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On Changes in Inputs and Outputs of Agricultural Mineral Nutrients (e. g. Ca, Mg, K and Si) in Finland Between 1950-75 - with Discussion on Problems and Solutions

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ABSTRACT

The role of pure or semi-pure mineral elements has changed in the nutrition of agricultural soils during the 20th century. According to an old database potassium mineral fertilizers, K.fm, composed in the 1920's ca 8 % and manure (recycled, rcl), K.rcl ca 92 % of the total potassium fertilization (K.ft). In the 1970's the proportion of K.fm increased upto little over 70 %. About similar increase occurred in other main mineral nutrients (N, nitrogen and P, potassium). Strong increase in NPK and in Ca (mainly in liming agents) supplementation caused dilution of other mineral elements in soil, food and recycled soil nutrients (manure). Based on this same database (economic and ecologic survey) mean input of total potassium (K.ft) in period 1920-60 was annually ca 5 (5.1) kg lower than K content in yield (K.yi). This long-lasting difference can be seen as an obvious sign of coincidental weathering of soil minerals, silicates, causing coincidental K, Mg and silicon (Si) liberation, too. Excess Mg, labeled Mg.we, approximated by Mg/K ratio in groundwater (0.77), composed ca 50 % of the Mg in yield before 1950. The rapid decrease in Mg and Si supply in the 1950's and the stop in 1961 is represented as one additional cause for the rapid increase of male and female CHD mortality since 1957. This article is discussing on effects (or associations) of weathering and recycling of soil nutrients on mineral composition of soil, food, fodder, manure, groundwater, fishery and carbon binding, as well as participating in some health indicators. Changes caused by food processing are mainly excluded in this assessment.

Conclusions: Weathering of agricultural soils has been an important factor in the 20th century in the dietary supply of magnesium silicon and several microelements. Enhanced weathering of silicates as promoted by ice-ages can rejuvenate our biosphere, improve health of plants, livestock, humans and the globe, e.g. by carbon capturing.

Keywords: Weathering; Carbon (Binding); Silicon; Magnesium; Trace elements; Heart; pH; Agriculture; Fishery; Oceans; Lakes

Abbreviations: CHD: Coronary (Ischaemic) Heart Disease; fm: Chemical, Artificial, 'Conventional' Or Mineral Fertilizers; f.rcl: Recycled Fertilizers; ft: Total (given) Fertilizers, Input Fertilizers; [.we]: Weathered, [.yi]: yield

Introduction

At the end of the 19th century Liebig made his discoveries on the main mineral elements needed for fertilization. The same time Julius Hensel observed that broken mill stones promoted plant growth and developed the stone meal fertilization method, which has been described as follows: "Liebig claimed that plants require three main elements—nitrogen, phosphorus and potash—the basis of which conception chemical fertilizers were manufactured that supplied these elements. On the other hand, Hensel claimed that plants need many more than these three major elements, stressing the importance of the trace minerals, which at that time were ignored. In place of chemical fertilizers, supplying only three elements in an unnatural, caustic form, Hensel recommended the bland minerals of pulverized rocks,

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especially granite, a primordial rock which contains the many trace minerals that meet all needs of plant nutrition" [1]. Hensel has got followers, mostly they recommend meal of volcanic or basalt rocks [2], even granite meal has been represented [3]. The aim of this study is to assess the role of weathering of potassium and its obvious association with inputs and outputs of weatherable or weathered Mg and Si in Finnish cropland and its environmental effects in 1920-75.

Material and Methods

Data on potassium (K) fertilization data: input of artificial, mineral fertilizers (K.fm) and K from manure, recycled fertilizers (K.rcl) in 1920-75 are attained from [4] by measuring with ruler and calculating (Figure 1 & Table 1). K.rcl was determined by the number of farm animals, without estimating the effects of the increased size of the animals, but estimating the effects of improved methods in storing of mineral elements of recycled nutrients. The focus in [4] was to evaluate the effectivity of increased fertilization. Soil was seen as a bank, which could give loan, without discussion on specific mecnisms. [.we]: Weathered, [.yi]: yield

