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Soil Weathering, Silicon and CHD in Finland

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Abstract

Conventional risk factors cannot satisfactorily explain the geographic risk of coronary heart disease (CHD). There are plenty of reports on statistical associations between CHD and drinking-water element contents. The idea for this study came from geology, where the weathering rate from forest soils has been estimated by using a model that uses parameters effective temperature sum (ETS) and concentrations of Ca and Mg in till fraction < 2 mm.

Methods

We benefited provincial parameters: CHD mortality of men, groundwater (gw) silicon , Ca and Mg concentrations of groundwater, agricultural coarse mineral soils without silts (coms), silts (silt), clays (clay), organic (org) and of all agricultural soil-types (tot), potassium [K.tot] , [pH.tot] and mean annual temperatures [Temp]. Agricultural soil values, totaling ca 620,000 samples, were collected from 21 Rural Centers (RC). Via weighting these soil values by cultivated land areas of RCs in each province we got provincial soil values. Mainly we assessed the usefulness of parameters: [Temp], [(Ca+Mg)] of different soil-types in explaining CHD, [Si.gw], [(Ca+Mg).gw] and [pH.tot] variation.

Results

(Regression by) [Temp; (Ca+Mg).coms] explained variation in CHD by 66 % ($p = 0.008$), in [(Ca+Mg).gw] by 96 % ($p < 0.001$), in [pH.tot] by 86 % ($p < 0.001$) and in [Si.gw] by 64 % ($p = 0.010$). Respective associations of [Temp; (Ca+Mg).tot] were weaker, but significant.

Conclusion

Similar parameters as benefited in evaluation of weathering rate, mean annual temperature and (Ca+Mg) of agricultural (especially coarse mineral) soil, explained significantly provincial variation in CHD, [Si.gw], [(Ca+Mg).gw] and [pH.tot]. This suggests on the role of agricultural soil, its potency to liberate mineral elements like Si, in epidemiology of CHD, as well as on potential benefits of recycling minerals in food chain.

Introduction

The CHD risk in the East Finland has been ca 35 % higher than in West Finland between 1973 and 1997 [1]. Smoking, blood pressure, cholesterol, high-density lipoprotein cholesterol, diabetes, height, body mass index and family history of CHD and socioeconomic status have explained this difference only by 40 % [2]. This suggests on necessity of additional explaining factor(s). A common trend has been to explain different regional cardiovascular risks by water quality, e.g. drinking water hardness [3], in practice by the sum of Ca and Mg [4], but by other mineral elements, too [5]. Highly significant inverse association between drinking-water Ca and cardiovascular, as well as total mortality of middle-aged men and women has been reported from the UK, while the associations of Mg were negligible [6]. But in Finnish countryside high Ca/Mg ratio of groundwater has been associated with increased CHD risk [7]. Despite of significant statistical associations between water hardness and cardiovascular diseases, causal associations have been suspected [8]. Direct Analyses of foodstuffs – i.e. not determined with aid of food composition tables - have shown no significant differences in their Ca nor Mg contents between eastern and western parts of Finland [9]. Provincial timothy Mg/Ca ratio has explained less than 1 % of CHD variance in continental Finland. [10].

Because Si is one of the candidates for “water factor” [5,6], we decided to assess it as a function of weathering rate, with similar parameters as in geology applied for forest soils. In geology the best preliminary estimations of weathering rate of soils has been obtained by using a model that uses ETS and parameters of “coarse till fraction” (in practice the sum of (in strong) acid soluble Ca and Mg concentrations in < 2.0 mm till fraction). The use of “fine mineral fraction” (fraction < 0.06 mm) has generally resulted in over-estimation of weathering rate [11]. In this study we benefited mainly parameters of mean annual temperature [Temp] and sum of exchangeable Ca and Mg of coarse mineral soils, [(Ca+Mg).coms], as such or by replacing the latter by [(Ca+Mg)] of other soil-types. These parameters were applied in predicting provincial CHD, [(Ca+Mg).gw], [pH.tot] and [Si.gw]. In discussion we assess the associations of weathering rate with soil-type distribution and Si uptake by plants.

Materials and Methods

Provincial age adjusted CHD of 35-64 y. old men (1/100,000), (three years sliding means from 1964-84) were obtained from Valkonen and Martikainen [12] (Tabl. 1). Provincial values of Si.gw, Ca.gw and Mg.gw of total 735 captured springs and dug wells from 1999, was provided by Geological Survey of Finland (GSF) [13] (Tabl. 1 and 3). The lowest number of samples was 6 (Åland), second lowest 50 (Vaasa).

Total 621,134 samples with concentrations of exchangeable (soluble) Ca, Mg and K of 22 soil-types from cultivated fields separately from 21 Rural Centers (RC, earlier Agricultural Advisory Centres) are from Eurofins Viljavuuspalvelu Oy [14]. Soil analyses were determined by using acetic acid ammonium acetate buffer (0.5 M, pH 4.65) [15]. Soil values of the provinces were determined by weighting the soil values of RCs by their areal proportions of cultivated land in each province. For this we benefited catalogue of Official Statistics of Finland (OSF) [16], which includes a map with boarders of RCs and municipalities and another map including boarders of provinces and municipalities [17]. In order to separate the similar names of provinces and RCs, the provincial names are in general attached with a prefix number from a map in Wikipedia [18] (e.g. 01.Uusimaa) and RCs with a different type prefix number from the map [16], e.g. (01).Uudenmaan. Labels for RC names are given as in catalogue text of OSF [16]. In this catalogue [16] the municipalities of 03.Åland are included in (04).Finska Hushållningss. A second catalogue of Eurofins Viljavuuspalvelu Oy [19] was useful in determining the names of the municipalities of Finska Hushållningss., which are included in Åland, “(04.b).Finska Hushållningss.” Area of Åland was calculated by using these names and OSF catalog [16]. After subtracting it from Finska Hushållningss gave the area of “(04.a). Finska Hushållningss.” By these data [16-19] we got the following areal weights for calculating provincial values (Table 1).

