Carbon in the soil and in interchange with the environment

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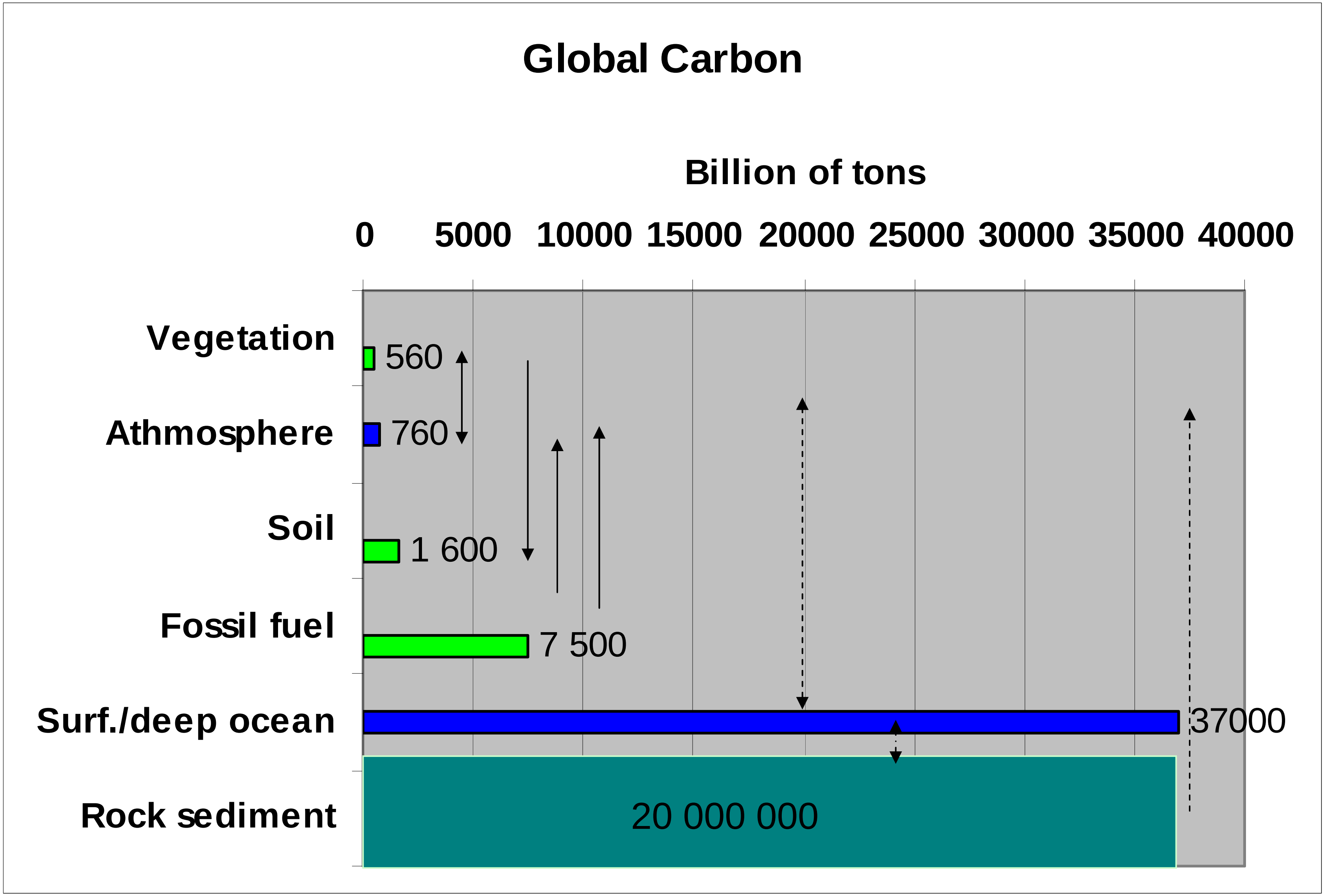
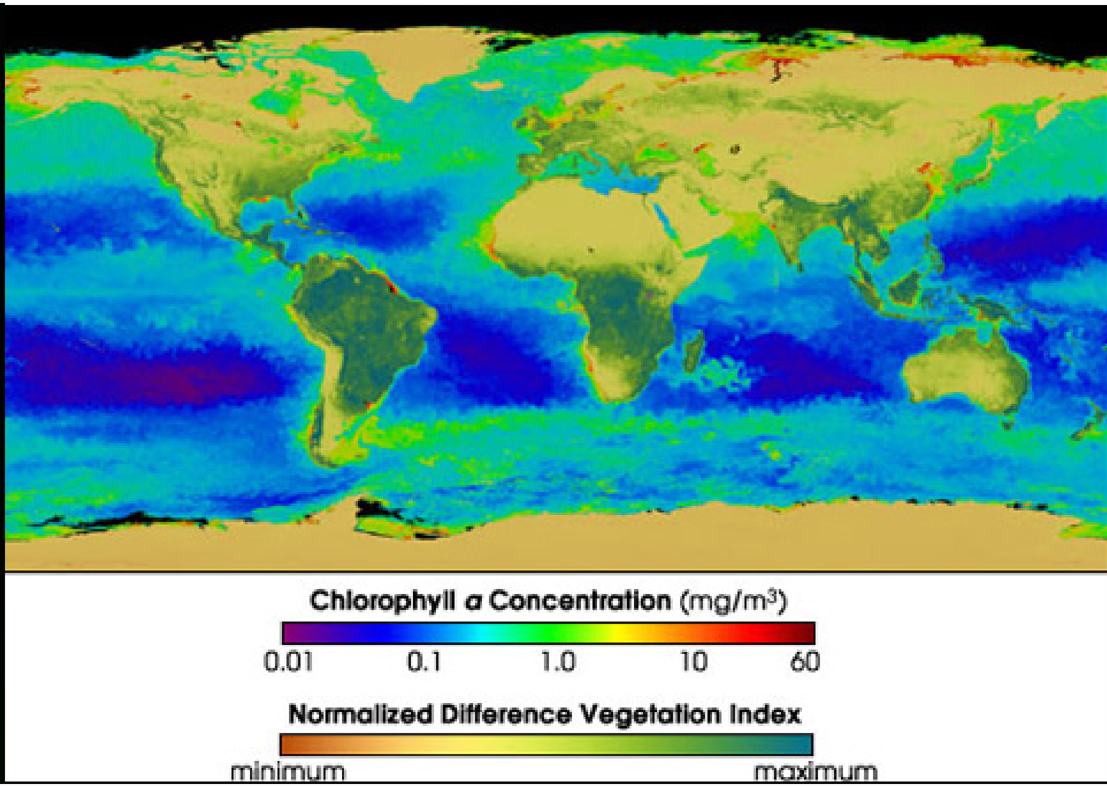
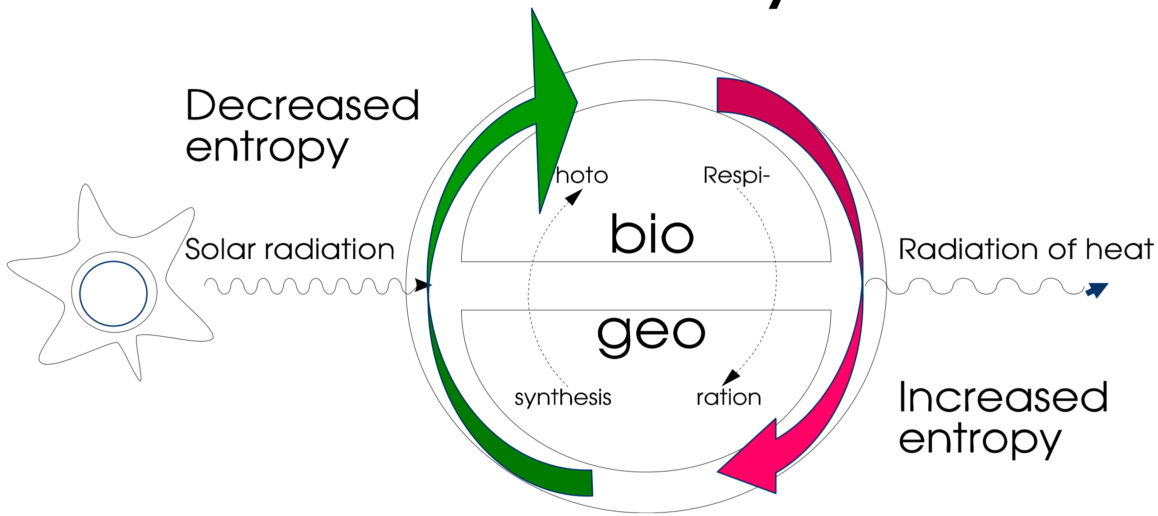
http://www.jdb.se/sbfi/


Global Carbon
Billion of tons
0
5000
10000
15000
20000
25000
30000
35000
40000
Vegetation
Athmosphere
Soil
Fossil fuel
Surf./deep ocean
Rock sediment
560
760
1 600
7 500
37000
20 000 000

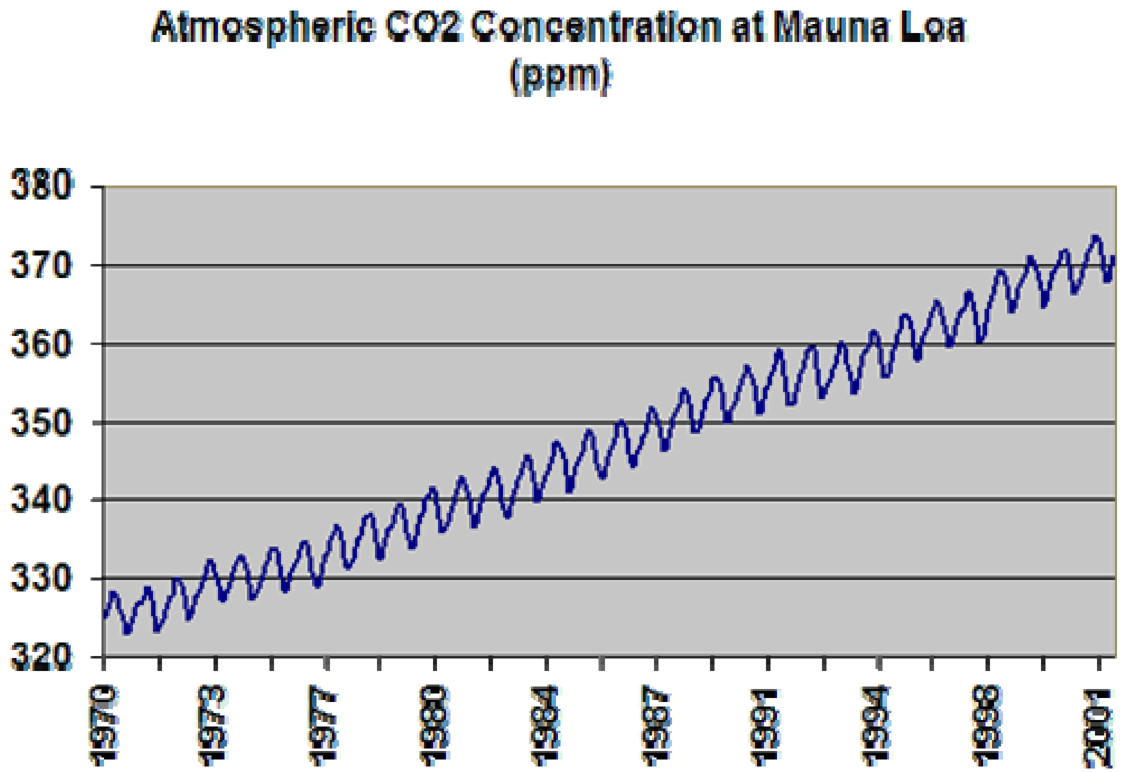


Photosynthesis is in its first step a **light process,** it is the light itself that is captured by the green leaf's chlorophyll in the thin global surface of life

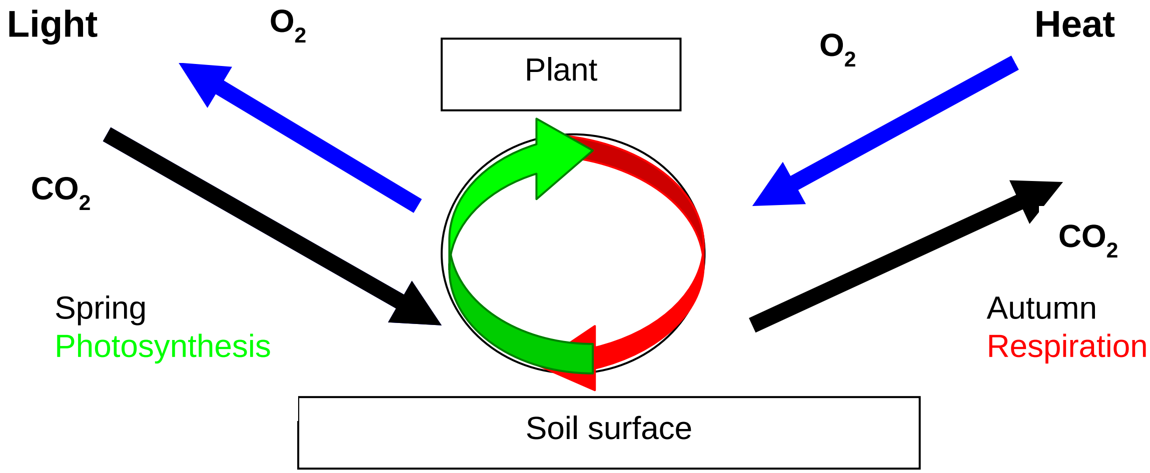
Terrestrial ecosystem



3. The global perspective. Light coming into the Earth is transformed through synthesis and decomposition, carbon assimilation and combustion and diverse living organisms and released as heat into the large surroundings.



In 1950 the climatologist Charles Keeling climbed to the top of Mauna Loa Mountain on Hawaii and began to measure the concentration of carbon dioxide in the atmosphere. The so- called Keeling curve shows how our planet breathes. The seasonal variations dependent on the amount of vegetation and life's breathing as well as the long-term trend with an increasing percentage of carbon dioxide can be followed here.



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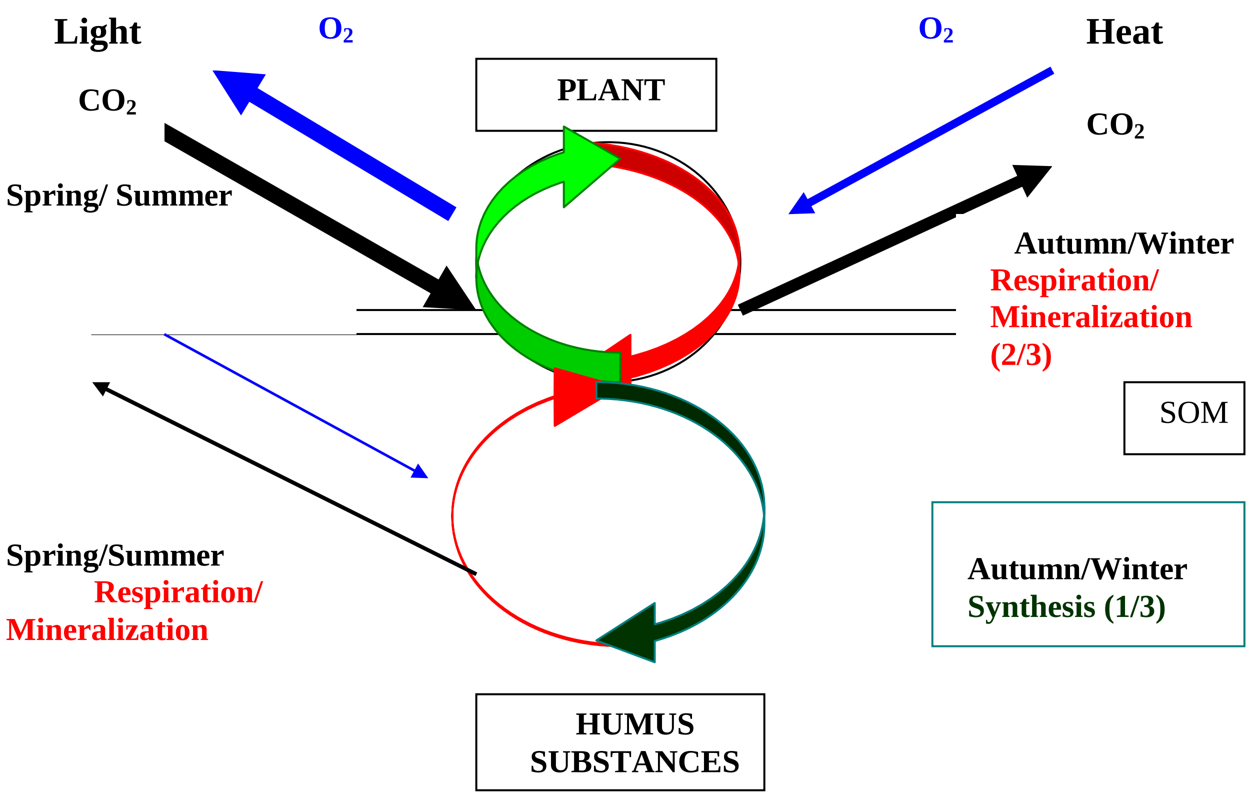
Photosynthesis:

