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.

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

<p>| Location, soil and groundwater Ca, Mg and soil pH of Finnish Rural Centers |
|---|---|---|---|---|---|---|---|</p>
<table>
<thead>
<tr>
<th>Central Commune/ Town</th>
<th>CHD</th>
<th>Latitude</th>
<th>Longitude</th>
<th>Ca.soil</th>
<th>Mg.soil</th>
<th>K.soil</th>
<th>Ca.gw</th>
<th>Mg.gw</th>
<th>pH.soil</th>
<th>Temperature</th>
</tr>
</thead>
</table>

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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 °E (longitude) responds only ca 5 °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. 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. 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. 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°) were higher than by CHD.
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°) 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 (+; -).
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 from 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.

<table>
<thead>
<tr>
<th>Dependent variables</th>
<th>Independent variables</th>
<th>R square</th>
<th>Sign</th>
<th>R square comparison</th>
<th>R square</th>
<th>Sign</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHD.est</td>
<td>Si.gw</td>
<td>0.15</td>
<td>0.082</td>
<td>&lt;</td>
<td>0.43</td>
<td>0.002</td>
</tr>
<tr>
<td>CHD.est</td>
<td>(Ca+Mg).gw</td>
<td>0.52</td>
<td>&lt; 0.001</td>
<td>&gt;</td>
<td>0.35</td>
<td>0.006</td>
</tr>
<tr>
<td>CHD.est</td>
<td>[Lat;Long]</td>
<td>0.93</td>
<td>&lt; 0.001</td>
<td>“=“</td>
<td>0.91</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Si.gw</td>
<td>[Lat;Long]</td>
<td>0.19</td>
<td>0.151</td>
<td>&lt;</td>
<td>0.44</td>
<td>0.007</td>
</tr>
<tr>
<td>(Ca+Mg).gw</td>
<td>[Lat;Long]</td>
<td>0.53</td>
<td>0.001</td>
<td>&gt;</td>
<td>0.45</td>
<td>0.006</td>
</tr>
<tr>
<td>[(Ca+Mg).gw]</td>
<td>(Ca+Mg).soil</td>
<td>0.53</td>
<td>&lt; 0.001</td>
<td>&gt;</td>
<td>0.46</td>
<td>0.001</td>
</tr>
<tr>
<td>Si.gw</td>
<td>(Ca+Mg).gw</td>
<td>0.07</td>
<td>0.241</td>
<td>&lt;</td>
<td>0.62</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Si.gw</td>
<td>[Temp;pH.soil]</td>
<td>0.68</td>
<td>&lt; 0.001</td>
<td>&gt;</td>
<td>0.66</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Si.gw</td>
<td>[Temp;(Ca+Mg).soil]</td>
<td>0.31</td>
<td>0.035</td>
<td>&lt;</td>
<td>0.38</td>
<td>0.017</td>
</tr>
</tbody>
</table>

Table 3

<table>
<thead>
<tr>
<th>pH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silicate buffer</td>
</tr>
<tr>
<td>Carbonate buffer</td>
</tr>
</tbody>
</table>

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.

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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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