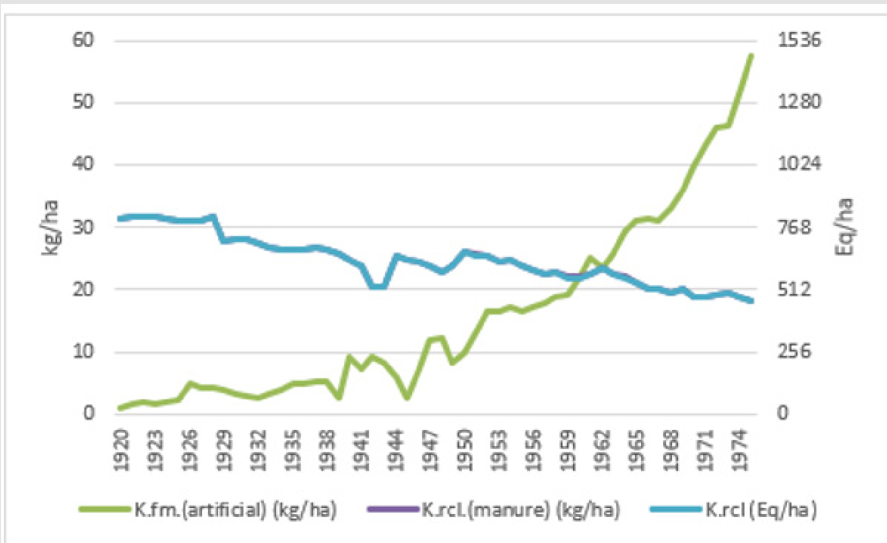

Figure 1: Potassium supplementation (input) of Finnish agricultural soils by recycled (rcl) and mineral fertilizers (fm) in 1920-75.

Table 1: Potassium given in mineral fertilizers (fm) and recycled (rcl) [4], K.supply from [5], K in yields K.weathered (K.we) (netto, discussed), K.loss and proportion of K.rcl to total K (K.ft). Values are given by native and 3-year means. K.rcl and K.fm 3ym are adjusted to K.supply by their ratios in ft

	K.fm	K.rcl	K.sup-py	K.yield	K.fm 3ym	K.rcl3ym	K.(rcl/ft) 3ym	K.supply 3ym	K.yield 3ym	K.rcl 3ym.a	K.fm 3ym.a	K.we 3ym	K.loss 3ym
kg/ha													
1920	1.1	31.5	32	28									
1921	1.7	31.7	32	34	1.6	32	95	32	32	31	1.5	0.1	
1922	2	31.7	33	35	1.8	32	95	33	33	31	1.8		-0.4
1923	1.7	31.7	34	29	1.9	32	94	33	34	31	1.9	0.5	
1924	2	31.5	33	38	2	31	94	34	35	32	2	1.6	
1925	2.2	31.2	34	40	3	31	91	35	39	32	3	4.4	
1926	4.9	31.2	36	39	3.8	31	89	35	40	31	3.9	4.7	
1927	4.4	31.2	36	41	4.6	31	87	36	39	31	4.5	3.5	
1928	4.4	31.7	36	38	4.2	30	88	34	37	30	4.4	2.8	
1929	3.9	27.8	32	33	3.8	29	88	33	37	29	3.7	4.3	
1930	3.2	28	31	41	3.3	28	89	31	38	28	3.3	7.1	

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1931	2.9	28	30	41	2.8	28	91	30	41	28	2.8	10.5	
1932	2.4	27.3	30	41	2.8	27	91	30	41	27	2.8	10.9	
1933	3.2	26.8	29	40	3.2	27	89	30	42	26	3.1	12.4	
1934	3.9	26.3	30	45	4	27	87	30	42	26	3.9	12.4	
1935	4.9	26.3	31	42	4.6	26	85	30	44	26	4.5	13.4	
1936	4.9	26.3	31	45	5	27	84	31	44	26	4.9	12.9	
1937	5.4	26.8	33	46	5.2	27	84	32	46	27	5.4	14.1	
1938	5.4	26.3	33	48	4.4	26	86	31	45	27	4.7	13.4	
1939	2.4	25.9	29	40	5.7	26	82	32	40	26	5.2	8.3	
1940	9.3	24.9	33	32	6.3	25	80	31	34	25	6.8	3.4	
1941	7.3	23.9	31	31	8.6	23	73	31	32	23	8.5	0.5	
1942	9.3	20.5	30	33	8.2	22	72	30	33	22	8.2	3.2	
1943	8	20.5	29	35	7.7	22	74	30	34	23	7.5	3.4	
1944	5.9	25.4	33	33	5.4	24	81	30	34	24	6.2	4.1	
1945	2.4	24.9	27	32	5.2	25	83	31	33	25	4.7	2	
1946	7.3	24.4	32	32	7.2	24	77	31	33	24	7.3	1.2	
1947	11.7	23.9	35	33	10.4	24	69	34	37	24	10.7	2.4	
1948	12.2	22.7	35	44	10.7	23	69	34	41	23	10.9	6.6	
1949	8	23.9	32	45	10	24	71	35	44	25	9.4	9.7	
1950	9.8	26.1	37	44	10.2	25	71	35	44	25	11	8.5	
1951	12.7	25.6	37	43	12.9	26	67	39	44	26	13	5.1	
1952	16.3	25.4	42	44	15.2	25	62	40	45	25	16	4.5	
1953	16.6	24.4	42	47	16.7	25	60	42	45	25	17	3.2	
1954	17.1	24.6	42	44	16.7	24	59	41	44	24	17	2.4	
1955	16.3	23.7	40	40	16.8	24	59	41	42	24	17	1.2	
1956	17.1	23.2	41	42	17.1	23	57	41	42	23	17	1.7	
1957	17.8	22.4	41	44	17.9	23	56	41	44	23	18	2.9	
1958	18.8	22.9	41	45	18.6	22	55	41	43	22	19	2.3	
1959	19.3	22	41	41	20	22	53	43	45	22	19	2.9	
1960	22	22	45	50	22.1	22	50	45	46	22	22	1.7	
1961	25.1	22.4	47	47	23.5	23	49	47	48	23	24	1	
1962	23.4	23.4	47	45	24.8	23	48	47	46	23	25		-1.2
1963	25.9	22.4	47	45	26.2	23	46	48	45	22	25		-3.4
1964	29.3	22	50	44	28.8	22	43	50	46	21	29		-4
1965	31.2	21.2	53	48	30.7	21	41	52	46	21	31		-5.2
1966	31.5	20.2	52	47	31.3	20	40	52	48	21	31		-4.4
1967	31.2	20	51	47	32	20	38	52	47	20	32		-4.8
1968	33.2	19.5	53	47	33.5	20	37	53	46	20	33		-7.1
1969	36.1	20	55	43	36.3	19	35	55	46	19	36		-9.4
1970	39.5	18.8	59	48	39.7	19	33	58	47	19	40		-11.5
1971	43.4	18.8	61	50	42.9	19	31	62	47	19	42		-14.8
1972	45.9	19	65	43	45.2	19	30	64	47	19	45		-17.3
1973	46.3	19.5	66	47	47.8	19	29	67	42	19	47		-24.9
1974	51.2	18.8	70	36	51.7	19	27	69	42	18	51		-27.2
1975	57.6	18	72	43									
Sum	883	1381	2257	2300	826	1331	3613	2154	2229	1330	824	211	-136