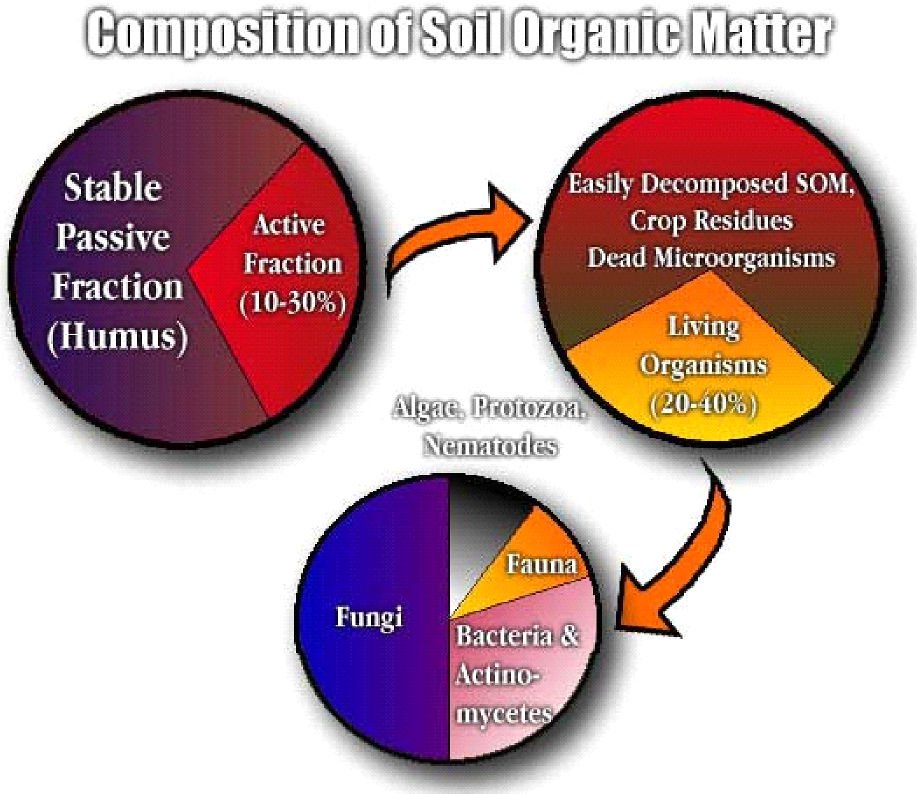
energy (sunlight) + $6CO_2$ +12 H_2O + $C_6H_{12}O6$ + $6O_2$ + 6 H_2O

Respiration:

$C_6H_{12}O_6$ (organic matter) + $6O_2$ +6 H_2O + $6CO_2$ + 12 H_2O + energy (heat)



Synthesis and decomposition above and below the soil surface



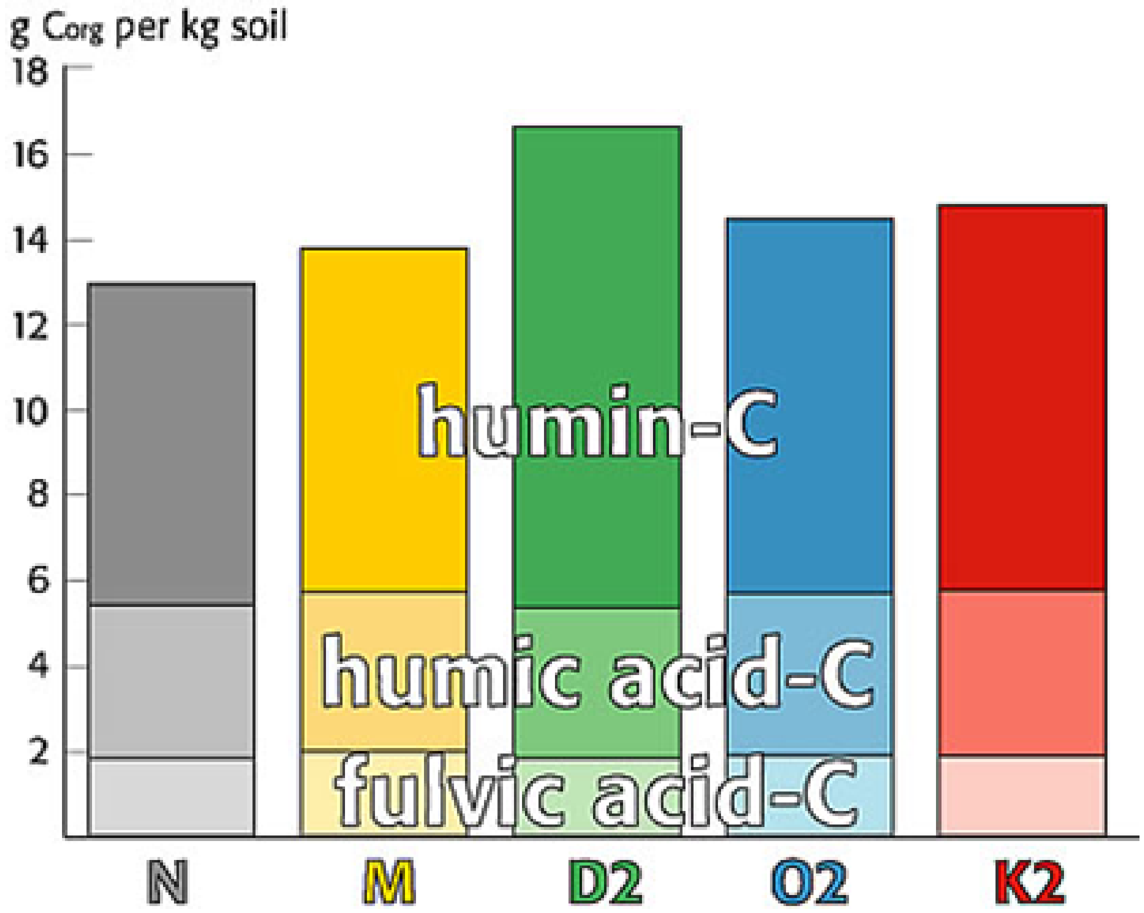
The total soil organic matter (SOM) can be divided into

living organisms and
raw mull matter (mainly

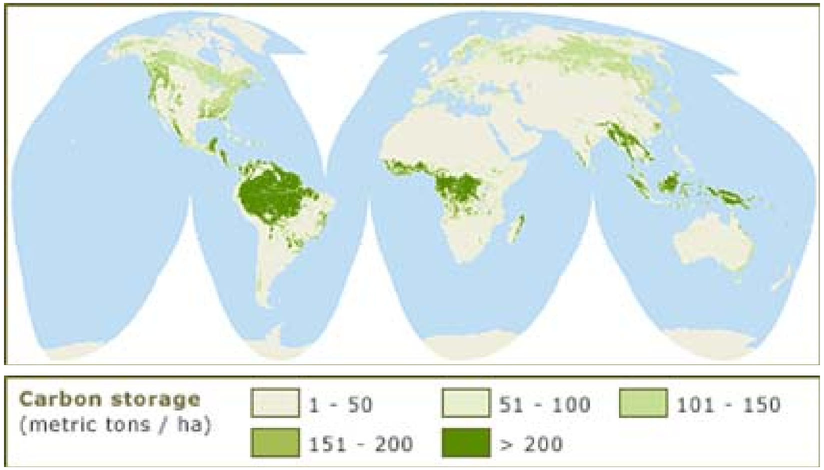
dead, more or less decomposed vegetation) and

humus substances (converted and stabilised organic material).

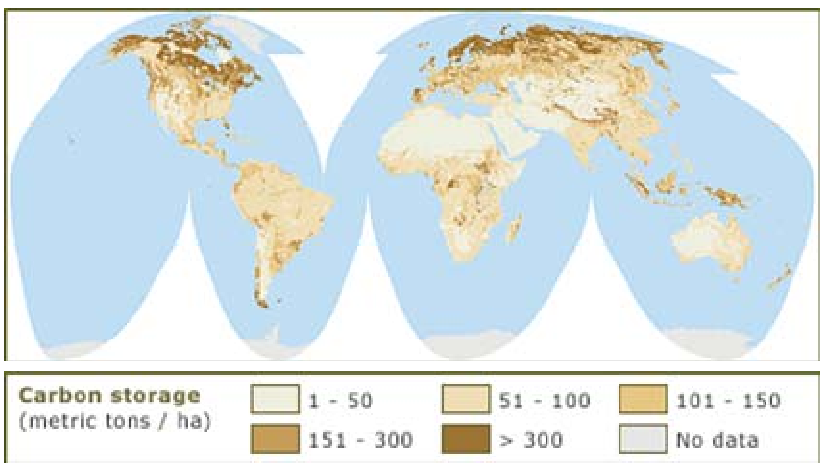
The organic matter in the soil includes both passive stabilised humus and an active fraction consisting of partially transformed organic material and of the living organisms



Various forms of humus identified in a well-known DOK experiment. Total soil organic matter content reacts slowly to farm management changes. Soil fractionation yields soil organic matter pools with defined functional attributes.



GLOBAL CARBON STORAGE IN SOILS



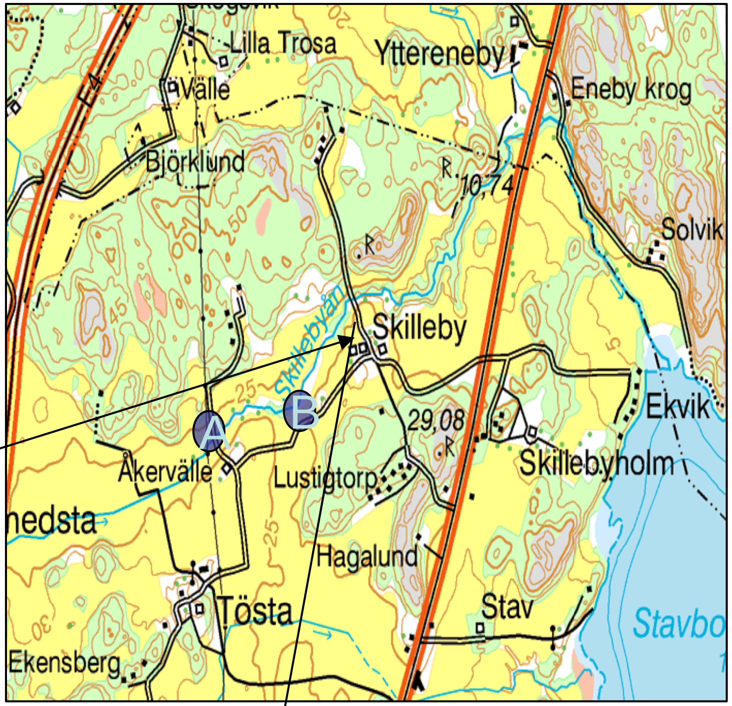
Soil formation is influenced by living organisms and how they interact with mineral soil or cold rock

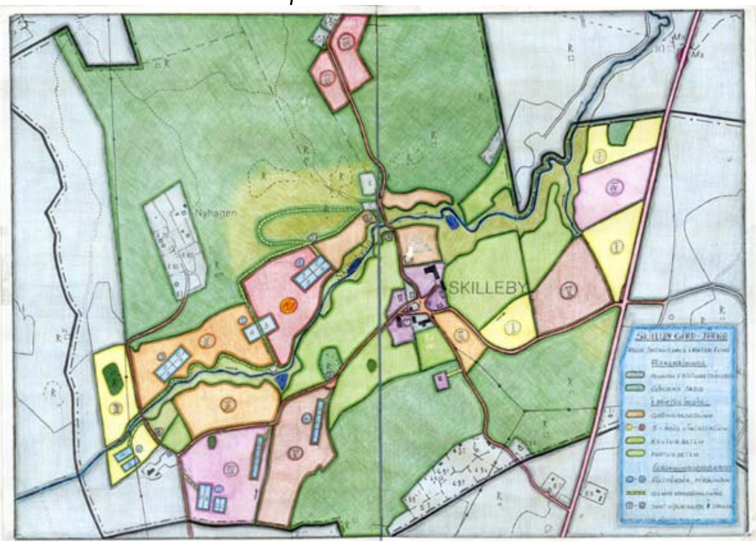
Soil formation factors:

- geological
- topographical
- climate (temperature, rainfall)
- biological activity
- time
- Cultivation and other human activities

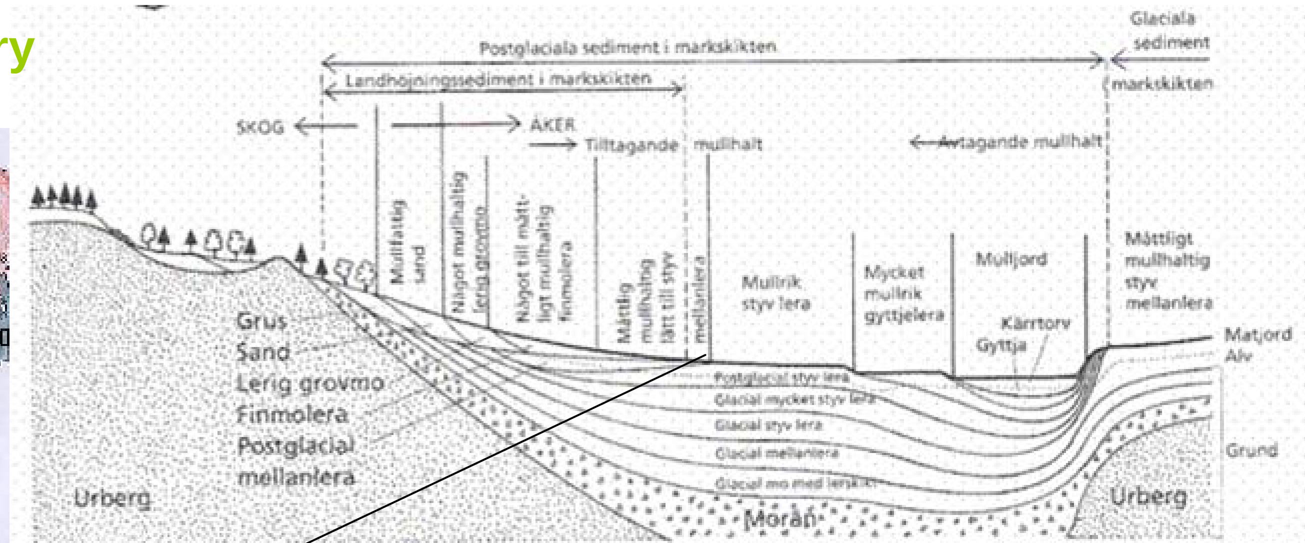
The amount of organic carbon in living organisms and in the soil, in tons/ha (World Resources Institute , 2000)

