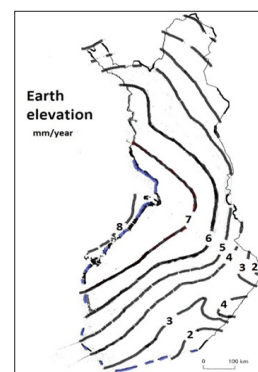


Figure 15: shows the speed of post-glacial earth elevation in different parts of Finland.

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.

Acknowledgement

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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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