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Mean. (1920-75)	15.8	24.7	40.3	41.1	15.3	24.6	67	39.9	41.3	24.2	15.3	3.9	-2.5
Mean of												5	-10
given values													

Proportion K.fm of total K fertilization (ft) was 8 % in the 1920's and achieved level of 75 % at 1975. Ratio (fm/ft) exceeded 50 % by phosphorus (P) in the 1940's and by N and K at about 1960. At 1975 this ratio was 88 % by P and 85 % by N. The principle in determination of K in yield (K.yi) was to measure the losses of potassium via yields from the farms, e.g. in cereals only grain potassium was included and straw excluded. In 1920-75 mean K supply was 40.3 and mean K in yields was 41.1 kg (Table 1). Values are given by original and by 3-year moving averages (3ym) Annual K.supply (input) and K in yields (output) are represented in Fig.2.

Figure 1 Potassium supplementation of Finnish agricultural soils by mineral (artificial) fertilizers (K.fm) and manure (recycled) [K.rcl] in 1920-75) is attained from [4]. Figure 1 shows K values in kg's and equivalents (10 kg responds 255.7 Eq's). Figure 2 shows K supply given via mineral and recycled fertilizers (native, measuredvalues from 85]).

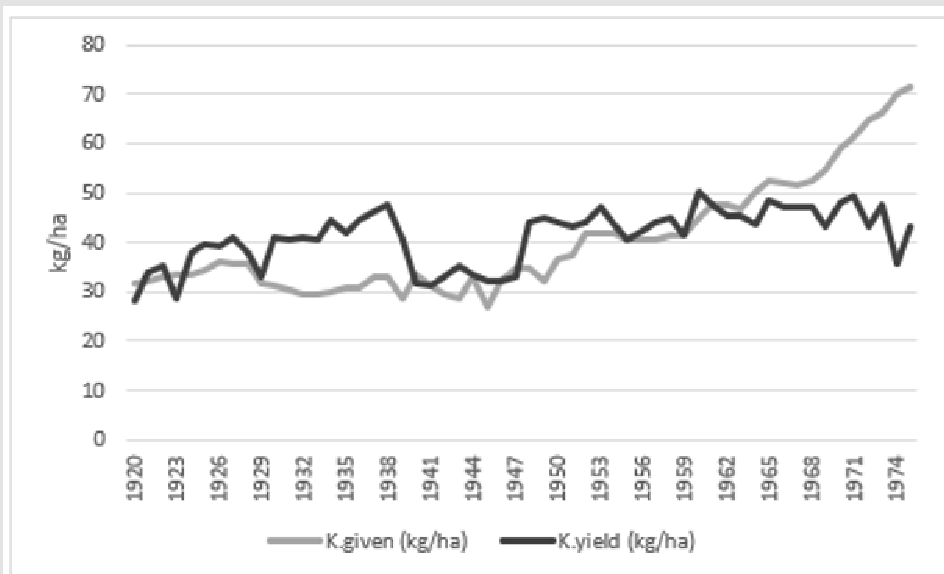

Figure 2: Finnish potassium supply and K in yields during 1920-75.

In 1920-75 mean K supply was 40.3 and mean K in yields was 41.1 kg. Values are given by original and by 3-year moving averages (3ym) (Table 1). Figure 3 shows that the role of recycled K has been reduced dramatically since 1920: in the 1920's its proportion was 92 %, in 1966-75 only 32 %. until 1960 K.rcl was higher to K.fm.