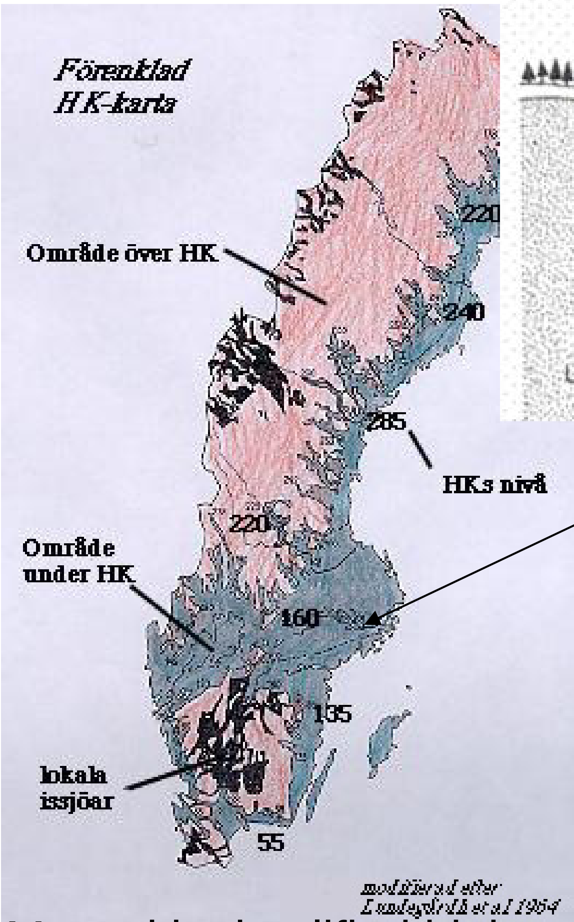

Bothnian Bay
Bothnian Sea
NORWAY
SWEDEN
FINLAND
Oslo
Helsinki
Gulf of Finland
St. Petersburg
Neva
Tallinn
ESTONIA
RUSSIA
Gulf of Riga
Riga
LATVIA
Kattegat
DENMARK
Copenhagen
Sound
Baltic Proper
Belt Sea
LITHUANIA
Daugava
Nemunas
Kaliningrad
RUSSIA
Vilnius
Minsk
Berlin
GERMANY
Oder
Vistula
Warsaw
POLAND
Prague
CZECH REPUBLIC
SLOVAK REPUBLIC
UKRAINE
0 100 200 km
Local ecological food initiatives
Selected ecological recycling farms
Baltic Sea drainage area. Sub-Regions and location of the selected 35 organic pilot farms 2002 in the research and development BERA (Baltic Ecological Recycling Agriculture) project co-ordinated of SBFI
(Artur Granstedt)


Lilla Trosa
Ytterenebý
Välle
Eneby krog
Björklund
10,74
Solvik
Skilleby
Skillebyån
A
B
29,08
Ekvik
Åkervälle
Lustigtorp
Skillebyholm
nedsta
Hagalund
Tösta
Stav
Stavbo
Ekensberg


Nyhagen
SKILLEBY

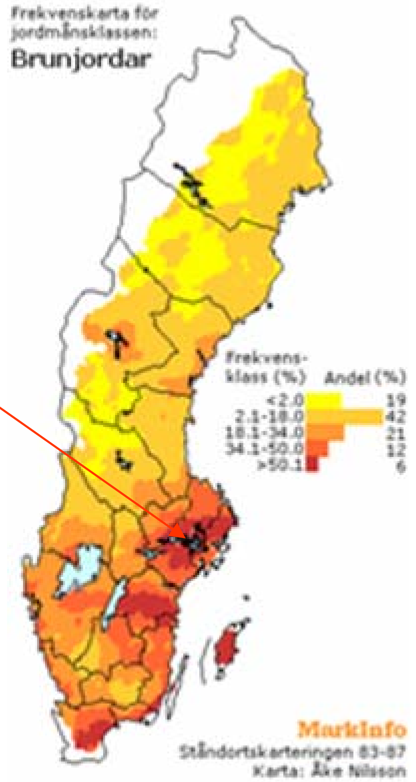
Natural history





Map with simplified high coast-line (HK), Area above the HK, Area under the HK.The black indicates local ice-lakes

In Sweden most arable land is found where there are sedimentary soil types below the high coast- line. The soils with limestone content balancing the acid quarts (chisel) dominated parent material have the best natural fertility.



Humus-iron podzol (Soil survey archive)

Brown earth

Pictures showing soil profile types in Sweden. The ongoing leaching in *podsoils* results in the characteristic layer of bleached soil.

And the man changed

Natural soil to cultivated soil

- Farm land differs from natural land due to the redistribution that takes place as a result of plowing and cultivation. In the 5000 year old clay loam soils of Skilleby experimental farm in Järna the clay content in the topsoil between 30 – 70 % and the humus content in the topsoil of several fields is 2.5 - 3%. This means that the total store of humus is about 120 to 140 tons per ha and that the five important elements that are in all living organisms are found here in their organic form: 70 000 - 80 000 kg carbon, 7000 kg nitrogen and approximately 2000 kg phosphorous per ha as well as hydrogen and oxygen.

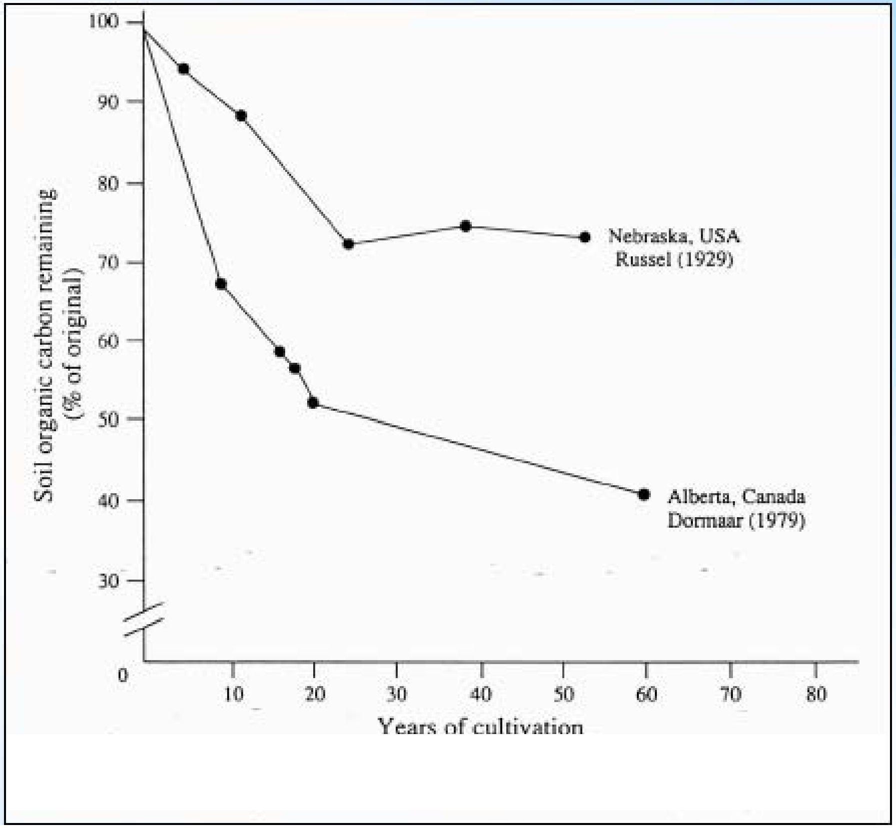
- Cultivation can result in soil improvement or in the depletion of that which the natural processes have built up."

Soil Organic Matter and Global Change

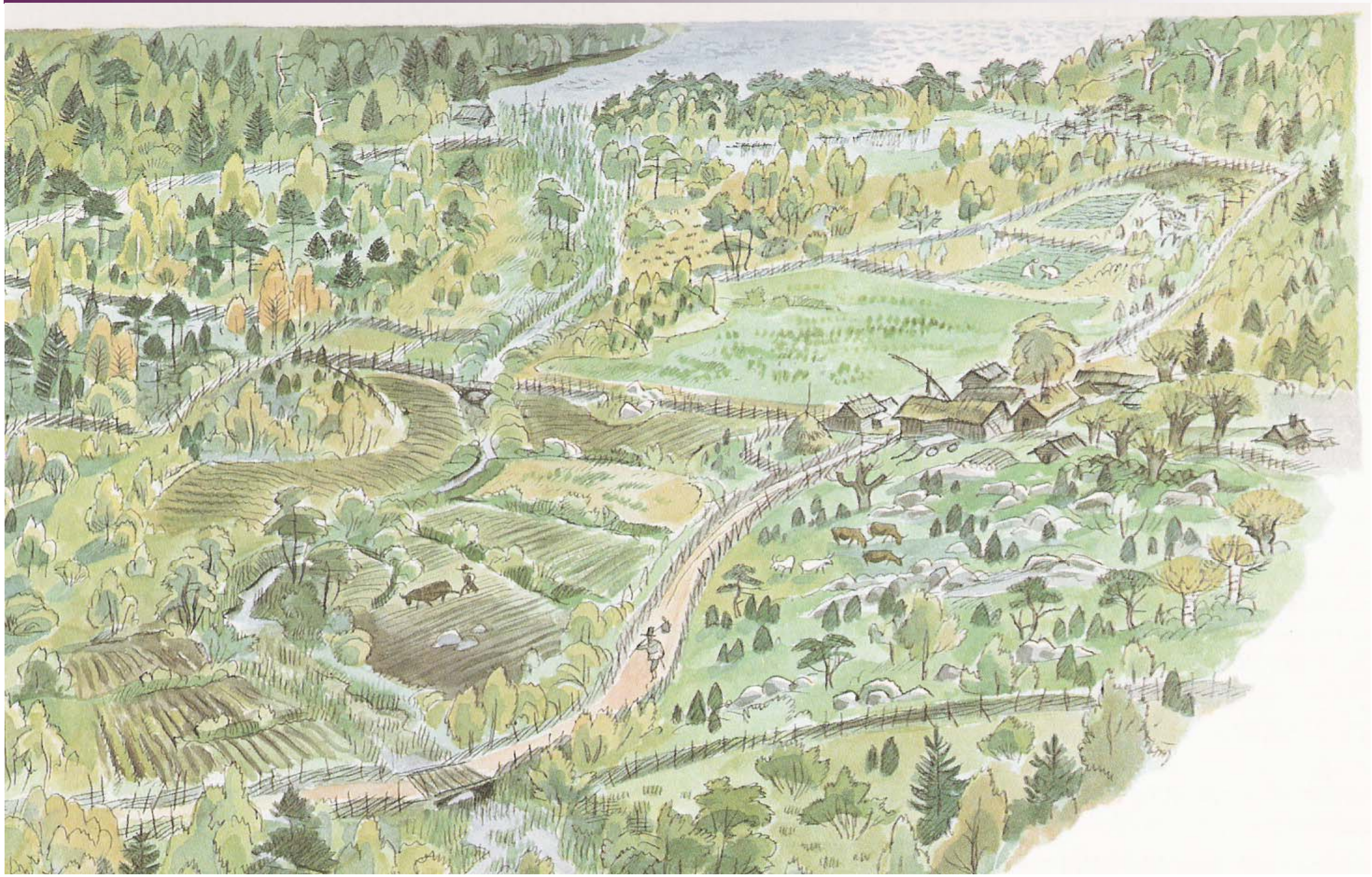
Cultivation reduces OC in soil (20-30%) in first few decades:

Due to lower prod of detritus and greater rate of decomp

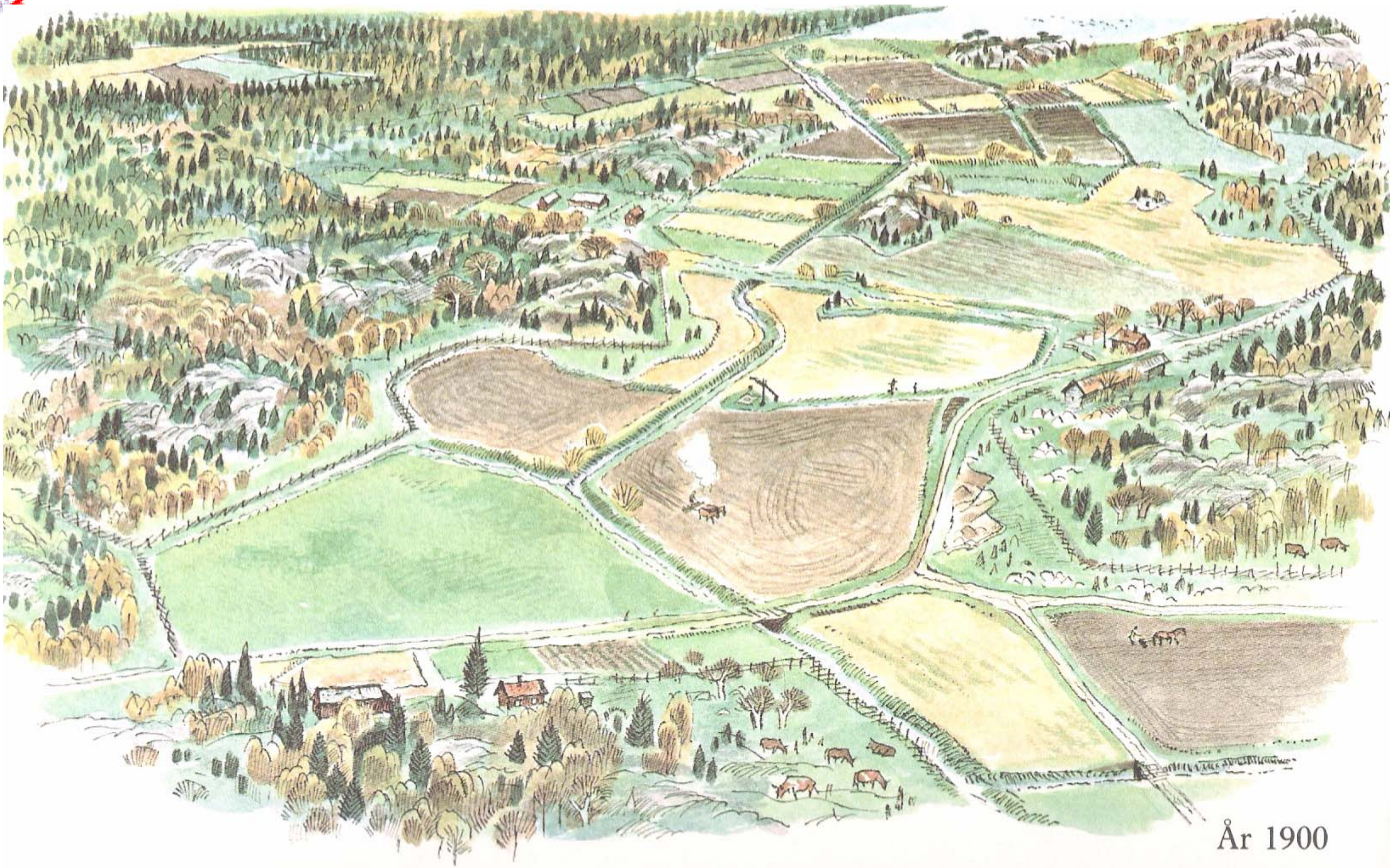
~0.8 x 10^{15} g C yr^{-1} added to atmosphere from land-use changes



Many studies show how humus halt declines considerably already after the first 10 years of cultivation (Schlesinger, 1986). Cultivation can reduce organic carbon in soil by 20 – 30 % in the first few decades due to a lower production of detritus and a higher rate of decomposition.



Looking to the past can help us learn for the future. Here is the documented agricultural landscape in Roslagen (Brusewitz and Emelin) in central Sweden about 500 years ago. There was a more or less well utilized cultivated grass and forest land, which through the animals gave manure to the small plots of arable land for cereal and crop production.

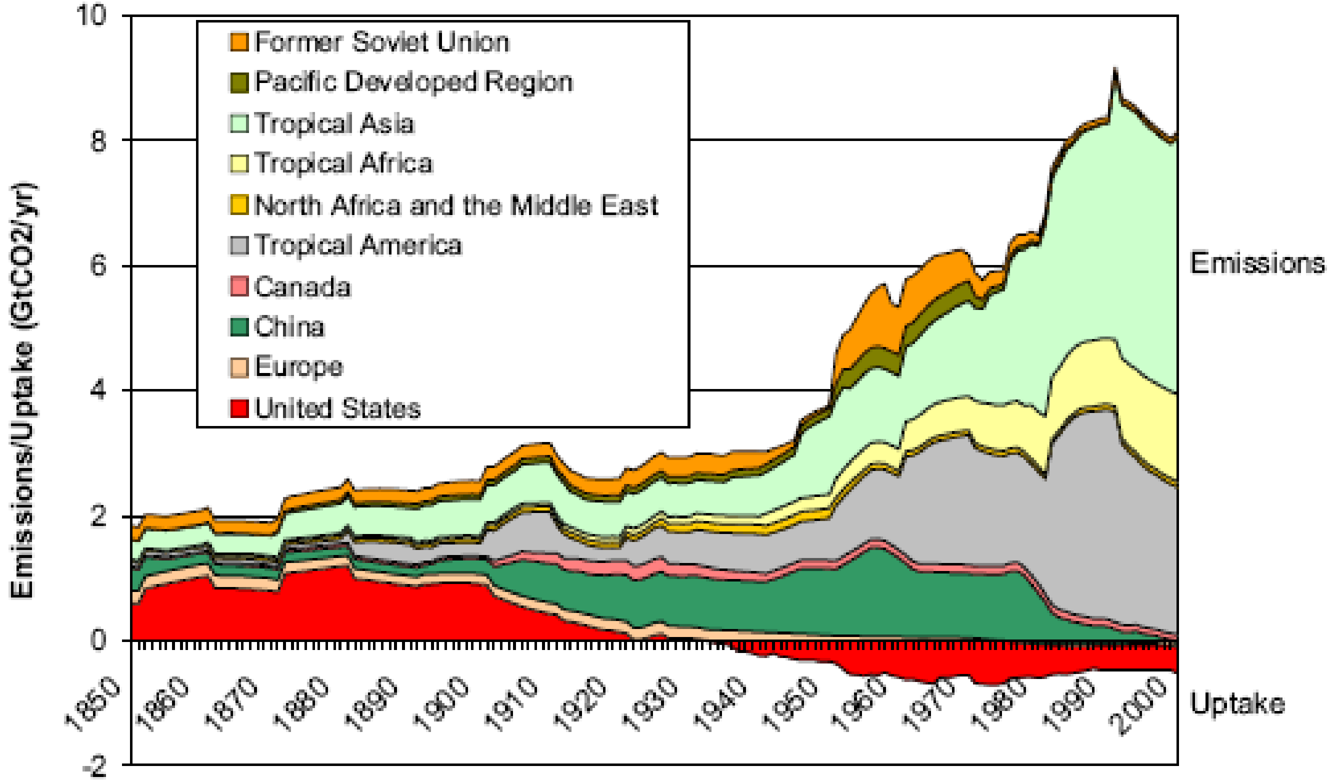


Here is the same landscape in the year 1900. The population grew in Sweden from 2 million to 7 million people and in Finland from 1 million to 4million people during the 150 years from 1800 to 1950. based on local and renewable resources - improvement of soil fertility.