Values of different soil types were combined [Moraines (mor): SrMr (Gravel moraine), HkMr (Sand moraine), HtMr (Fine sand moraine), HsMr (Silt moraine); Coarse mineral soils (coms): Moraines + KHk (Coarse sand). HHk (Sand), KHt (Fine sand), HHt (Finer fine sand); Silt soils: Hs (silt); Clay soils: SMr (Clay moraine), HtS (Sand moraine), HsS (Silty Clay), AS (Heavy clay), LjS (Gyttja clay); Organic soils: all the others]. (Table 5). Western and eastern provinces determined as by Pajunen et al. [1].

Names and location of the provincial residence cities were determined by benefiting the maps and data earlier mentioned [17,18]. Provincial annual temperatures (Temp) were determined by the locations of the residence cities with map of Finland [17] and the map of FMI [20] by gross visual interpolation between the temperature zones (Table. 2).

Table 1. Cultivated land of Finland 1988. Provinces, proportions of Rural Centers inside them with exceptional municipalities.

Provinces	1,000 ha	1,000 ha	Rural Centers (with municipalities) and their area (ha) of cultivated land
		131.453	(01).Uudenmaan
01.Uusimaa	201.492	70.039	(02).Nylands Svenska
		233.233	(03).Varsinais-Suomen
		17.324	(04a).Finska Hushållningss. (Non-Åland municipalities: Dragsfjärd, Houtskari, Iniö, Kemiö, Korppoo, Nauvo, Parainen, Västanfjärd)
		171.758	(05).Satakunnan
02.Turku_and_Pori	448.798	26.483	(06a).Pirkanmaan (Turku_and_Pori municipalities: Hämeenkyrö, Ikaalinen, Pirkanmaa)
03.Åland	10.842	10.842	(04b).Finska Hushållningss. [Åland proportion: Total - (04a).Finska Hushållningss.]
		75.139	(06b).Pirkanmaan [04.Häme proportion: Total - (06a).Pirkanmaan]
		150.205	(07).Hämeen
04.Häme	266.871	41.527	(08.a).Itä-Hämeen [04.Häme proportion: Total - (08.b).Itä-Hämeen -(08c). Itä-Hämeen]
		83.946	(09).Kymenlaakson
05.Kymi	146.305	62.359	(10).Etelä-Karjalan
		90.672	(11).Mikkelin läänin
06.Mikkeli	106.568	15.896	(08.b).Itä-Hämeen (06.Mikkeli municipalities: Hartola, Heinola, Heinolan mlk, Sysmä)
07.Northern_Karelia	100.514	100.514	(13).Pohjois-Karjalan
08.Kuopio	145.97	145.970	(12).Kuopion läänin
		94.472	(14).Keski-Suomen
09.Central_Finland	102.07	7.598	(08c).Itä-Hämeen (09.Central_Finland municipalities: Joutsa, Kuhmoinen, Luhanka)
		256.657	(15).Etelä-Pohjanmaan
		103.446	(16).Österbottens Svenska
10.Vaasa	405.847	45.744	(17a).Keski-Pohjanmaan [Vaasa proportion: Total - (17b).Keski-Pohjanmaan]
		23.689	(17b).Keski-Pohjanmaan (11.Oulu municipalities: Kalajoki, Reisjärvi, Sievi)
		177.024	(18).Oulun 177,024,
11.Oulu	240.987	40.274	(19).Kainuun 40,274)
12.Lapland	53.004	53.004	(20).Lapin läänin 53,004
Total	2229.268	2229.268	

Table 2. Finnish provinces 1988, their residence cities, age adjusted CHD mortality of 35-64 y. old men in 1964-84, (Ca+Mg) and Si in groundwater (gw), pH of all soil types (pH.tot) , mean annual temperatures (Temp) 1981-2010, (Ca+Mg+K).tot, (Ca+Mg) of agricultural clay, silt, coarse mineral (coms), organic, as well as of all soil-types (tot).

Some data is discussion has been given with symbol '*', i.e. can be calculated from the data of this table.

			Dependent				Independent							
Location in Finland	Province	Residence City	CHD	(Ca+Mg).gw	Si.gw	pH.tot	Temp	(Ca+Mg+K).tot	(Ca+Mg).clay	(Ca+Mg).silt	(Ca+Mg).coms	(Ca+Mg).org	(Ca+Mg).mor	(Ca+Mg).tot
			1/100,000	mmol/l	mg/l		°C	meq/l	meq/l	meq/l	meq/l	meq/l	meq/l	meq/
West	03_Åland	Mariehamn	265	1.48	4.82	6.31	5.3	149	173	225	130	215	152	145
	10_Vaasa	Vaasa	370	0.53	8.28	5.73	4.1	81	90	81	71	94	68	78
	02_Turku_and_ Pori	Turku	386	0.71	7.48	6.04	5.2	120	134	103	93	112	85	115
	04_Häme	Hämeenlinna	414	0.62	7.39	5.99	4.5	111	146	95	79	137	72	107
	01_Uusimaa	Helsinki	447	0.79	7.62	6.01	5.2	139	146	102	98	141	93	134
East	05_Kymi	Kouvola	511	0.54	6.92	5.88	4.6	108	142	90	83	118	74	104
	09_Central Finland	Jyväskylä	515	0.35	6.22	5.90	3.6	76	81	78	64	100	60	74
	12_Lapland	Rovaniemi	529	0.4	4.91	5.59	0.5	71	0	73	61	79	63	69
	06_Mikkeli	Mikkeli	531	0.57	6.64	5.98	3.9	83	83	82	73	120	71	80
	11_Oulu	Oulu	553	0.5	5.47	5.71	2.2	76	87	81	65	88	67	73
	08_Kuopio	Kuopio	564	0.43	5.52	5.86	3.1	80	3.1	84	85	67	64	100
	07_Northern Karelia	Joensuu	622	0.37	5.61	5.82	3.0	76	3.0	84	79	62	62	100
	Inter-provincial mean		**476**	**0.61**	**5.90**	**6.41**	**98**	**3.8**	**104**	**98**	**79**	**117**	**78**	**94**