The variation of the sum of K.fm and K.rcl was different to K.supply, especially when values for 1961-75 were taken from FAOSTAT. FAO values were different to the values of [4] and they have been changed during the last years. Multilying [(K.supply.3ym).(Sillanpää)] by [(K.rcl 3ym/K.(fm+rcl).3ym). Sillanpää] gives here satisfactorily similar values, which works as a check, that the measurements are satisfactorily performed. Figure 4. Annual output of potassium (K. yield) was higher to given in fertilizers until 1961 when they were 48 and 47 kg/ha, in 1962 46 and 47 kg/ha, respectively. In 1974-75 even K.fm had grown higher to K.yield. The excessive K in yield (K.yield – K.supply >0) before 1962 is labeled K.we (like K.weathered) and in opposite cases (K.yield – K.supply < 0) K.loss (with minus sign). The fate of the lost K is not seriously discussed because the data source excluded discussions on leaching and other routes of losses and stores in soil reserves. Figure 5 shows that in the 1930's the K.we (amount) represented for several years was over 25 % of K.yield.

Excess K in yield could be explained by (weathered) groundwater mineral elements or by (weathered) 'soil improvement materials': clay and peat soil [5] and labeled K.we. In 1950 use of manure was 13.7 'horse loads'/ha (by the data above: K.rcl 26.1 kg/ha and K proportion in manure ca 0.005 (Heinonen, et al. [6]) gives total 5,220 kg/ha, and so one horse load gets estimate 380 kg. In 1950 was even added clay and sand together, as well as peat soil, 2.2 horse loads, i.e. ca 840 kg/ha, both groups, sources of K, Mg and trace elements.

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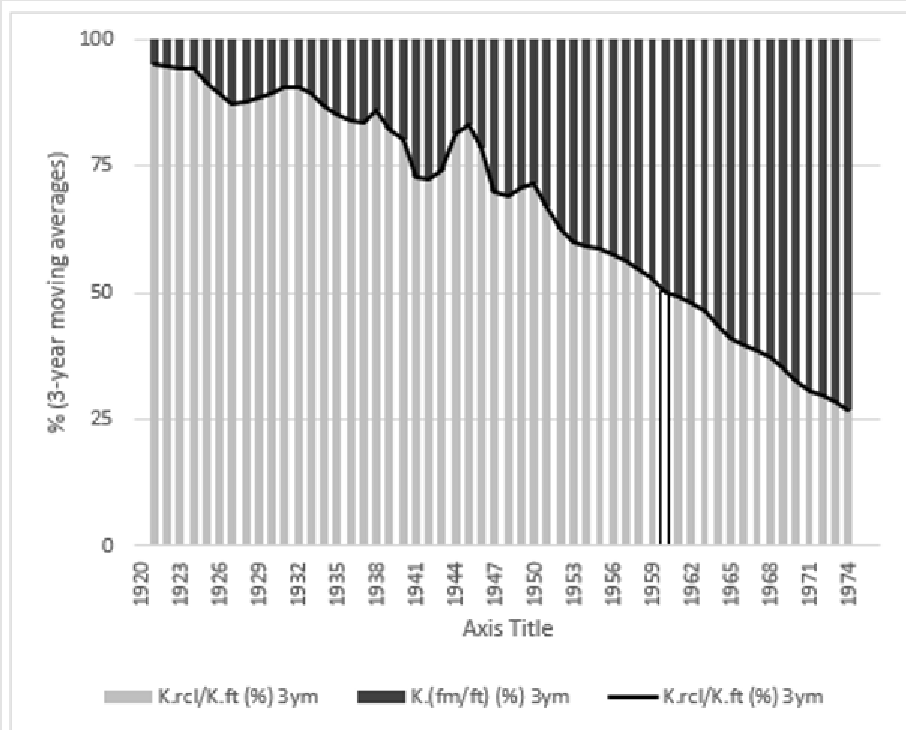

Figure 3: Proportional supply of potassium on Finnish agricultural soils by recycled (rcl) and 'artificial', 'chemical' (fm) fertilizers in 1920-75.