Here is the same landscape 85 year later. Part of the divers landscape has been forested and the rest of the area is under specialized crop production belonging to a farm further away

and specialized animal farms with high surplus of animal manure

Figure 13. Approximately a quarter of the yearly increase of carbon dioxide in the atmosphere is due to deforestation and land degradation. The global humus capital is decreasing and green areas are getting smaller. (Source: Carbon Dioxide Information Analysis Centre, CDIAC, 2002)



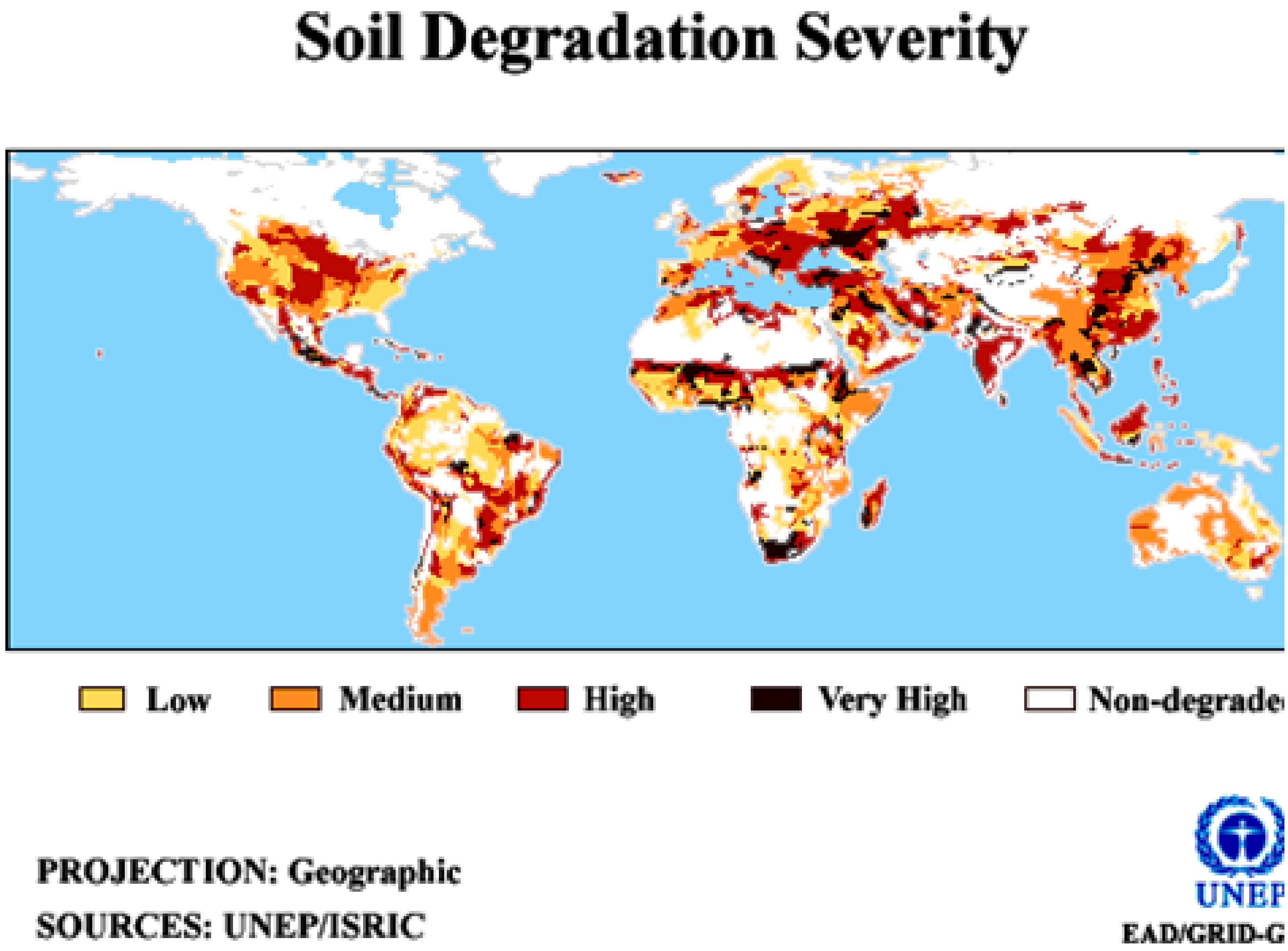
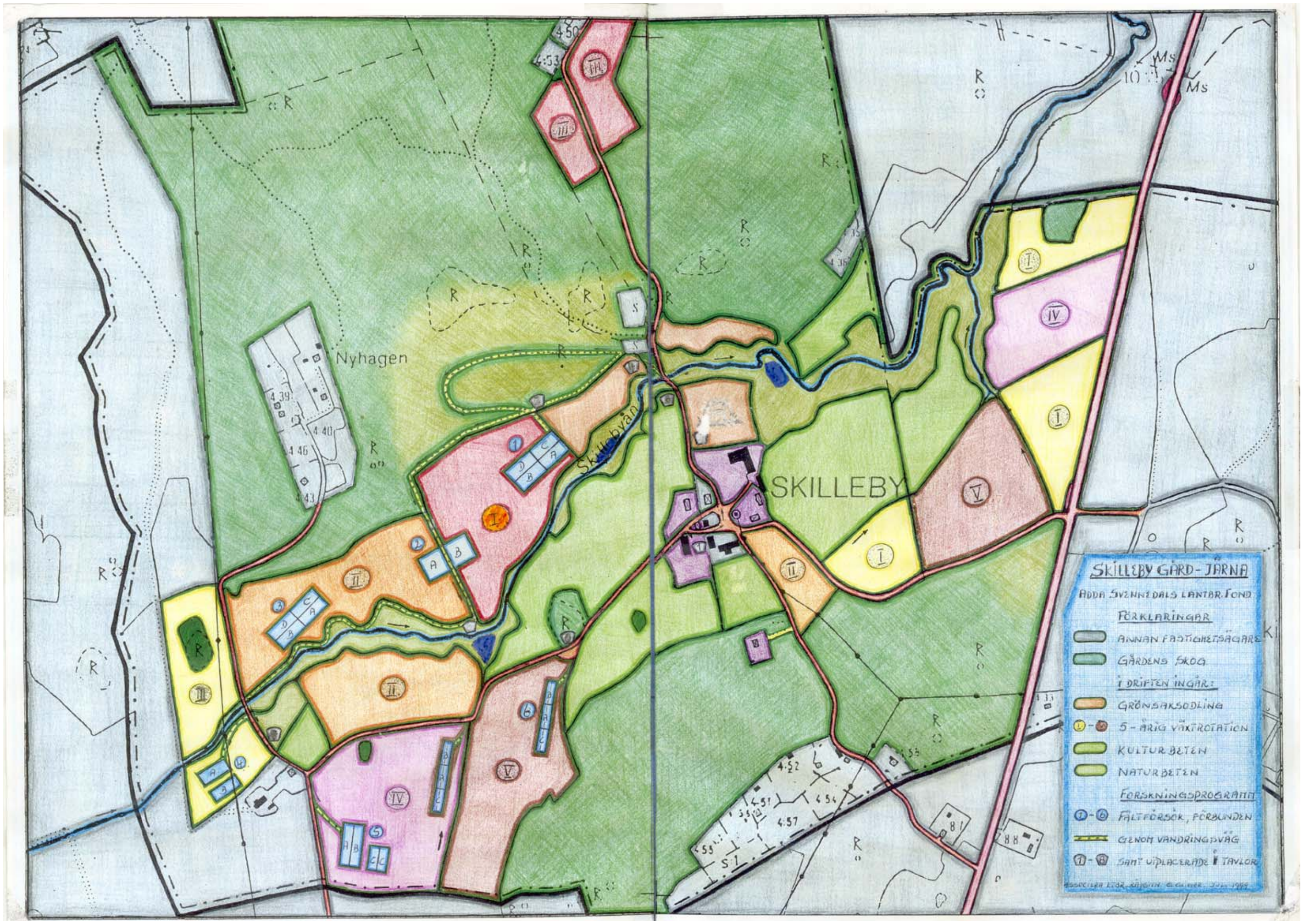
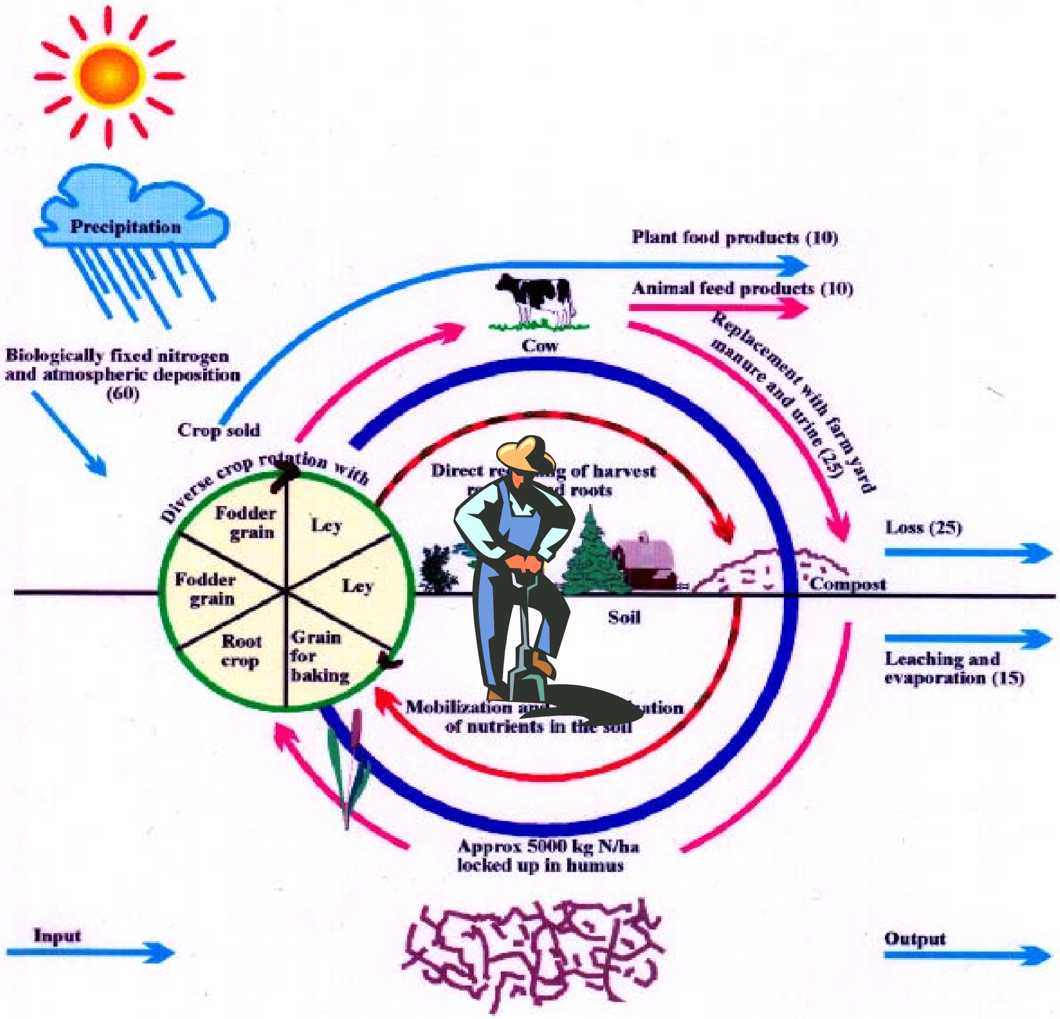


Figure 13. Global survey of soil degradation.


Nyhagen
SKILLEBY
SKILLEBY GÅRD - JÄRNA
ADDA SVENNEDALS LANTBR. FOND
FÖRKLARINGAR
ANNAN FASTIGHETSÄGARE
GÅRDENS SKOG
I DRIFTEN INGÅR:
GRÖNSAKSODLING
5 - ÅRIG VÄXTROTATION
KULTURBETEN
NATURBETEN
FORSKNINGSPROGRAM
FÄLTFÖRSÖK, FÖRBUNDEN
GENOMVANDRINGSVÄG
SAMT UPPLACERADE I TAVLOR



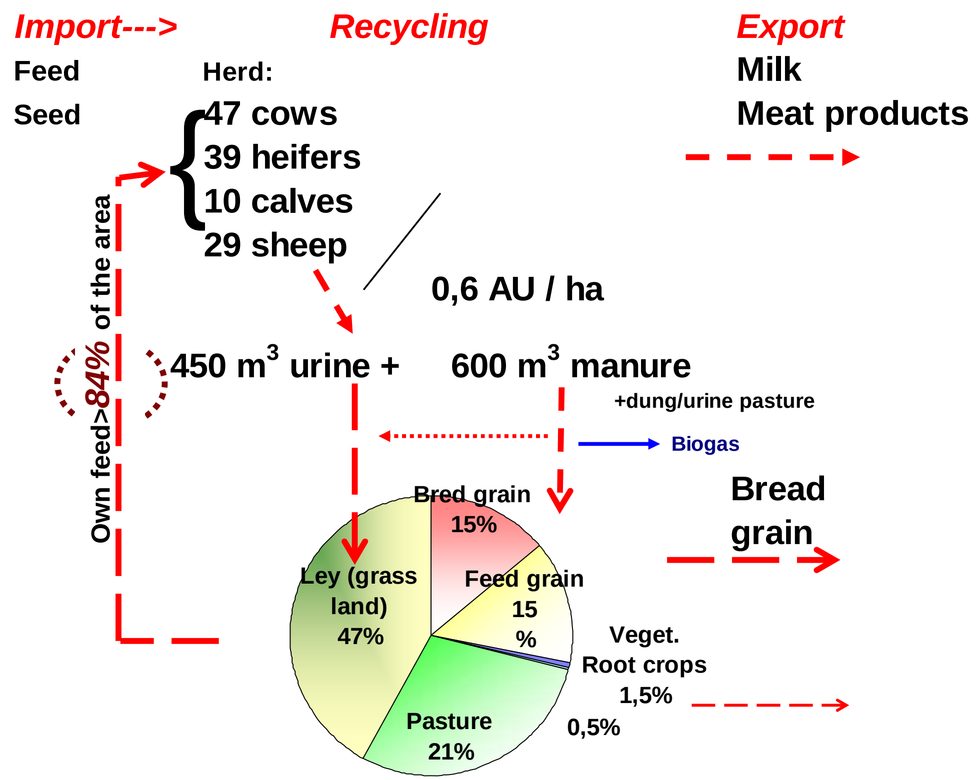
The Biodynamic agricultural organism. The recycling from the growing of legume crops whereas the crop residues are directly incorporated in the soil and the recycling via fodder and the on-farm animal manure (Source: Granstedt, 1992).