Results

Temp explained 41 % ($p = 0.024$), [(Ca+Mg).tot] 55 % ($p = 0.006$), [(Ca+Mg).coms] 65.1 % ($p = 0.002$) and [(Ca+Mg).mor] 59.3 % ($p = 0.003$) of variation in CHD (Tabl. 3). [(Ca+Mg).coms] explained best the variation in CHD and [pH.tot]. Variation in [(Ca+Mg).gw] was best explained by [(Ca+Mg).mor]. Si.gw associated nearly significantly with Temp ($p = 0.051$), but insignificantly with [(Ca+Mg)] values.

Table 3. Proportions (%) of inter-provincial variations in CHD, [(Ca+Mg).gw], [pH.tot] and [Si.gw] explained by [Temp], [(Ca+Mg).tot], [(Ca+Mg).coms], and [(Ca+Mg).mor].

	CHD	[(Ca+Mg).gw]	[pH.tot]	[Si.gw]
[Temp]	41	36	68	33
[(Ca+Mg).tot]	55	75	70	4
[(Ca+Mg).coms]	65.1	93	75	0.2
[(Ca+Mg).mor]	59.3	98.3	65	3

Figure.1 shows proportional CHD mortality, (Ca+Mg) in clay, silt, organic and coarse mineral soils, as well as in soils all soil-types and mean annual temperature in 1981-2010.

Figure 2. provides regressions of CHD by [Temp;(Ca+Mg).coms] and by [Temp;(Ca+Mg).tot].

(In these as in the following figures the provinces are ranked by their increasing CHD mortality.)

Figure.1. Proportional CHD, (Ca+Mg) in different soil-types and temperature of Finnish provinces

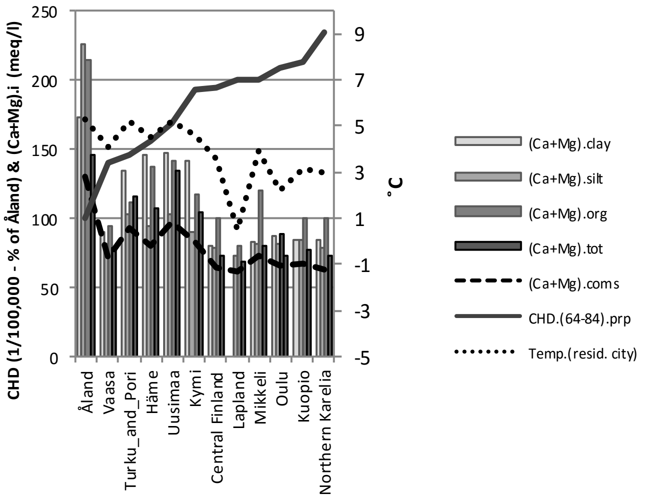
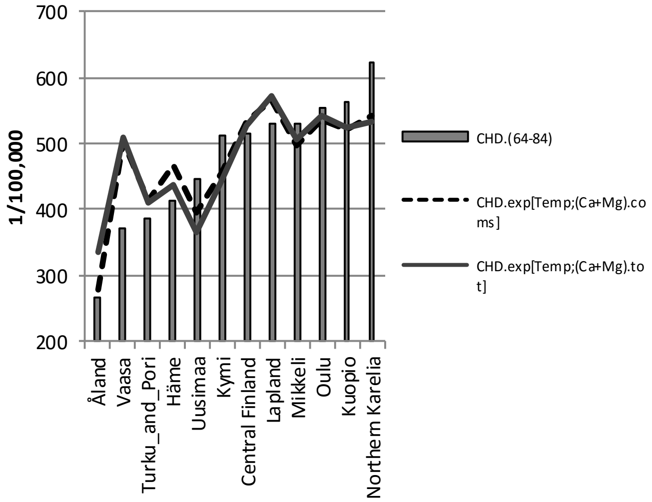


Figure. 2. CHD with regressions by [Temp;(Ca+Mg).coms], and [Temp;(Ca+Mg).tot]



Variation in [(Ca+Mg).gw] was explained 76 % (p = 0.002) by [Temp;(Ca+Mg).tot] and 96 % (p = 0.000) by [Temp;(Ca+Mg).coms] (Fig. 3). [Temp;(Ca+Mg).tot] explained variation in [pH.tot] by 77 % (p = 0.001) and respectively [Temp;(Ca+Mg).coms] by 83 % (p = 0.000). Figure 4.

Figures 3-4. Provide [(Ca+Mg).gw] and [pH.tot] regressions by [Temp;(Ca+Mg).coms] and by [Temp;(Ca+Mg).tot].