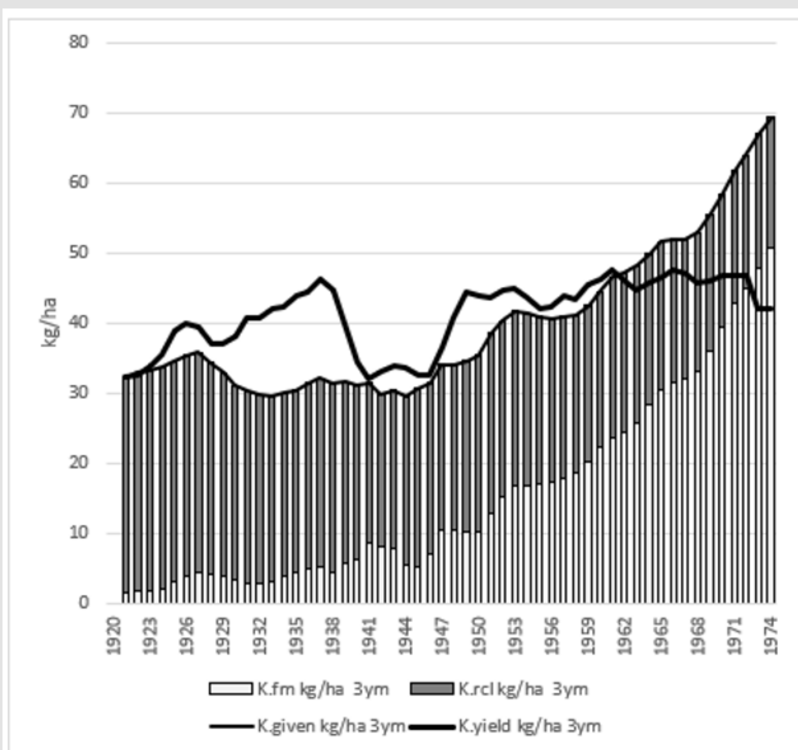

Figure 4: Development of K fertilization and K in yields.

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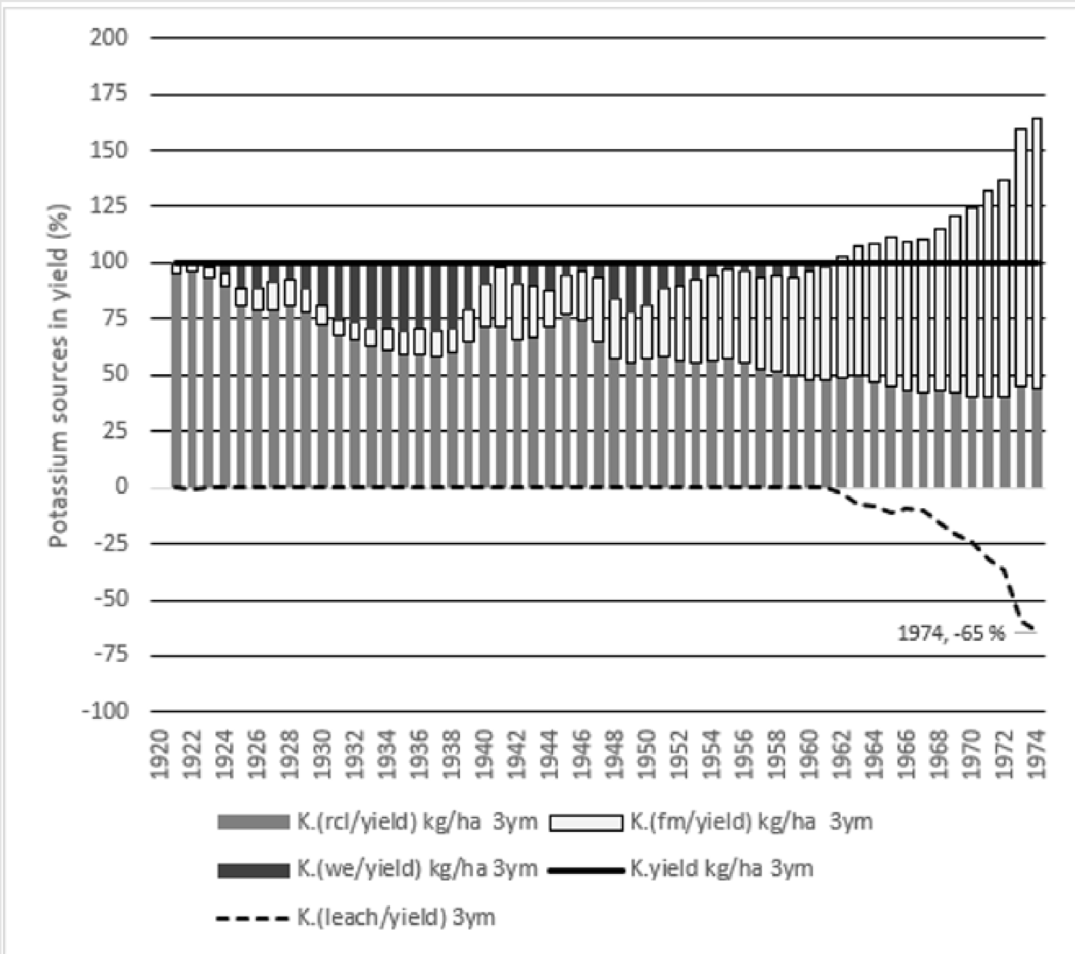

Figure 5: Relative amounts of K.fm, K.rcl, K.we and K.leach to K.yield.

Results

Potassium Excess in Yield, an Obvious Indicator of Weathered K, Ca, Mg and Silicon (Si)

N.B. Values are treated by 3-year means. If we suppose that the excessive K.we is formed in the same way as groundwater, its source could contain Ca, Mg and Si in weight ratios of 3.06, 0.77 and 1.31 -fold to K (Tables 2 & 3, Figure 6).

Table 2: Groundwater contents of calcium, magnesium, potassium and silicon and their wight and equivalent ratios. Molar weight SiO_2 is 60 (28+2*16) g.