BIODYNAMIC ecological recycling agriculture / ERA

The prototype farm Yttereneby – Skilleby in Järna)

- The animal density is adjusted to the own feed production: In this case on 84 % and crop for sale on 16 % of the farm area and with a animal density of 0,6 AU/ha (=average for Sweden)

Yttereneby and Skilleby 2003

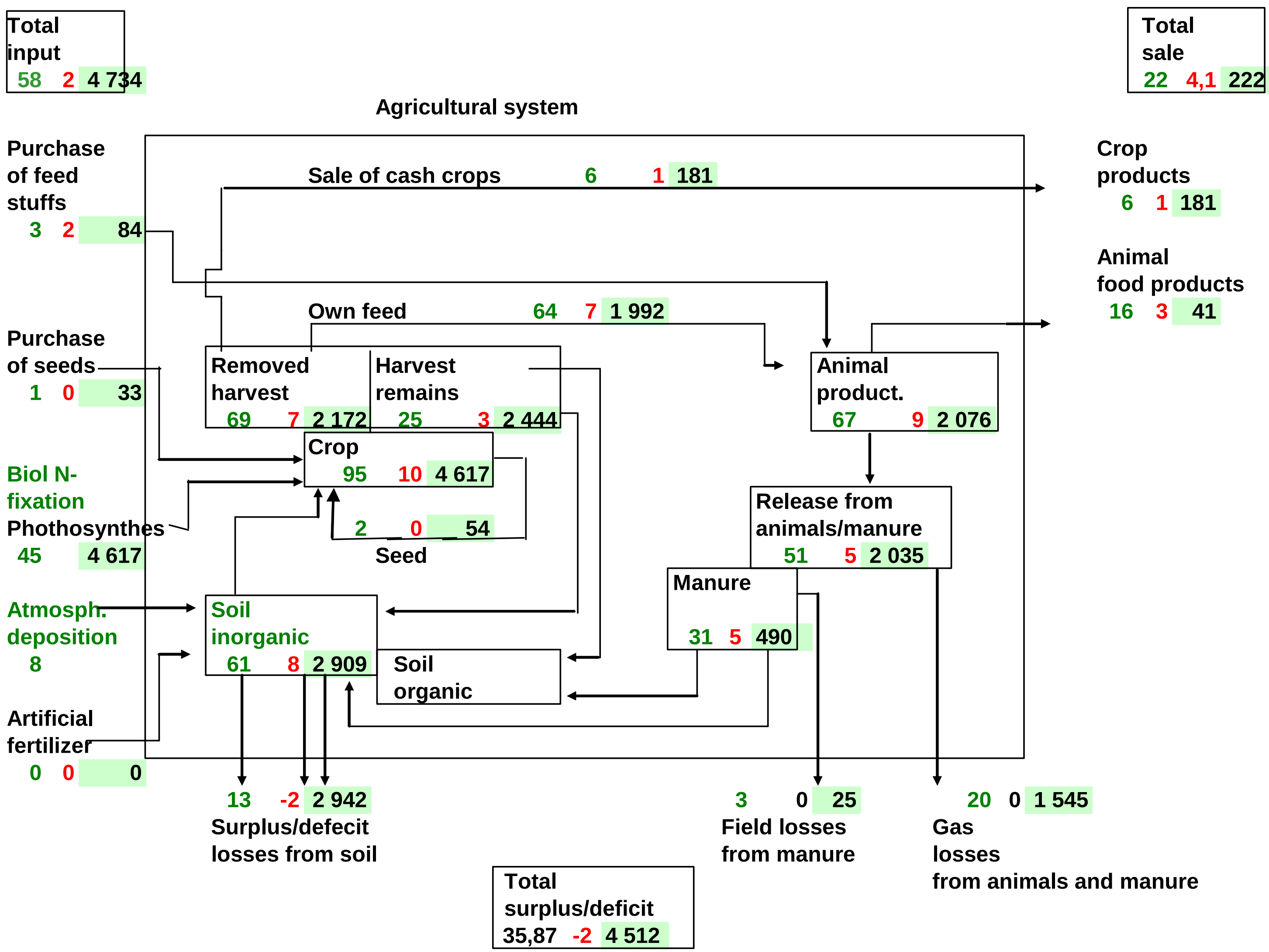


Arable land	ha
Crop rotation	106
Pasture	29
Vegetable -	

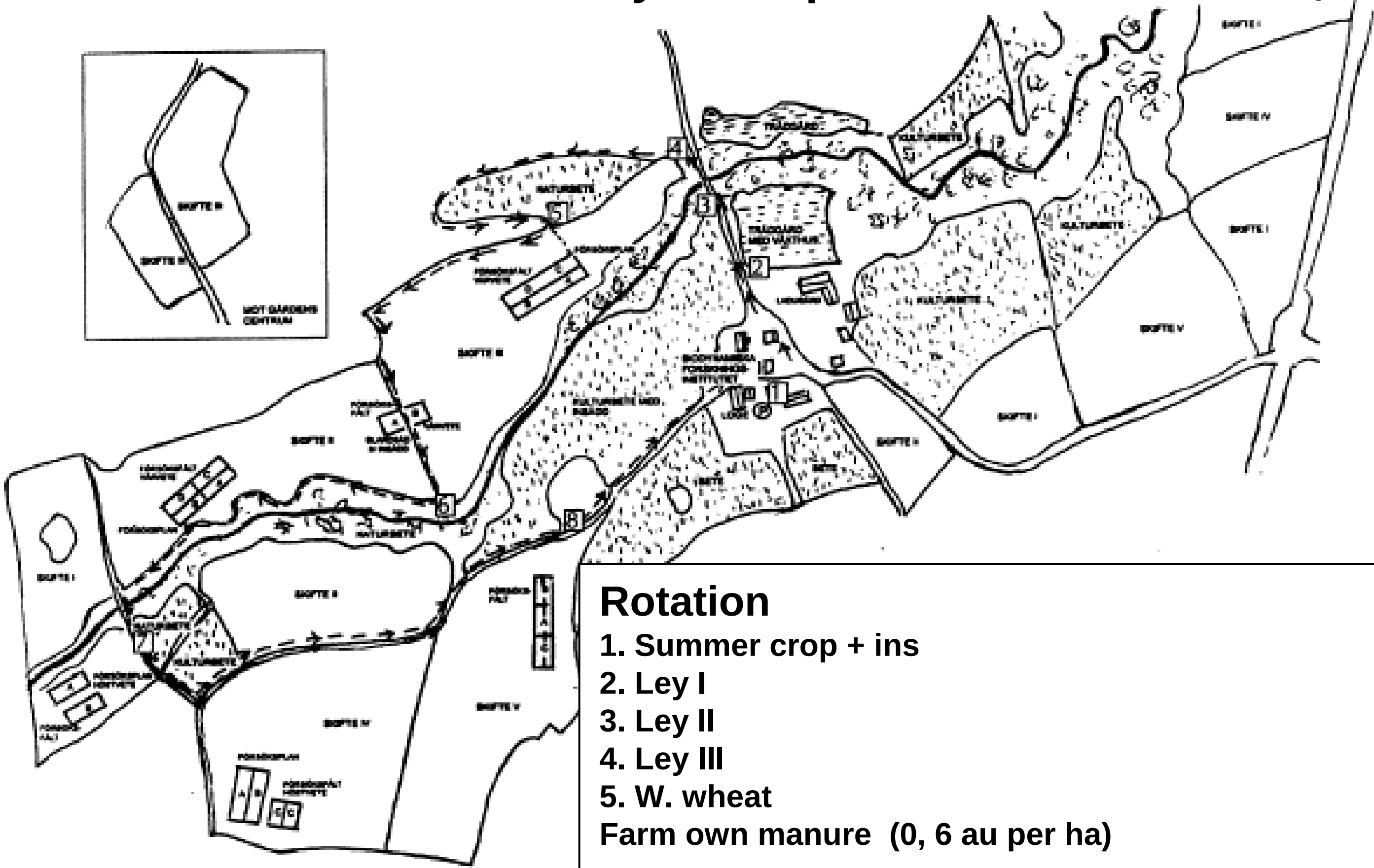
Crop rotation		
Year	1	Spring cerals + insowing
	2	Ley I
	3	Ley II

The Biodynamic Research Institute

Flow of N/P/C kg ha^{-1} $year^{-1}$ in the agricultural-ecosystem Skilleby-Yttereneby farm, Järna (0,6 animal unit/ha) 2003-2005



Skilleby BD experimental Farm Järna, 57 ha



Rotation

1. Summer crop + ins
2. Ley I
3. Ley II
4. Ley III
5. W. wheat
Farm own manure (0, 6 au per ha)

On farm long term experiment from 1991:

- non-composted and composted manure
- with and without biodynamic preparation (split plot design)
- three levels: 12.5 (0), 25 (normal) and 50 tons per ha)
- 2 – 4 replicates on each of the five rotation fields

Experimental plan Skilleby Long Term experiment, Järna from 1991

Main plot	Treatments winter wheat
F1	Not composted manure 12.5 ton (0 from 1995)
F2	25 ton
F3	50 ton
K1	Composted manure 12.5 ton (0 from 1995)
K2	25 ton
K3	50 ton
Subplot (splitplot) +	BD preparation (each plot each year)
-	Without BD preparation

Experimental plan from 1991

Main plot	Treatments winter wheat
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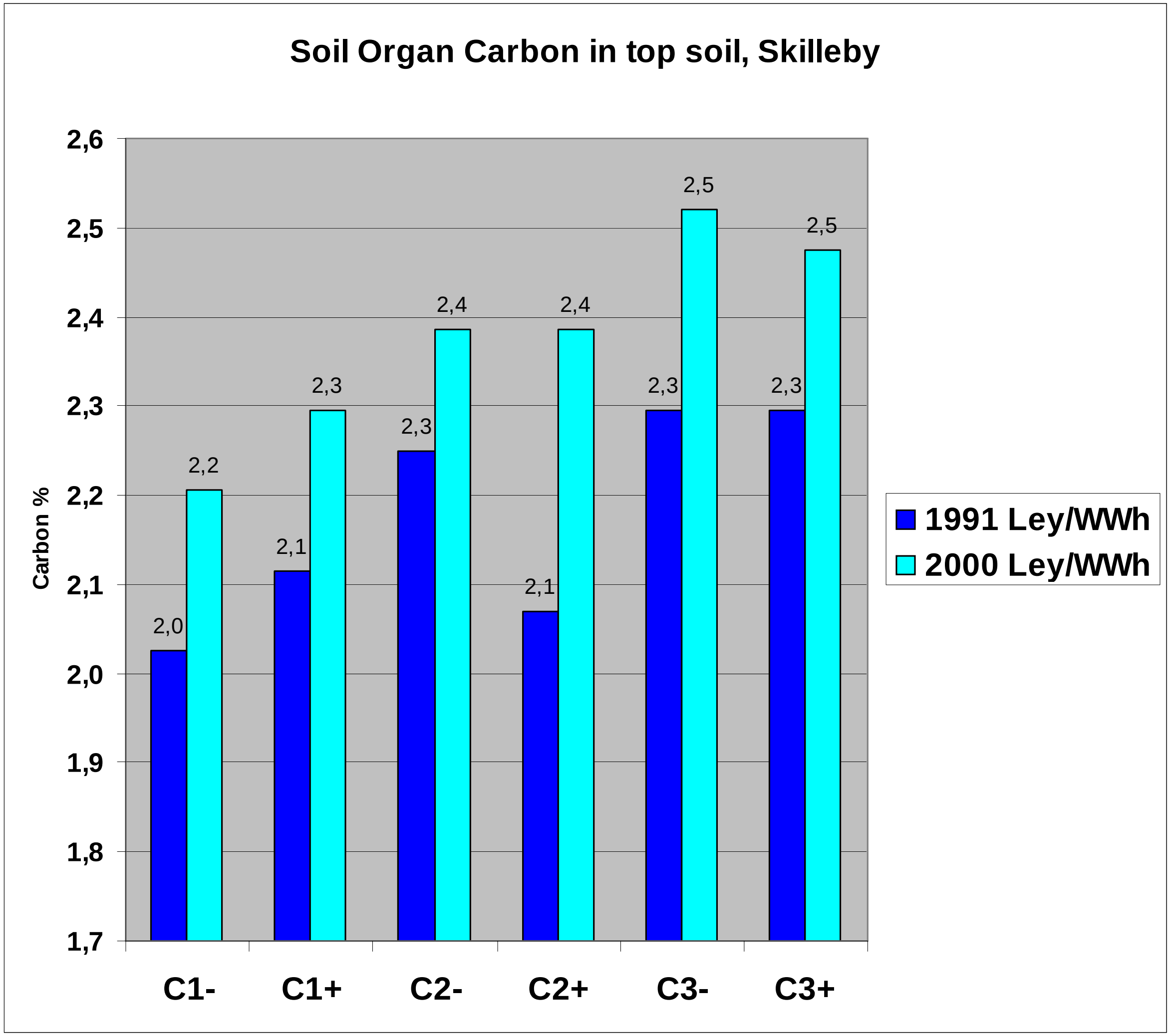
K3	50 ton
Subplot (split plot) +	BD preparation each plot each year
-	Without BD preparation



. Soil organic carbon content in percent in topsoil (0 – 20 cm) in long-term manure trials on Skilleby experimental farm 1991 – 2000. K1 (12,5) 0 ton; K2 25 ton and K3 50 ton composted farmyard manure without (-) and with (+) BD treatments to winter wheat. Soil sample average from the four replicates 1991 and 2000 after clover grass ley.

During these 9 years the average soil organic carbon increased by 9 % from 2,18 -2,38 %. This average increase in the 20 cm topsoil was calculated to 4 450 kg C from a level of 47 850 to 52 300.

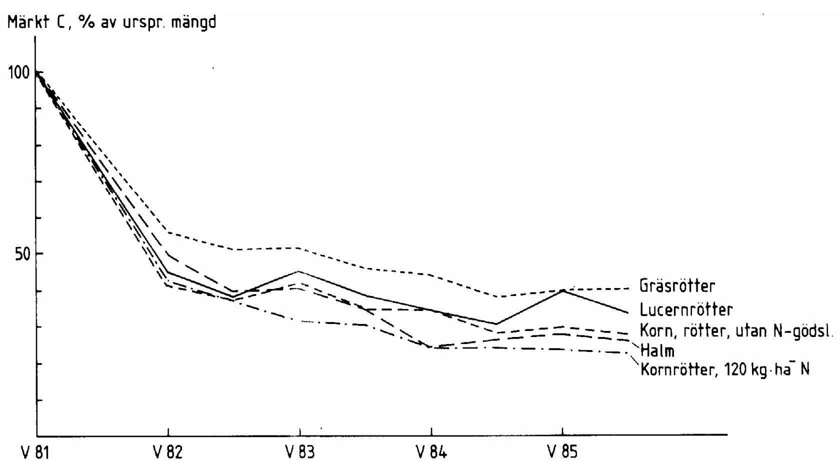
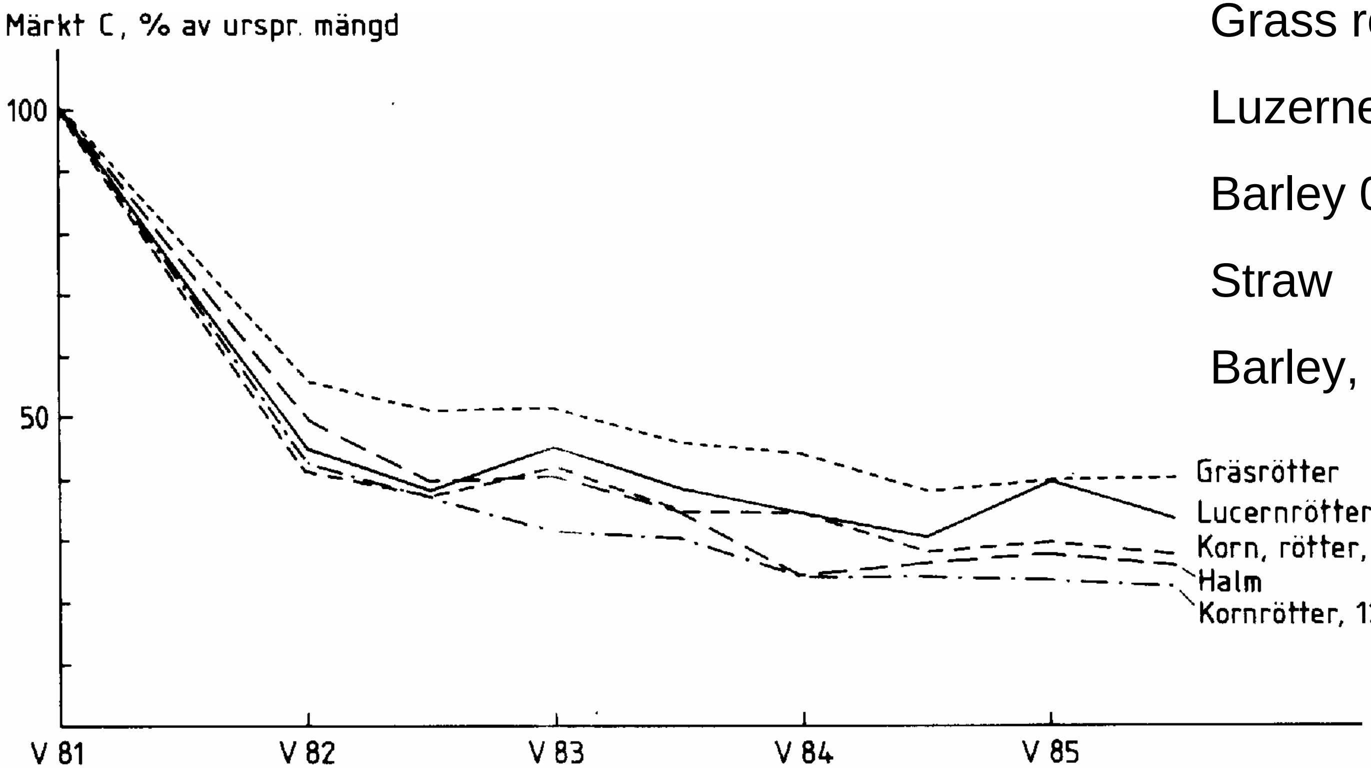