Fig. 3. (Ca+Mg).gw with regressions by [Temp;(Ca+Mg).coms] and [Temp;(Ca+Mg).tot]

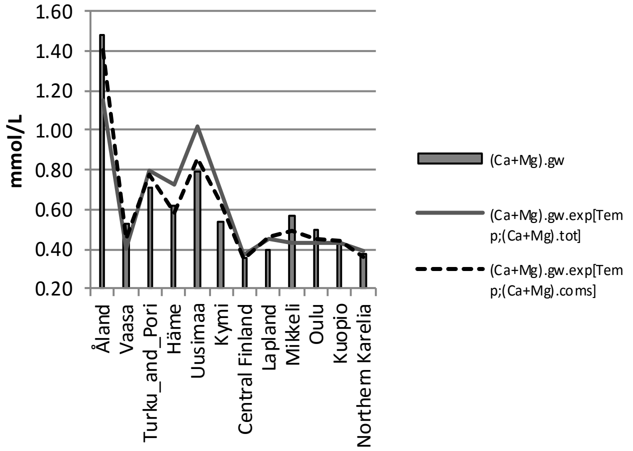
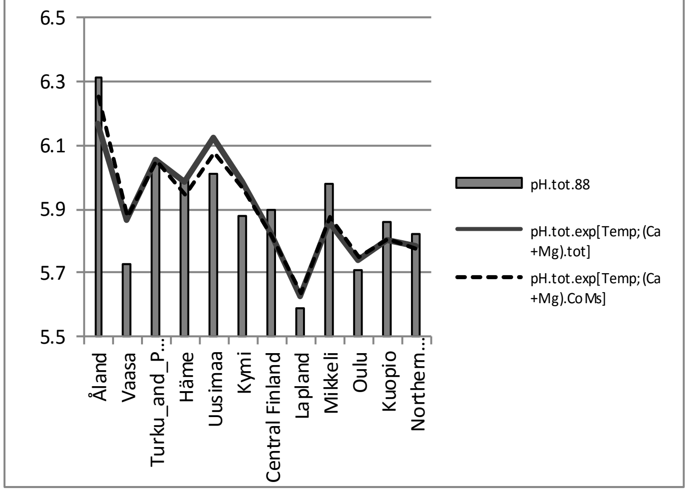


Fig. 4. pH.tot with regressions by [Temp;(Ca+Mg).coms] and [Temp;(Ca+Mg).tot]



[Temp;(Ca+Mg).tot] explained variation in [Si.gw] by 50% (p = 0.046), [Temp;(Ca+Mg).coms] by 64% (p = 0.010) (Fig.5). [Temp;pH.tot] explained variation in [Si.gw] by 83.7 (p = 0.000) (Fig. 6). Si-values form grossly an inverse U-figure (in Fig. 5 and Fig, 6), which explains the negligible direct associations between [Si.gw] and [(Ca+Mg)] of different soil-types (Table 3).

Regressions by [Temp] together with [(Ca+Mg)] of different soil-types explained variation in CHD by 42–66 % and in [(Ca+Mg).gw] by 49–96 % (Table.3). The strength of these associations increased with increasing coarseness of soil-types in general. Coarseness of soil-types in [Temp;(Ca+Mg)] did not explain the strength of associations with [pH.tot] nor (Si.gw].

Figure 5 shows [Si.gw] regressions by [Temp;(Ca+Mg).coms] and by [Temp;(Ca+Mg).tot].

In Figure 6 we see [Si.gw] regressions by [Temp;pH.tot]

Figure 5. Groundwater Si with regressions by [Temp;(Ca+Mg).tot] and [Temp;(Ca+Mg).coms]

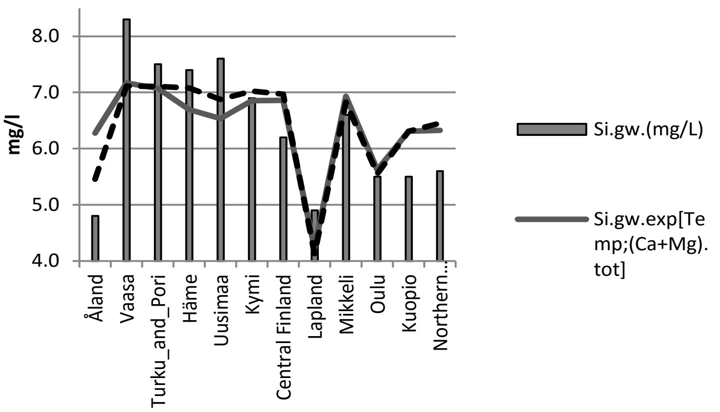


Figure 6. Groundwater Si with regression by [Temp;pH.tot]

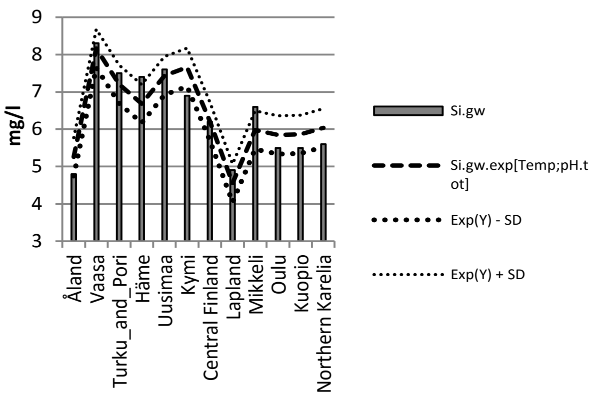


Table 4. Proportions of inter-provincial variations in CHD, [(Ca+Mg).gw], [pH.tot] and [Si.gw] explained by [Temp] combined with [(Ca+Mg)] of different soil-types and groundwater.

	CHD	[(Ca+Mg).gw]	[pH.tot]	[Si.gw]
	%			
[Temp;(Ca+Mg).tot]	56	76	77	50
[Temp;(Ca+Mg).org]	55	88	90	75
[Temp;(Ca+Mg).clay]	42	49	71	49.5
[Temp;(Ca+Mg).silt]	64	94.7	87.3	78
[Temp;(Ca+Mg).coms]	65.7	96	83	64
[Temp;(Ca+Mg).mor]	65.6	98.5	85	71
[Temp;(Ca+Mg).gw]	69.9		84.4	65.2

[Temp;(Ca+Mg).gw] explained variation in CHD, [pH.tot] and [Si.gw] rather similarly as [Temp;(Ca+Mg).coms] and [Temp;(Ca+Mg).mor]. In [Si.gw] regressions by [Temp] and [(Ca+Mg)] of different soil-types coefficients of [Temp] were positive and coefficients of [(Ca+Mg)] always negative.