	Ca	Mg	K	SiO2	Si
Contents (mg/l)	15.2	3.83	4.97	13.9	6.5
Equivalent weight (g)	20.05	12.15	39.1		7
Contents (mEq/l)	0.758	0.315	0.127		0.929

Table 3: Groundwater, mutual ratios of Ca, Mg, K and Si (weight and equivalents).

	Ca/K	Mg/K	Si/K	Ca/Si	Mg/Si	K/Si
Weight ratios	3.06	0.77	1.3	2.35	0.59	0.77
Equivalent ratios	5.96	2.48	7.28	0.82	0.34	0.14

Table 2. shows groundwater contents of Ca, Mg, K and Si (silicon) and their weight and equivalent ratios [7,8].

Weathered Mineral Elements in Equivalents

Figure 6 shows excess K, K.we, and weathered Ca, Si and Mg (kg/ha), supposing that their formation and proportions are similar than in groundwater (Tables 1-3) (as reference is given annual K.fm for comparing with Figure 7). Height orders: Ca > Si > K > Mg. Table 4 shows that in 1920-49 the approximate Mg.we was 4.8, which repre-

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sented about half of the annual Mg uptake [6,9]. Mg.we was in 1950-55 3.2, 1956-61 1.6 kg/ha, after that 0 kg/ha. In original values the end occurred in 1960. K.we was 5.3 kg/a in 1921-61, was ca 13 % of the K in yield (Table 1). Ca.we was 4-fold to Mg.we in groundwater [7] and more higher in agricultural soil [10] and fertilization [11], anyhow Ca/Mg ratio in cereal food was ca 30 % (41/130), in vegetable food their proportions were about equal [12], so the role of weathered Ca was obviously lesser than by the others. It is possible to suppose that the change in Si availability was relatively higher, because Si content of Finnish food was only 1/15 to respective content of Mg in the 1970's [12]. In 1962-75 mean calculated annual K.losses were ca 11 kg/ha/a, 17 % of the given fertilizers, 23 % of the K in yield, max 65 % (Figure 5).

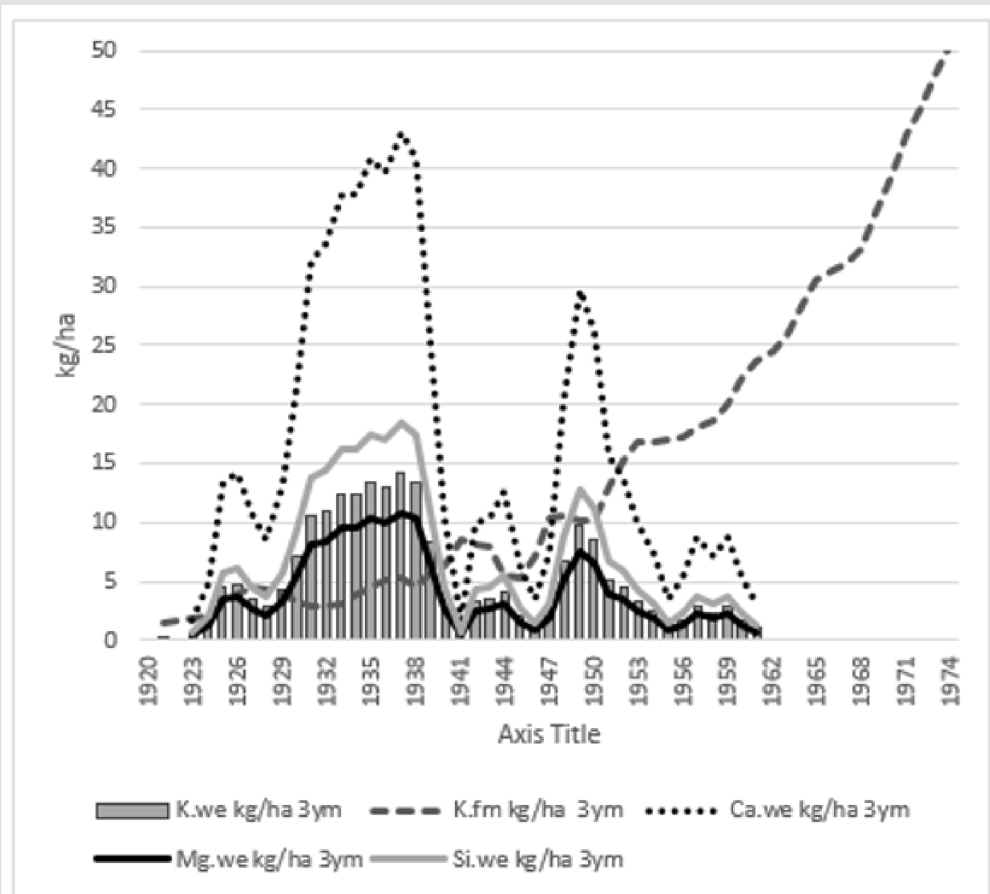

Figure 6: Supposed weathered amounts of Ca, Si, K and Mg, with reference annual K.fm's.