Fig. 4. Mineralisering av isotopmärkt organisk material. – *Mineralization of isotope-labeled organic material.*

Isotope-labeled C, % of recently organic substance



Grass rots

Luzerne roots

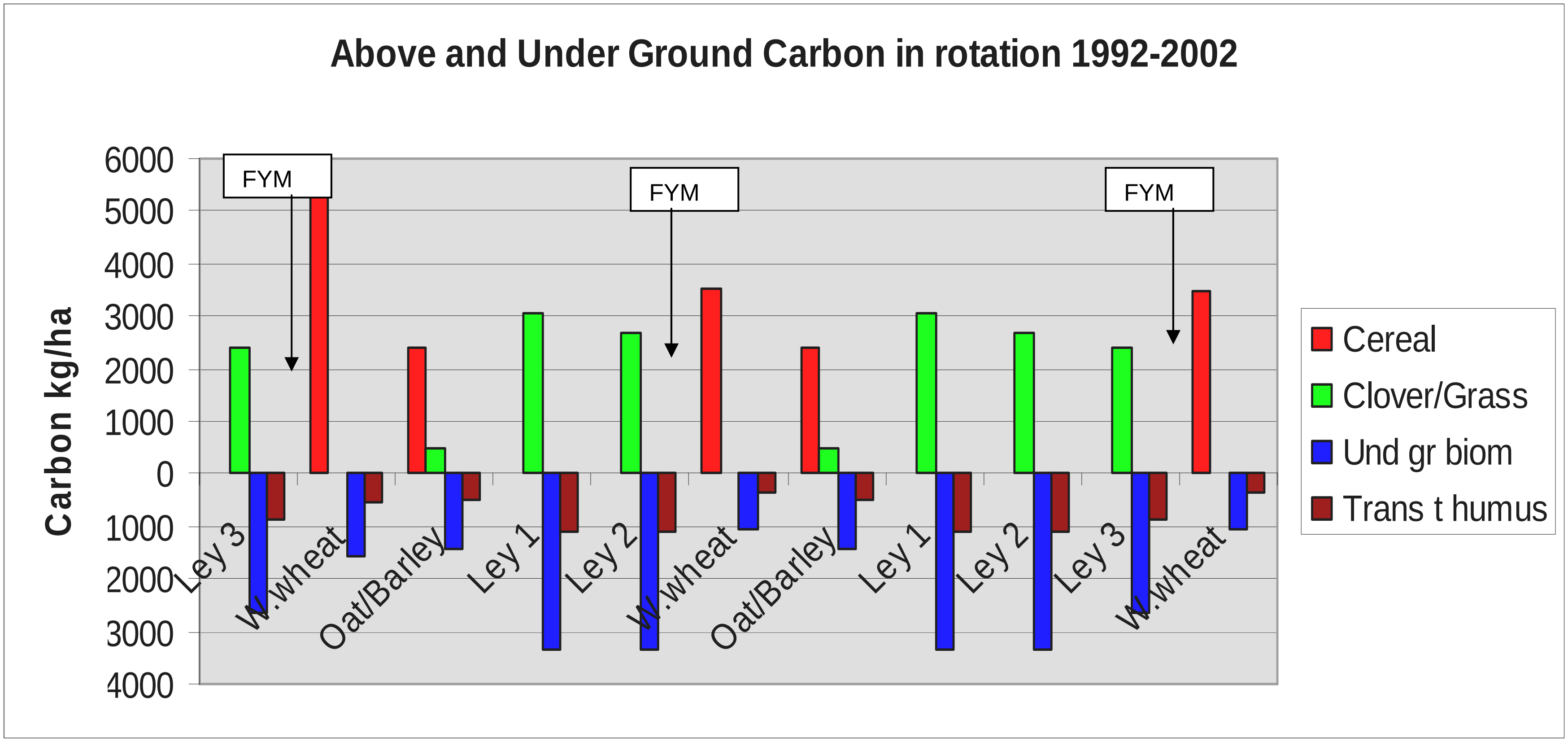
Barley 0 N-fertilizers

Straw

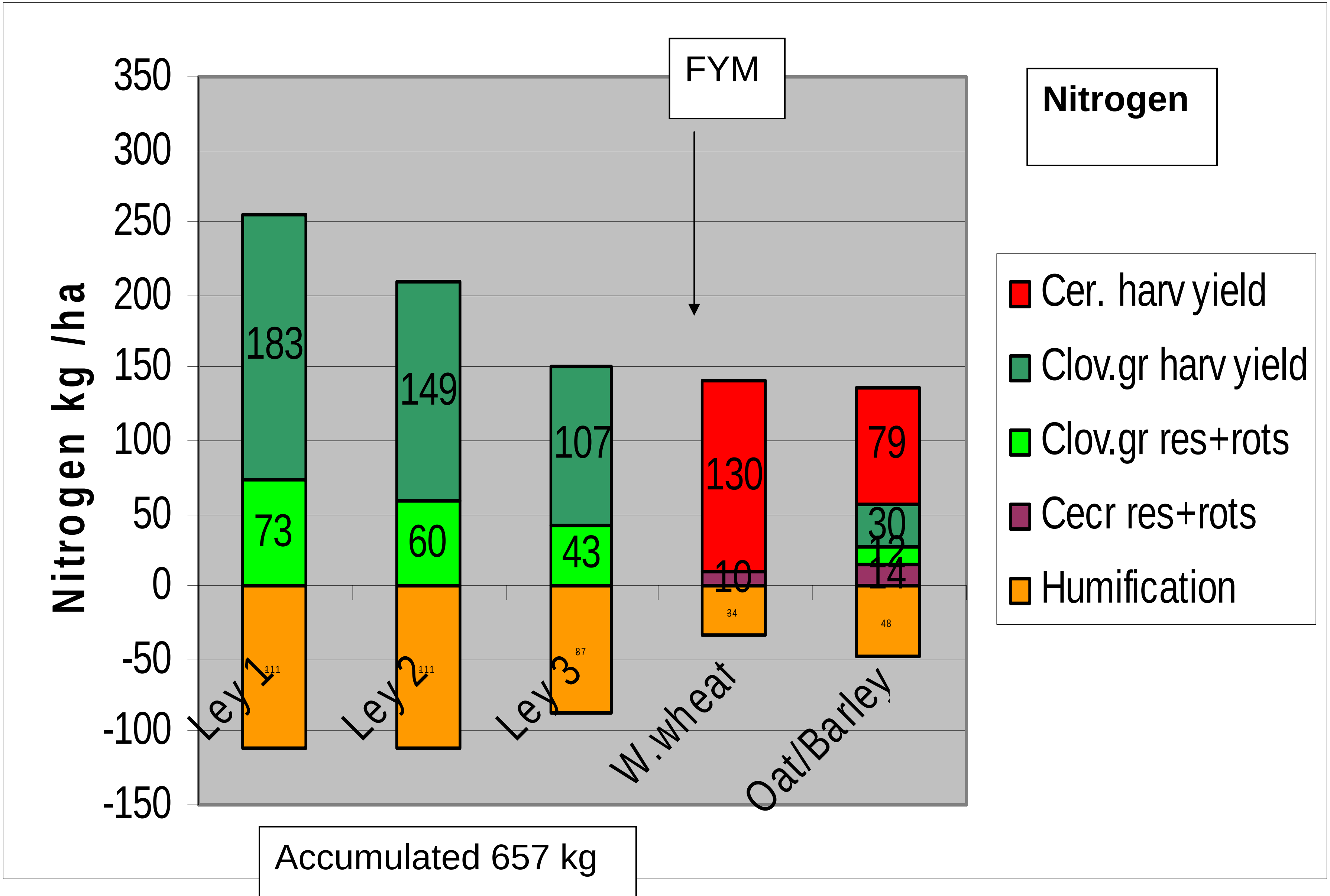
Barley, 120 kg N/ha

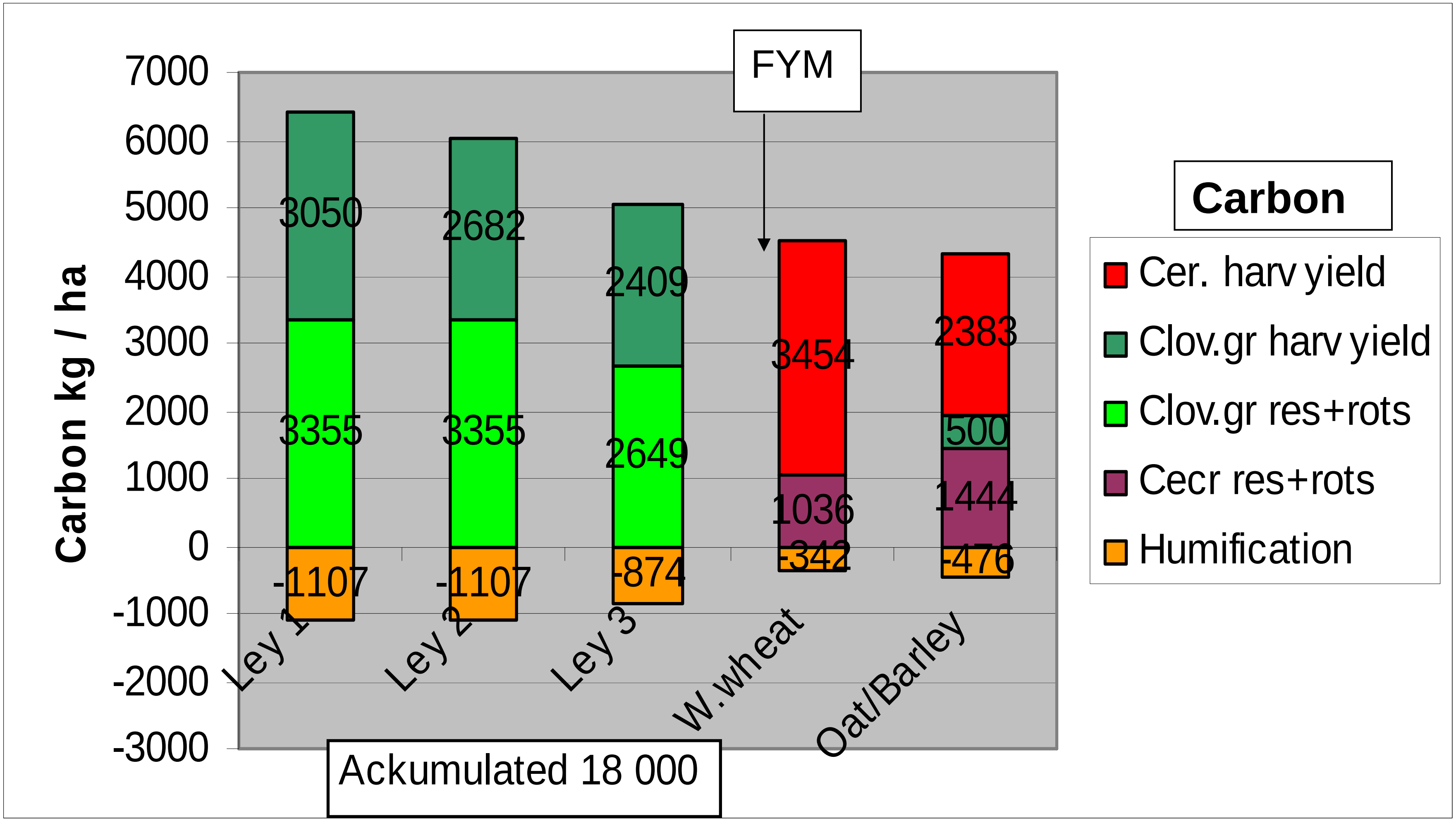
– Mineralization of isotope-labeled organic material.