[Temp;(Ca+Mg).coms] explained variation in [(Ca+Mg).tot] by 93 %. [(Ca+Mg).tot] explained the variation in [(Ca+Mg+K).tot] by 99 % (p = 0.000).

Discussion

This survey revealed that parameters, which are similar to the parameters benefited for evaluation of weathering rate of forest soils, [Temp] and [(Ca+Mg).coms], explained together 65.7 % of regional variation in CHD. This is more than earlier reported [2]. The same factors explained significantly variation in [(Ca+Mg).gw], [Si.gw], [pH.tot] and [(Ca+Mg).tot]. The plain [(Ca+Mg).coms] explained variation in CHD nearly as well as together with [Temp], obviously because it is as such a weathering product of solid particles, and its variation is closely related with [Temp] (with one remarkable exception: Lapland). [(Ca+Mg).gw] reflected ("explained") better the respective sum of coarse mineral elements, than that of finer mineral elements of agricultural soils. This rule worked also with the values of continental Finland (i.e. Åland excluded) (Table. 2*). This resembles the behavior of forest soils, where the weathering rate can be better estimated by the sum of Ca and Mg from “coarse” than “fine” till fractions [11]. The strong association of [(Ca+Mg).mor] with [(Ca+Mg).gw] is as such slightly surprising, because the agricultural fields are a biased sample from Finnish soils and proportion of moraine soils is only 16 % of them and they have been a target of intensive fertilization with universal recommendations at least for sixty years. Possibly this is associated with regional distribution of the “coarse till fraction”. More epidemiological importance is included in association of [(Ca+Mg).coms] with CHD, because (samples of) coarse mineral soils (without silts) compose 51 % total samples.

Calcium, Magnesium in Groundwater, Food and Soil-type

The inter-provincial maximum of Ca (55 mg/l), Mg (6.6) mg/l) and Si (8.3 mg/l) in Finnish gw [13] (Tabl. 5) responded by Ca 3.7 %, by Mg 1.5 % and by Si 29 % of daily allowance in food (1500, 440 and 29 mg, respectively) [21]. The main intake of these mineral elements does not occur via tap-water in Finland. Anyhow this shows that water quality could moderately effect on daily allowance of Si in Finland, as well as in the UK [5,6]. Groundwater was not the only source of tap-water in Finland, so the real variation in drinking-water contents could have been higher. Not direct nor indirect evidence [9,10], has shown significant regional differences in foodstuff Ca or Mg contents between East and West Finland (additional, individual or time-related effects are not disclosed, but are not within the scope of the main topics). Shortly we can note that Ca/Mg in gw was the highest in Åland, 20 mg/l, (carbonate soils), lowest in West Finland, 2.9 – 4.1 mg/l, (high or moderate proportion of clay soils) and slightly higher in East Finland, 4.1 – 5.3 mg/l, (mainly organic and coarse mineral soils) (Tables 4 & 5).

Groundwater Si and Soil pH

Because the regression by [Temp;(Ca+Mg).mor] explained 71 % (p = 0.004) of inter-provincial variation in [Si.gw] and regression by [Temp;pH.tot] even better (84 %) (p = 0.000) (Tabl. 1, Fig. 3, Fig. 6), biases in six samples of gw values from Åland were obviously only moderate. [(Ca+Mg).tot] and [(Ca+Mg).mor] explained ca 40 % of [Si.gw] variation (p < 0.04) in continental Finland (i.e. Åland excluded), but only 3-4 % (insignificantly), when Åland was included*. This could possibly be explained by the silicate–carbonate buffering systems [22] and the difference between the pH values gained by standard soil analyses and those in the colloidal micro-milieu of roots, which are affected by the acidic extracts of plant roots and micro-organisms [23]. In [Si.gw] regressions by [Temp] and [(Ca+Mg)], coefficients of [Temp] were positive and those of [(Ca+Mg)] (like of a substitute of carbonate) negative.

Indirect Evidence on Association of Foodstuff Si with CHD

We have no direct statistics concerning regional Si-contents of plants (or foodstuffs). Indirectly we can estimate proportional Si contents of plants by benefiting the results of a trial carried out by the researchers of Maatalouden Tutkimuskeskus (MTT - Agricultural Research Center).

Via multiplying products (Co.i*Stprp.i) with proportional [(Ca+Mg).i]. – i.e in each soil-type provincial [(Ca+Mg).i] divided by its mean - [(Ca+Mg)].(.i/.µ.i) - we got Si.est2. Because “Co.i”s were determined in “southern and central Finland” – Fin.(S+C) - Si.est2 needed adjustment. Because closer data on location of test fields were not available, values of the Fin.(S+C) were determined as the provincial mean after exclusion of Åland, Oulu and Lapland. By multiplying provincial Si.est2 values by their mean of Southern and Central Finland and dividing it by the mean of the whole Finland we got Si.est3 (%).

Table 5. Provincial groundwater Ca and Mg (mg/l) and their ratios.