Table 4: Annual means of weathered K, Mg, Si and loss of K (kg/ha), by their ratios in groundwater (1:0.77:1.3). K.loss % is calculated by ratio K.loss/K.given.

	K.we	Σ.(K.we)	K.loss	K.loss %	Mg.we	Σ.(M.we)	Si.we	Σ.(M.we)
1920-49		6.2				4.8		8.1
1950	8.5				6.6		11.2	
1951	5.1				3.9		6.7	
1952	4.5				3.5		5.9	
1953	3.2				2.5		4.2	
1954	2.4				1.9		3.2	

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1955	1.2				0.9		1.5	
1950-55		4.2				3.2		5.4
1956	1.7				1.3		2.2	
1957	2.9				2.2		3.8	
1958	2.3				1.8		3.1	
1959	2.9				2.2		3.8	
1960	1.7				1.3		2.2	
1961	1				0.8		1.3	
1956-61		2.1				1.6		2.7
1962-75			10	23		0		0

Fig. 7 shows excess K, K.we, and weathered Ca, Si and Mg (Equivalents/ha), supposing that their formation and proportions are similar than in groundwater (Table 1, 2, 3)) (as reference is given annual K.fm for comparing with Fig. 6). In Fig.7 height orders: Si > Ca > Mg > K.

Reduction of weathering has reduced plant available Mg and Si remarkably in the 1950's (Fig. 2, 7 and 7).

Discussion

The study of professor Sillanpää, director of Soil Science Department in Agricultural Research Center – MTT [4] was a remarkable summary on efficacy N, P and K fertilizers (fm + rcl). Although the study has several causes on discussions (exclusion of leaching, changes in benefiting of soil dressings (clay, peat soil),). forest pastures and human recycling), it shows that the annual losses of Mg, Si and trace elements via deficient recycling have been remarkable during 1920-75. Increase in K.fm (as well as Ca.fm, Mg.fm, K.fm, P.fm and N.fm) [11] have decreased proportion of recycled mineral elements, the source of other essential (about 26 or more) mineral elements [13], although many of them are supplemented (Fig.3).

Every year (or treatment by fertilizers) reduced the proportion of mineral elements not given in fertilizers. The most important source of Mg in Finnish soils is biotite, black mica, a three layer silicate [7] (or biotite group, Wikipedia [14]). In biotite formula K(Mg,Fe)3AlSi3O10(F,OH)2 [14] molar ratios of K:Mg:Si are 1:3:3, equivalent ratios: 1:6:12. Liberation reaction of Mg is not reversible [7,15] as the diffusion of K. Liberation of Mg means destruction of the framework [15] and seems to be more temperature dependent than the diffusion of K [16]. Liberation of Mg from biotite (micas) liberates implicitly potassium, too (i.e. reduces its ability to store K between its layers. Main sources of Ca have been the feldspars (a component of granites, like micas) [17], outside carbonate soils. The feldspars have augmented K-supply, too. The liberation of soil minerals is partially dependent on micro-organisms, e.g. [18]. A finding that Cock's foot (Dactylis glomerolata) has grown well without K fertilizers in soil where exchangeable K content was 70 mg/L and producing plant K content of 3 % [19], can suggest on weathering and on its special abilities (or symbiosis with microbes).

Delay in Mg compensation in the 1950's and 1970's was discovered by decrease in Mg content of grass fodder 20 % (from 0.21 to 0.17 % (D.W.) in 1958-69 [20] (depending partially on disappearance of clover, which was partially dependent on "invisible" Mg deficiency [6]). Veterinary surgeon Nuoranne reported on several syndromes of pigs, which were relieved by Mg supplements. He discovered that Mg-content of barley and oats was reduced by 22 and 16 %, respectively [21]. Development of epidemic of Mg deficiency can be seen in references for "normal" human plasma Mg: In 1968 (published) 0.80 – 1.10 (mean 0.95) [22] and in 2023 0.71-0.94 mmol/l (mean 0.825) [23], respectively – decrease 13 %. The rapid decrease and the stop of (estimated) Mg and Si weathering (1950-61) increased need for Mg (and Si) fertilization and associated with the begin of the Finnish CHD epidemic in 1957 [24]. The main human dietary loss of Mg was obviously caused by food processing, e. g. milling [24]. Magnesium (Mg) is a cofactor in more than 300 enzymatic reactions [25], why (low or high) Mg can be a cofactor in any disorders. Cellular magnesium content can have a role in myocardial infarction [26], as well as in liver and muscle diseases [27] and so in general well-being.

Benefits of Si can be based on its structural [28] and anti-inflammatory and antioxidant characteristics [29]. Anti-atheromatous effect of Si has been shown experimentally in rabbits [30] and epidemiologically associations have been represented in humans, e. g. [31,32]. In soil Si is associated besides with soil pH regulation [2,3,11], with humus content and carbon binding, possibly with humus structure and water balance [33,34]. In the UK has been studied mineral element contents of vegetables between the 1930's and the 1980's [35]. Reduction in most mineral elements was evident, least in phosphorus: Following ratios between new and old values were observed (new/old): Ca 0.81, Mg 0.65, Fe 0.78, Cu 0.19, Na 0.57, K 0.86, P 0.94. Remarkable was: Reduction was highest in copper (Cu). Reduction in Mg was higher than in Ca, or K, or P, in accordance with analyses of fodder [20,21] and blood tests [22,23]. Such Mg-Ca-K-P-profile can suggest on increased nervous irritability [36]. Lesser mineral element reduction was detected in fruits than in vegetables [35], which suggests on the roles of groundwater and long roots of fruit trees.