Persson, J. 1987

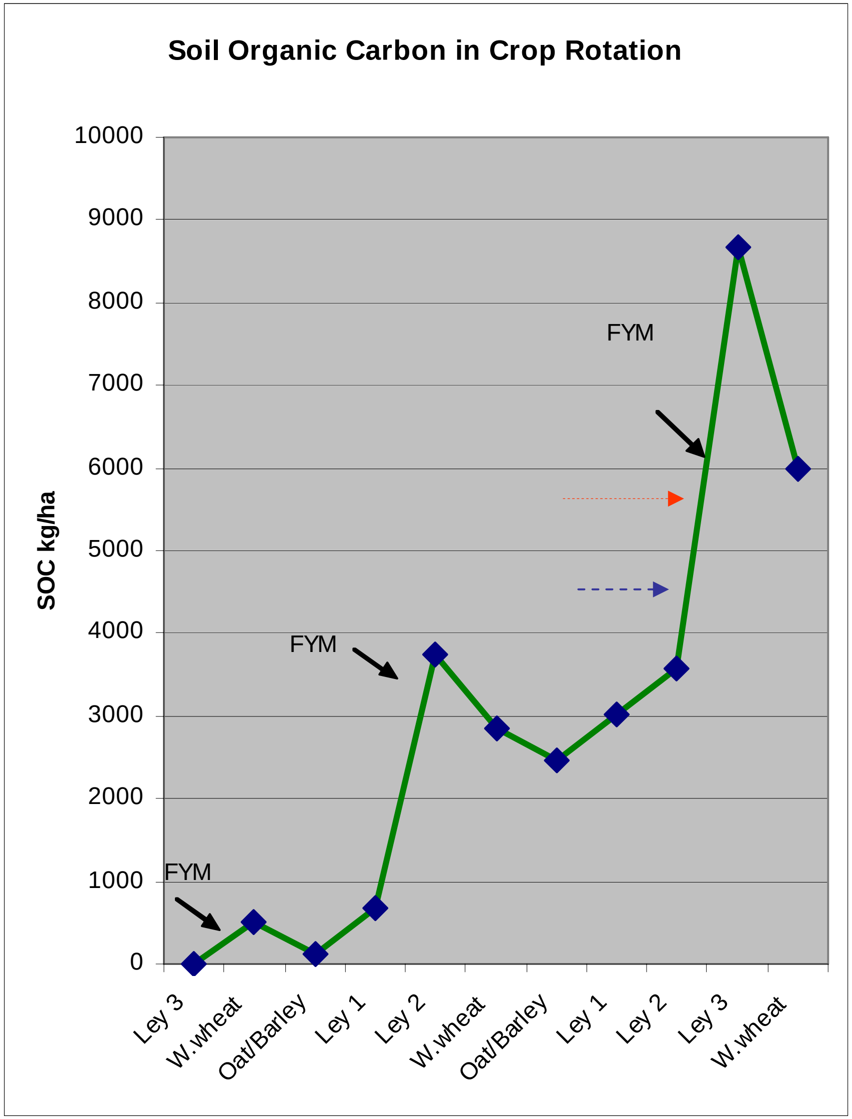


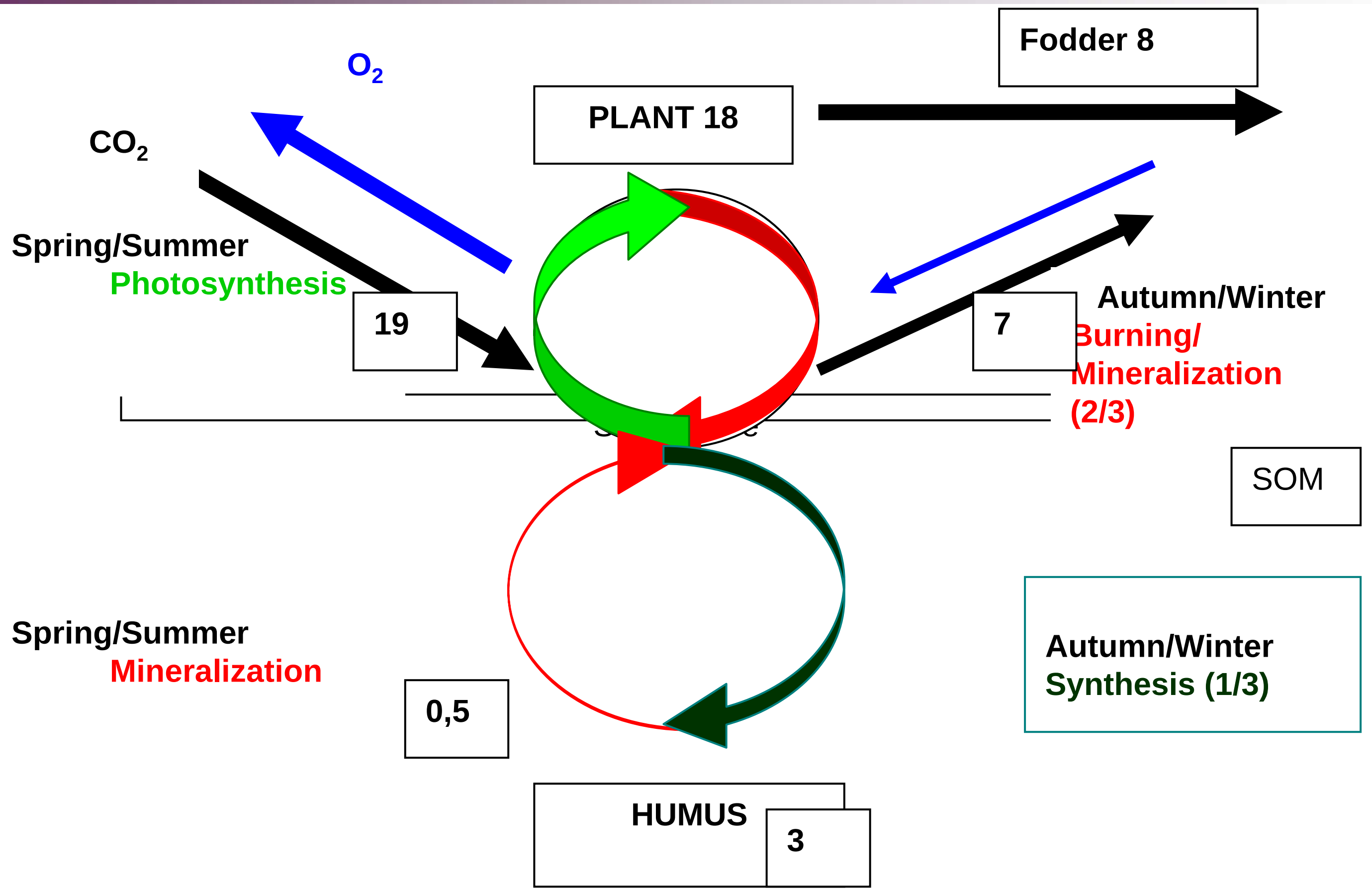
Calculated humus formation from measured above and calculated underground biomass in field HV 1 at Skilleby on farm experiment 1991 – 2002. FYM= Farm Yard Manure applied after ley 3 before winter wheat.


FYM
Nitrogen
Nitrogen kg /ha
350
300
250
200
150
100
50
0
-50
-100
-150
183
73
111
149
60
111
107
43
87
130
10
34
79
30
12
14
48
Ley 1
Ley 2
Ley 3
W.wheat
Oat/Barley
Cer. harv yield
Clov.gr harv yield
Clov.gr res+rots
Cecr res+rots
Humification
Accumulated 657 kg


FYM
Carbon
Carbon kg / ha
7000
6000
5000
4000
3000
2000
1000
0
-1000
-2000
-3000
3050
2682
2409
3454
2383
3355
3355
2649
500
1036
1444
-1107
-1107
-874
-342
-476
Ley 1
Ley 2
Ley 3
W.wheat
Oat/Barley
Cer. harv yield
Clov.gr harv yield
Clov.gr res+rots
Cecr res+rots
Humification
Ackumulated 18 000

The total here calculated accumulated value 5 799 (before application 25 ton manure with total 3000 kg carbon) was a little higher than the measured value of 4450.





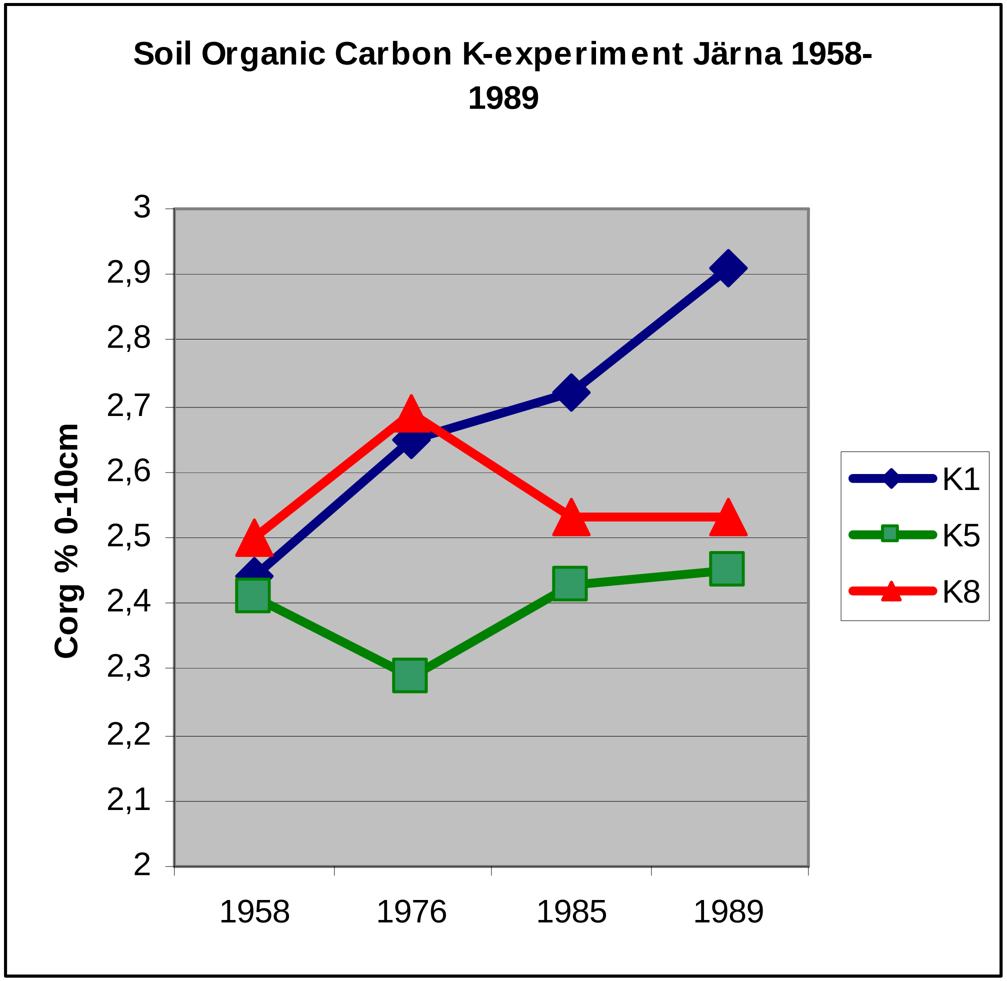
The building through photosynthesis, harvested carbon, decomposition of root biomass and harvest residues and finally the building up of humus carbon in soil in a three year ley at Skilleby experimental farm in Järna. The amounts presented in boxes refer to ton carbon per ha and are net values in biomass. They do not include the amount of carbon built by the plant’s metabolism during the growing season and later decomposed and the emission of carbohydrates in the form of root exudates in to the soil.

Crop rotation in K-experiment 1958 – 1990

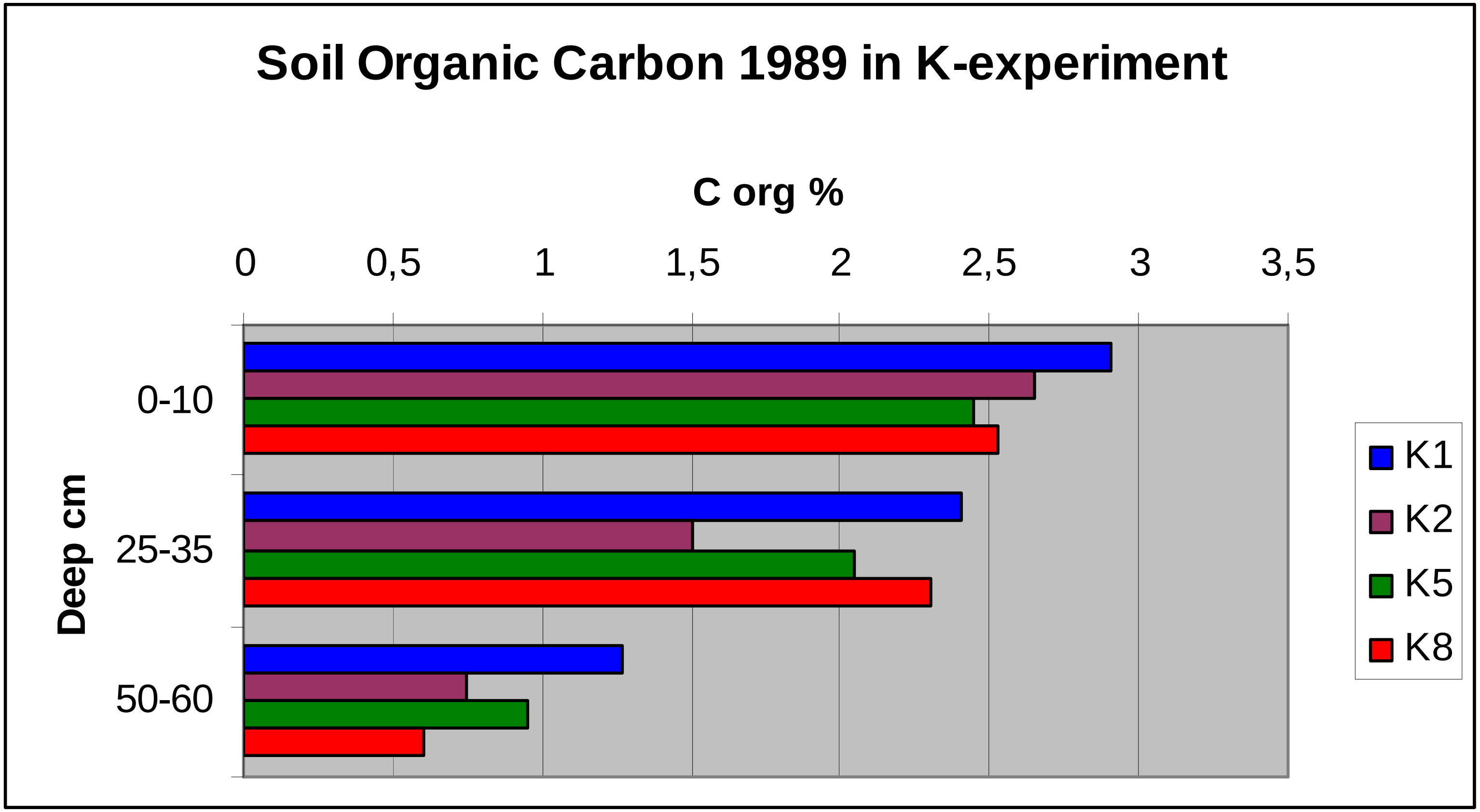
- Summer wheat
- Ley with legumes
- Potatoes
- Beets

The eight treatments in K-experiment 1958 – 1990

- **K1. *Biodynamic composted manure and BD field preparation***
- K2. Biodynamic composted manure without the BD field preparation
- K3 Raw farm yard manure
- K4 Raw farm yard manure and mineral fertilizer (NPK)
- **K5 *Without manure or fertilizer***
- K6 Low mineral fertilizer (NPK
- K7 Medium mineral fertilizer (NPK)
- **K 8 *High fertilizer (NPK)***



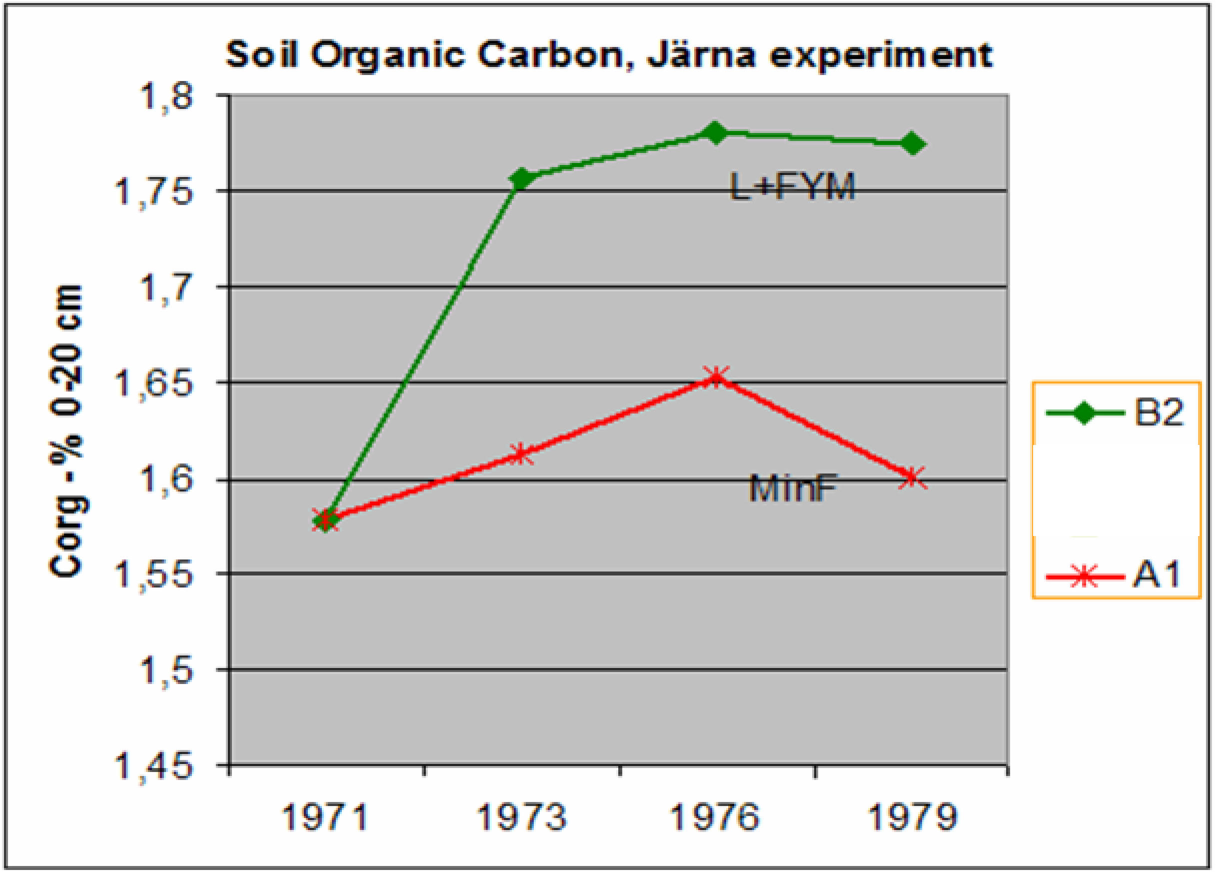
Organic Carbon in the topsoil 0 – 10 cm in Järna K-experiment 1958 – 1989 in K1 (Biodynamic fertilizing), K5 (without fertilizing) and K8 (mineral fertilizing)