		Åland	Vaasa	Turku_and_Pori	Häme	Uusimaa	Kymi	Central Finland	Lapland	Mikkeli	Oulu	Kuopio	Northern Karelia	Inter-provincial mean	Inter-provincial max.
Si.gw	mg/l	4.8	8.3	7.5	7.4	7.6	6.9	6.2	4.9	6.6	5.5	5.5	5.6	6.4	8.3
Ca.gw	mg/l	54.9	15.0	18.8	15.9	20.7	15.5	10.6	11.4	17.5	15.1	13.0	11.1	18.3	54.9
Mg.gw	mg/l	2.7	3.7	5.9	5.5	6.6	3.8	2.0	2.8	3.3	3.1	2.5	2.2	3.7	6.6
Ca/Mg	(mg/l)	20.3	4.1	3.2	2.9	3.1	4.1	5.3	4.1	5.3	4.9	5.2	5.0	5.6	20.3

In a three years trial on 18 fields in "southern and central Finland" – without more precise definition - they measured Si contents of grass (cocksfoot and meadow fescue) by different rates of N-fertilizers on fine mineral soils (including supposedly clay and silt soils as referred in other studies [10]), coarse mineral soils and organic soils [24]. By the sketch (Fig.7) of the figure in [24] it is possible to estimate grossly the Si content of grass in 1964-84, when we know the mean level of nitrogenous fertilization during those years. Mean mineral N-fertilization level (69 kg/ha) was estimated by the statistics of FAOSTAT [25,26] and recycled nitrogen (ca 19 kg/ha) by the data of Sillanpää [27], together 88 kg/ha. Values for 88 kg N/ha have been interpolated and added to Fig.7 by the authors. Result of the estimation: Si % content of grass on fine mineral soils [24] was 1.81 %, on coarse mineral soils 1.31 % and on organic soils 1.11 %. By multiplying these soil-type (i) coefficients (Co.i) by soil-type proportions (Stprp.i) and summing the products we got provincial Si estimates Si.est1 (%).

Figure. 7. Si content of grass by different rates of N-fertilization on fine mineral, coarse mineral and organic soils

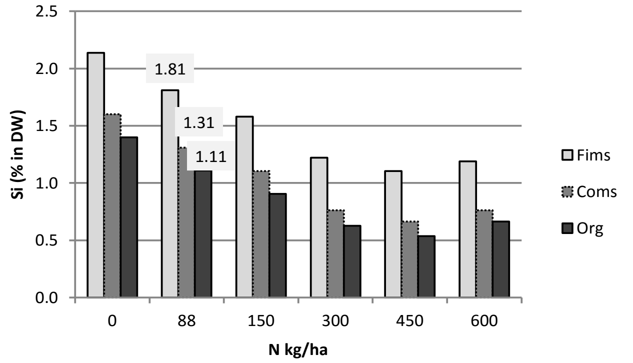


Table 6. Soil-type proportions and estimates of Si content of grass (closer in the text).

	Clay	Silt	Coms	Org	Si estimates		
Coefficients (Si (% in DW) [24]	1.81	1.81	1.31	1.11	est1	est2	est3
					%	%	%
Åland	0.265	0.005	0.683	0.046	1.44	2.38	2.40
Vaasa	0.083	0.016	0.659	0.243	1.31	1.14	1.15
Turku_and_Pori	0.453	0.066	0.361	0.119	1.55	1.87	1.88
Häme	0.220	0.270	0.395	0.115	1.53	1.70	1.71
Uusimaa	0.658	0.071	0.189	0.082	1.66	2.23	2.24
Kymi	0.260	0.083	0.513	0.144	1.45	1.64	1.65
Central Finland	0.002	0.253	0.577	0.168	1.40	1.14	1.15
Lapland	0.000	0.013	0.580	0.407	1.23	0.91	0.92
Mikkeli	0.004	0.056	0.802	0.138	1.31	1.22	1.23
Oulu	0.002	0.041	0.642	0.315	1.27	1.02	1.03
Kuopio	0.000	0.263	0.584	0.153	1.41	1.21	1.22
Northern Karelia	0.000	0.294	0.543	0.163	1.42	1.15	1.15
Inter-provincial mean (μ.prov)	**0.162**	**0.119**	**0.544**	**0.175**	**1.42**	**1.47**	**1.48**
Fin.[S+C] **(μ.prov)**	0.187	0.152	0.514	0.147	1.45	1.48	1.49

Si.est3 explained variation in [(Ca+Mg).gw] by 71 % ($p = 0.001$) (Fig.8) and CHD 51 % ($p = 0.009$). Deviation of curves of Si.est3 and [(Ca+Mg).gw] in Kuopio and Northern Karelia could depend on deficiency of specific Co.i for silt. Combined regressions by [Si.est1;(Clay/Fims)] explained stronger (77 %) CHD variation than [Si.est3;(Clay/Fims)] (71 %). Number of clay samples [14] can underestimate their agricultural area, because generally it is known that their soil values are more stable and frequency of sampling can be lower. Deviation concerning Uudenmaa (Fig.9) could be explained by "overpopulation" (need of external food production) and large scale use of surface water. Deviation in Kymi could be explained by its rapakivi soils [11], where the weathering rate is lower than their estimates [11].

Figure 8. Soil-type distribution and estimated Si content of grass

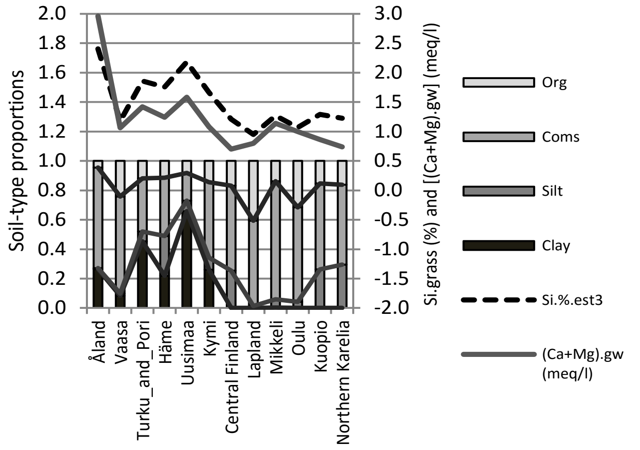
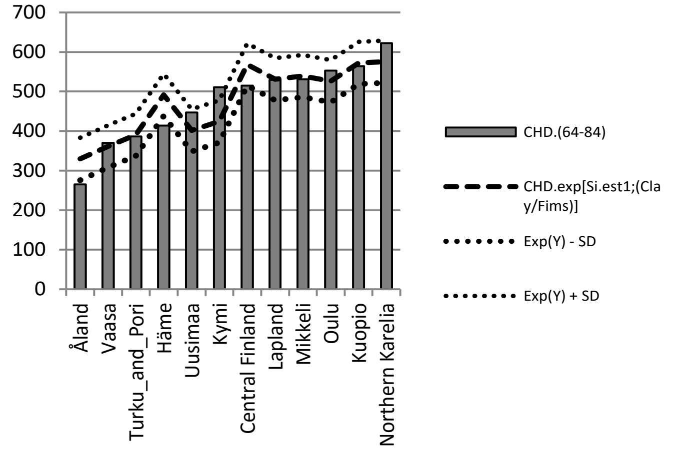