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Copper (Cu) deficiency of soils (Cu < 15 kg/ha, equals 7.5 mg/L soil (0.5 x 15 million mg/2 million dm3 in 20 cm plough layer of one hectare) has been quite common and treated in Finland since the 1950's by plants against malformation of leaves and reduced yield, by livestock for blood formation, gastro-intestinal, reproductive and nervous disorders [37]. Since the 1950's grass tetany has been treated in Finland prophylactically with fodder salt mixture, which contains, Mg, NaCl and Cu [38]. Copper is an example of heavy metals and microelements, which is beneficial when treated professionally. Pulverized rocks work as silicon supply. It is not enough that they are natural, because agricultural soils are different [1] (N.B. Mineral fertilizers are "natural", too, opposite to [1]). It is known that eating fertilizers is not healthy, but when distributed on the fields they can promote plant, animal, human and global health. The same can work with mining wastes, which have an analyzed composition. On farmlands, where soil fertility analyses have been made, proper targets are possible to find. Below every hectare there is about a half cubic kilometer (depth of soil crust is ca 50 km and ha is 0.1 x 0.1 km2) fertilizers (rock) to become weathered.

Because it has been estimated that biotite comprises up to 7 % of the exposed continental crust and the biotite formula [14] K(Mg,Fe)3AlSi3O10(F,OH)2, gives weight proportions (%) as follows: K 6.3, Mg 11.7, Fe 26.9, Al 4.3, Si 13.5, F 6.1. Molar ratios of K:Mg:Si are 1:3:3, equvalent ratios (mole x valence) 1:6:12. The main source of Mg is biotite (group) [6,14] (micas). K is attained from micas and additionally from feldspars separately or included in granites. Mg/K ratio ratio of groundwater 2.48 to 6.0 of biotite suggests that the main source of K is not biotite, but feldspars (+ fertilizers). Groundwater analyses are from 1999. Weathered K defined by the difference: K. yield minus K.supply could contain leaching, if we think that the real K.we were higher to this difference and is balanced by leaching. Wang et al. have written that annual erosion of potassium (in soil with clay material) could have been 33 kg/ha and leaching 15 kg/ha [39]. Soil weathering, especially production of silicates, seems to been beneficial for fishery, too [40]. Even human wastes and fertilizers can be (temporarily) beneficial, when silicon supply is sufficient [40,41]. The newest FAOSTAT data show that recycling of livestock manure has still decreased after 1975 [42], and consumption of NPK-fertilizers is reduced, too: PK fertilizers to the level of the 1950's.

Reduced NPK-fertilizers in the topsoil encourage plants to grow longer roots, deeper to the groundwater [1] but exhausted soils and oceans need pulverized silicates for mineral element supply and treating pH for sustaining carbonates and promoting carbon capture, as well as water balance of soils, in a sustainable way. Carbon loss caused by carbonate-liming agents can be reduced by replacing them (partially?) by silicates. Mineral elements in community sewages make up a big gap in recycling, especially concerning its trace elements. One hundred years ago the grain yields were less than a half of the nowadays yields. Because (beneficial in many ways) rotting of organic materials produce about the same amount of CO_2 than burning, studies and compromises are needed with "organic" and conventional farming and "restoration" of the nature, because everything is changeable and needs to be optimally managed (e.g. burning forests and bubbling of peat soils).

Mankind needs new studies and good co-operation in fertilization of soils, forests and oceans. Enhanced weathering ensures us sufficient supply of Si and Mg and possibly most macro and trace elements. Anyhow because local nature can be poor or rich, rejuvenation needs continuous follow-up.

Economy and ecology of fertilization has been obviously in the global interest since 1961, because of the high compliance between Finnish and West-European fertilization rates [44].

Table 5: Equivalent Ratios of Biotite.

	Mg/Si	K/Si	K/Mg
Equivalent ratios	6:12	1:12	1:06
Eq. ratios	0.5	0.083	0.17

Table 6: Comparison of Ca, Mg, K and Si Equivalent Ratios in Biotite and Finnish Groundwater.

	Ca/Si	Mg/Si	K/Si	Mg/K
Biotite (bi)	0	0.5	0.084	6
Groundwater (gw)	0.82	0.34	0.14	2.48
Ratio (bi/gw)	0	1.47	0.59	2.41

Conclusion

Weathering of agricultural soils has been an important factor in the 20th century in the dietary supply of magnesium, silicon and several microelements. Enhanced weathering of silicates as promoted by ice-ages can rejuvenate our biosphere, improve health of plants, livestock, humans and the globe, e.g. by carbon capturing.

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