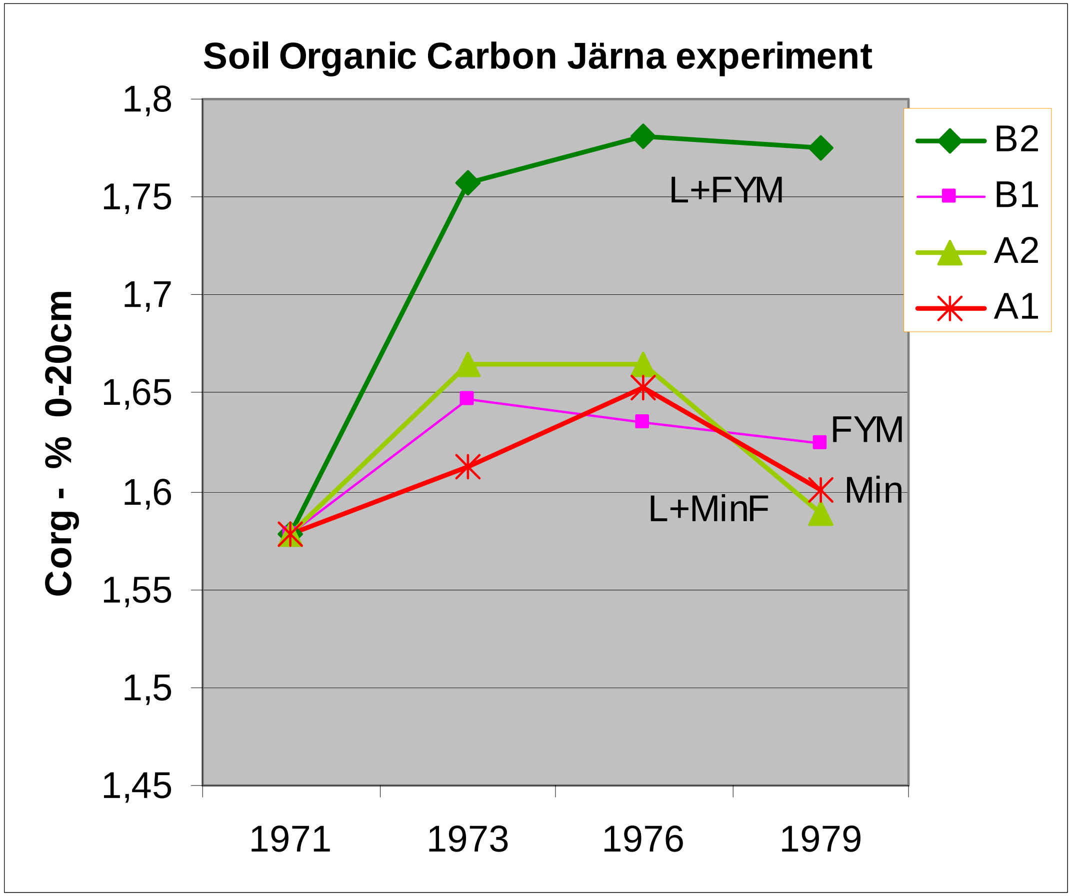
Organic carbon 0-10, 25-35 and 50-60 cm 1989 in K experiment in Järna in the treatments K1 (Biodynamic composted manure and the BD field preparation) , K2 (Biodynamic composted manure without use of the BD field preparation), K5 Without manure or other fertilizers and K8 (High fertilizer, NPK). ***The total amount of organic carbon to a depth of 60 cm is 160 ton per ha (16 kg per m2) in the biodynamic treatment and 135 ton per ha (13 kg m2) in the mineral fertilized treatment.***

Trial plan for the collaborative trial between Biodynamic Institute and SLU in Ultuna and in Järna 1971 – 1979. Two locations, each crop each year and for repetitions

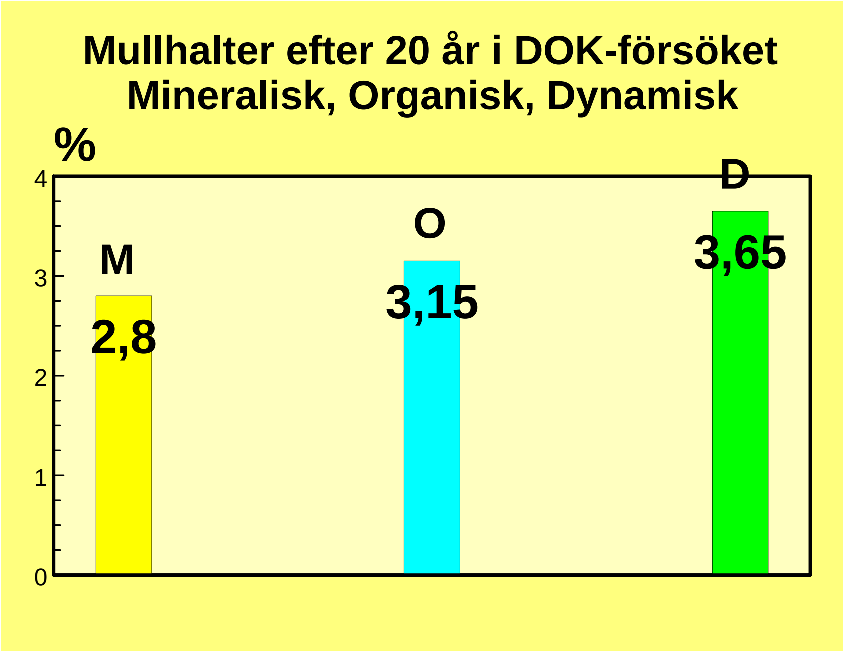
Rotation Conventional cultivation	Conventional cultivation	Biodynamic cultivation	Biodynamic cultivation
A1	**A2**	**B1**	**B2**
1. Summer wheat	Summer wheat + insown ley	Summer wheat +	Summer wheat insown ley
2. Barley	Ley with clove/grass	Barley	Ley with clover/grass
3. Potato	Potato	Potato	Potato



Trials comparing biodynamical and conventional cultivation in Järna 1971 – 1979 (Pettersson 1982). The soil organic carbon content in percentage of the dried soil (=humus content x factor 0,58) in the trial stage A1 (conventional cultivation without ley and with mineral fertilizers) and B2 (biodynamic cultivation with leys and biodnamically composted farm yard manure).



Trials comparing biodynamic and conventional cultivation in Järna 1971 – 1979. The soil organic carbon content in the trial stage A1 (Conventional cultivation without leys and with conventional mineral fertilizers.), A2 (Conventional cultivation with leys and conventional mineral fertilizer), B1 (Biodynamic cultivation without leys but with biodynamically composted farmyard manure) and B2 (Biodynamic cultivation with leys and biodynamically composted farmyard manure).



K

D

DOK-experiment

[1] Mäder, P., Fliessbach, A.,Dubois D., Gunst L., Fried P. & Niggli, U. 2002. Soil Fertility and Biodiversity in Organic Farming. Science VOL 296 pp 1592-1597.

B E R

Baltic Ecological Recycling Agriculture and Society

Humus content after 20 years in DOK trials comparing conventional, organic and biodynamic treatments. In the Swiss DOK -trials comparing t biodynamic, organic and conventional treatments in FiBL the humus content was, after 20 years, in conventional farming 2,8 % (M), in organic farming with organic manure 3,15 % (O) and in biodynamic farming with biodynamic manure treatments and the use of biodynamic preparations 3,65 % (D). (Mäder, et al, 2002).

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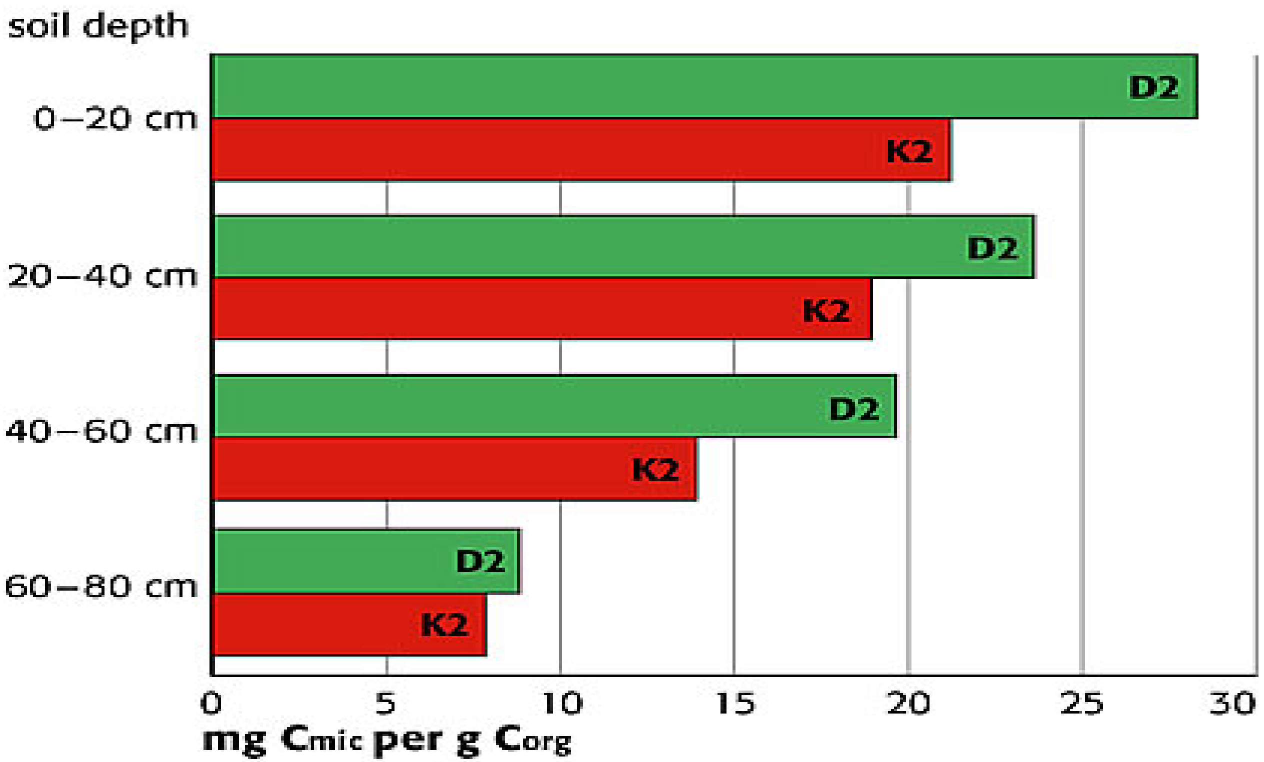
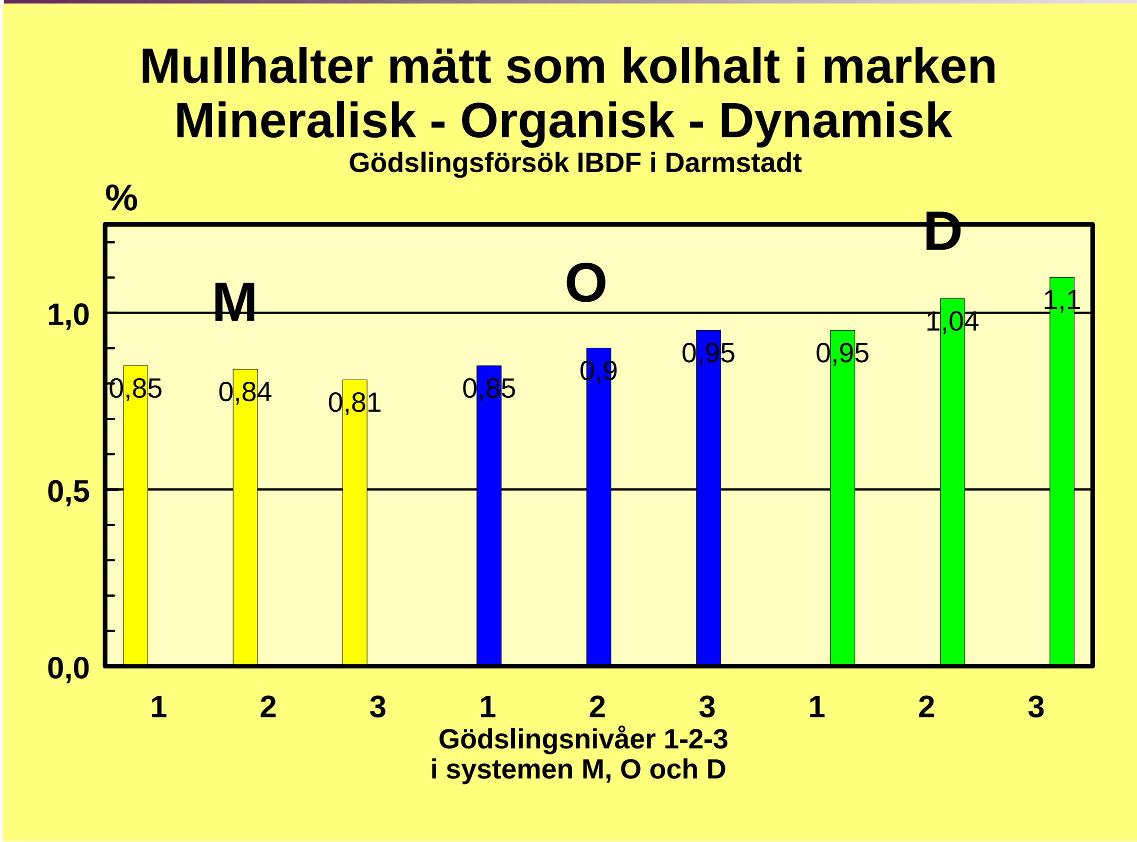


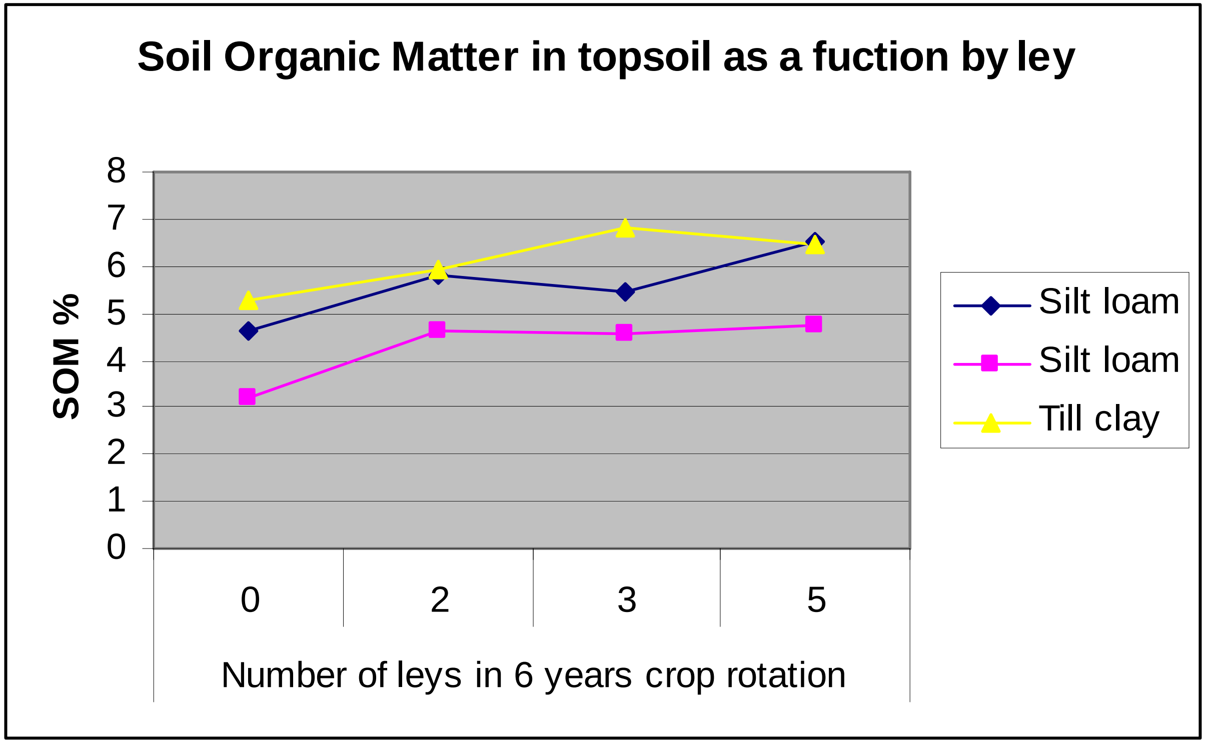
DOK-trial microbial biomass K<O<D (Mäder, et al, 2002).

D 3 ton microbial biomass/ 110 ton humus

K 2,1 ton microbial biomass / 95 ton humus



Humus content measured as carbon content in the soil. Mineral – Organic – Biodynamic. Fertilisation/manuring trial IBDF in Darmstadt. Fertilization levels 1-2-3 in M, O and D treatments Comparative trials with four repetitions and three manure levels throughout. They showed the highest humus content (on average 13 percent higher) when all biodynamic preparations were used (D), compared to organic manuring (O) under otherwise similar conditions. All organic manure has been composted and the experiments have been going since 1980 in humus-poor sandy-soil (Raupp and Oltmans. 2003).



Soil Organic Matter = SOM in top soil after three rotations in North Sweden (Persson, 1994)