Figure 9. Regression of CHD by [Si.est1;(Clay_Fims)]



Si mechanisms

The low impact of the classical risk factors on the regional difference in CHD [1] suggests on the need of additional explaining factor(s). One idea is that the pulse effect on vascular wall consists of action and reaction of the whole vascular wall [2,28]. Schwarz, 1974 [29] suggested that the anti-atheromatous effects of Si could be explained by its participation in collagen structures and stabilization of arterial wall. The authors suggest that the structural mechanisms could reduce intramural irritation, inflammation and production of cytokines in vascular walls (N.B. hs-CRP!) and so possibly inhibiting cholesterol synthesis [30] – even intramurally. The role of Si as an anti-atherosclerotic factor is supported epidemiologically: Vegetable food is rich in Si [31] is generally known to protect against CHD. Experimentally: Loeper et al. [32] have reported that Si supplements could lessen the vascular atheroma formation in rabbits, administered intravenously or per os. Reports on cardiovascular benefits [33] and a few reports on nephrotoxicity [34] of Si have been published. It seems that positive and negative characteristics of Si are associated with its structural characteristics. It is generally known that over half of the Finnish crops is composed of monocotyledons (grain and grass), so it is suggested that the general proportional Si-content in Finnish primary products and in the food chain could reflect the equation: $\sum C.i{*}Stprp.i$ (= Si.est1) after adjusting by [(Ca+Mg).coms], but if the latter were not available by [(Ca+Mg).tot]. In Finnish wheat and rye Si-content of grains was in generally slightly below 0.1 g/kg [35]. Schultz and French (1976) have reported higher Si contents of wheat grain in Australia: 0.5 -5.3 g/kg [36]. In Finland, Karhu, an expert in growing of leguminous plants, reported of wheat, which contained 1.1 g Si/kg [37]. Rinne et al. [24] reported that the mean Si-content of grass showed a decreasing trend with the age of grassland: 1st year it was 1.2 %, 2nd year 1.1 % and 3rd year 1.0 %. If this result could be confirmed, it could suggest on plowing as a method of Si liberation and "Si-fertilization".

The effects of gw Ca, gw Mg, their sums, contradictory ratios and scanty mineral concentrations will obviously become understandable via their associations with soil-types, soil weathering and Si-uptake by plants. In this study soil weathering – especially weathering capacity - seems principally to be a positive phenomenon. Mother-earth can balance mineral losses by volcanic eruptions, glacial procedures and sea bottom elevations. During waiting of these human beings could counteract losses of soluble minerals in agricultural soils by recycling the nutrients up taken by plants and by silicate supplementation [38], besides of conventional fertilization and crop rotation, possibly including leguminous plants. By improving water control [39] Si could even rejuvenate eroded soils. Liberation of other mineral elements than silicon can be of importance, too.

Conclusion

Similar parameters as benefited in evaluation of weathering rate, mean annual temperature and [(Ca+Mg)] of agricultural (especially coarse mineral) soil, explained significantly provincial variation in CHD, [Si.gw], [(Ca+Mg).gw] and [pH.tot]. This suggests on the role of agricultural soil, its potency to liberate mineral elements like Si, in epidemiology of CHD, as well as on potential benefits of recycling minerals in food chain.

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References

1. Pajunen P, Torppa J, Huohvanainen M, Salomaa V, Vartiainen V. The difference in coronary heart disease mortality among men from eastern and western Finland has decreased over the past 30 years, Finnish Medival Journal. 2004, 59: 5013-5016.

2. Jousilahti P, Vartiainen E, Tuomilehto J, Pekkanen J, Puska P. Role of the known risk factors in explaining the difference in the risk of coronary heart disease between eastern and southwestern Finland. Ann Med. 1998, 30(5): 481-487.

3. PubMed Search Aug 25, 2015 for [“water hardness” cardiovascular]: “Results 84.” 1964-2015.

4. Wikipedia: water hardness.

5. Crawford MD. Hardness of drinking-water and cardiovascular disease. Proc Nutr Soc. 1972, 31(3): 347-353.

6. Crawford MD, Gardner MJ. Mortality and hardness of local water-supplies. Lancet. 1968, 291(7547): 827-831.

7. Kousa A, Havulinna AS, Moltchanova E, Taskinen O, Nikkarinen M et al. Calcium:Magnesium Ratio in Local Groundwater and Incidence of Acute Myocardial Infarction among Males in Rural Finland. Environmental Health Perspectives. 2006, 114(5): 730-734.

8. Hardness in Drinking-water.

9. Koivistoinen P, Ahlström A, Nissinen H, Pekkarinen M, Roine P. Mineral Element Compositions of Finnish Diets Part I: Fe, Cu, Mn, Zn, Mg, Na, K, Ca and P. Suomen Kemistilehti B43. 1970, 426-430.

10. Toysa T. Agro-Geology and CHD in Finland. J J Agriculture. 2015, 1(2): 006.

11. Johansson M, Tarvainen T. Estimation of weathering rates for critical load calculations in Finland. Env Geol. 1997, 29(3): 158-164.

12. Valkonen T, Martikainen P. Sepelvaltimotaudin väestöryhmittäinen kehitys Suomessa. Summary: Development of mortality from ischaemic heart disease in subgroups of the population in Finland. Sosiaalilääketieteellinen Aikakauslehti. Journal of Social Medicine. 1990; 27: 273-288.

13. Lahermo P, Tarvainen T, Hatakka T, Backman B, Juntunen R et al. Tuhat kaivoa - Suomen kaivovesien fysikaalis-kemiallinen laatu vuonna 1999. Summary: One thousand wells - the physical-chemical quality of Finnish well waters in 1999, 2002.

14. Acidity and mineral element contents per soil-type in Finnish Rural Centres. 1986-1990.

15. Sippola, Jouko, Tares, Tauno. The soluble Content of Mineral Elements in Cultivated Finnish Soils. 1978, 20: 11-25.

16. Official Statistics of Finland: Farm, 1988.

17. Tiainen H. Peruskoulun Karttaopas. Graphics Tiainen H. Maanmittaushallitus. Helsinki. 1985, 32-33.

18. Wikipedia Names and approximate locations of the Finnish provinces their numbers and province capitals 1996.

19. Maalajisuhteet kunnittain ja maaseutukeskuksittain vuosina 1986-1990.

20. FMI: Mean annual temperature, 2015.

21. Koivistoinen, Pekka. Mineral Element Composition of Finnish Foods: N, K, Ca, Mg, P, S, Fe, Cu, Mn, Zn, Mo, Co, Ni, Cr, F, Se, Si, Rb, Al, B, Br, Hg, As, Cd, Pb and Ash, 1980.

22. Kauppi P, Kämäri J, Posch M, Kauppi L. Acidification of forest soils: Model development and application for analyzing impacts of acidic deposition in Europe. Ecological Modelling. Terrestrial Ecosystems. International Institute for Applied Systems Analysis, A-2361 Laxenburg Austria. 1986, 33(2-4): 231-254.

23. Boyle JR, Voigt GK, Sawhney BL. Chemical weathering of biotite by organic acids. Soil Sci. 1974, 117(1): 42-45.

24. Rinne S-L, Sillanpää M, Hiivola S-L, Huokuna E. Effect of N-fertilization on Si-content of grass. (Typpilannoituksen vaikutus ruohon piipitoisuuteen. Kehittyvä Maatalous 35:7-10. 1977, Helsinki. [in Finnish, with a short Swedish summary]. Permission for publishing Feb 22, 2016.

25. FAOSTAT Nitrogenous fertilizers, 2011.

26. FAOSTAT Arable land, 2011.

27. Sillanpää M. Lannoitus ja maan ravinnevarojen kehitys. Käytännön Maamies 1978, 3: 17-20.

28. Thubrikar MJ, Baker JW, Nolan SP. Inhibition of atherosclerosis associated with reduction of arterial intramural stress in rabbits. Arteriosclerosis. 1988, 8(4): 410-420.

29. Schwarz K. Recent dietary trace element research, exemplified by tin, fluorine and silicon. Federation Proceedings. 1974, 33(6): 1748-1757.

30. Memon RA, Grunfeld C, Moser AH, Feingold KR. Tumor necrosis factor mediates the effects of endotoxin on cholesterol and triglyceride metabolism in mice. Endocrinology. 1993, 132(5): 2246-2253.

31. Varo P, Lähelmä O, Nuurtamo M, Saari E, Koivistoinen P. Chapter VII. Potato, Vegetables, Fruits, Berries, Nuts and Mushrooms. Mineral Element Composition of Finnish Foods: N, K, Ca, Mg, P, S, Fe, Cu, Mn, Zn, Mo, Co, Ni, Cr, F, Se, Si, Rb, Al, B, Br, Hg, As, Cd, Pb and Ash. Acta Agriculturae Scandinavica Supplementum 22. Stockholm 1980, (21).

32. Loeper J, Goy-Loeper J, Rozensztajn L, Fragny M. The antiatheromatous action of silicon. Atherosclerosis. 1979, 33(4): 397-408.

33. Maehira F, Motomura K, Ishimine N, Miyagi I, Eguchi Y, Teruya S. Soluble silica and coral sand suppress high blood pressure and improve the related aortic gene expressions in spontaneously hypertensive rats. Nutr Res. 2011, 31(2): 147-156.

34. Dobbie JW, Smith MJ. Silicate nephrotoxicity in the experimental animal: the missing factor in analgesic nephropathy. Scott Med J. 1982, 27(1): 10-16.

35. Varo P, Nuurtamo M, Saari E, Koivistoinen P. Chapter III. Annual Variation in the Mineral Element Composition of Cereal Grains. Mineral Element Composition of Finnish Foods: N, K, Ca, Mg, P, S, Fe, Cu, Mn, Zn, Mo, Co, Ni, Cr, F, Se, Si, Rb, Al, B, Br, Hg, As, Cd, Pb and Ash. Acta Agriculturae Scandinavica Supplementum 22. Stockholm 1980, 21: 22-30.

36. Schultz JE, French RJ. Silicon uptake by wheat and its relation to grain yield and water use. Australian Journal of Experimental Agriculture and Animal Husbandry. 1976, 16(78): 123-128.

37. Karhu Y. Ryöstöviljely ja sydänkuolema, Helsinki. 1974, 62.

38. Hensel J. Bread from Stones: A New and Rational System of Land Fertilization and Physical Regeneration 1894.

39. Ma JF, Takahashi E. Soil, Fertilizer, and Plant Silicon Research in Japan, 2002.