Conservation Agriculture

Quantative Analysis of Cropping and Grassland Systems (PPS30806)

Derk van Balen, 03-25-2013

Wiepie Haagsma, Steve Crittenden, Bert Vermeulen, Wijnand Sukkel

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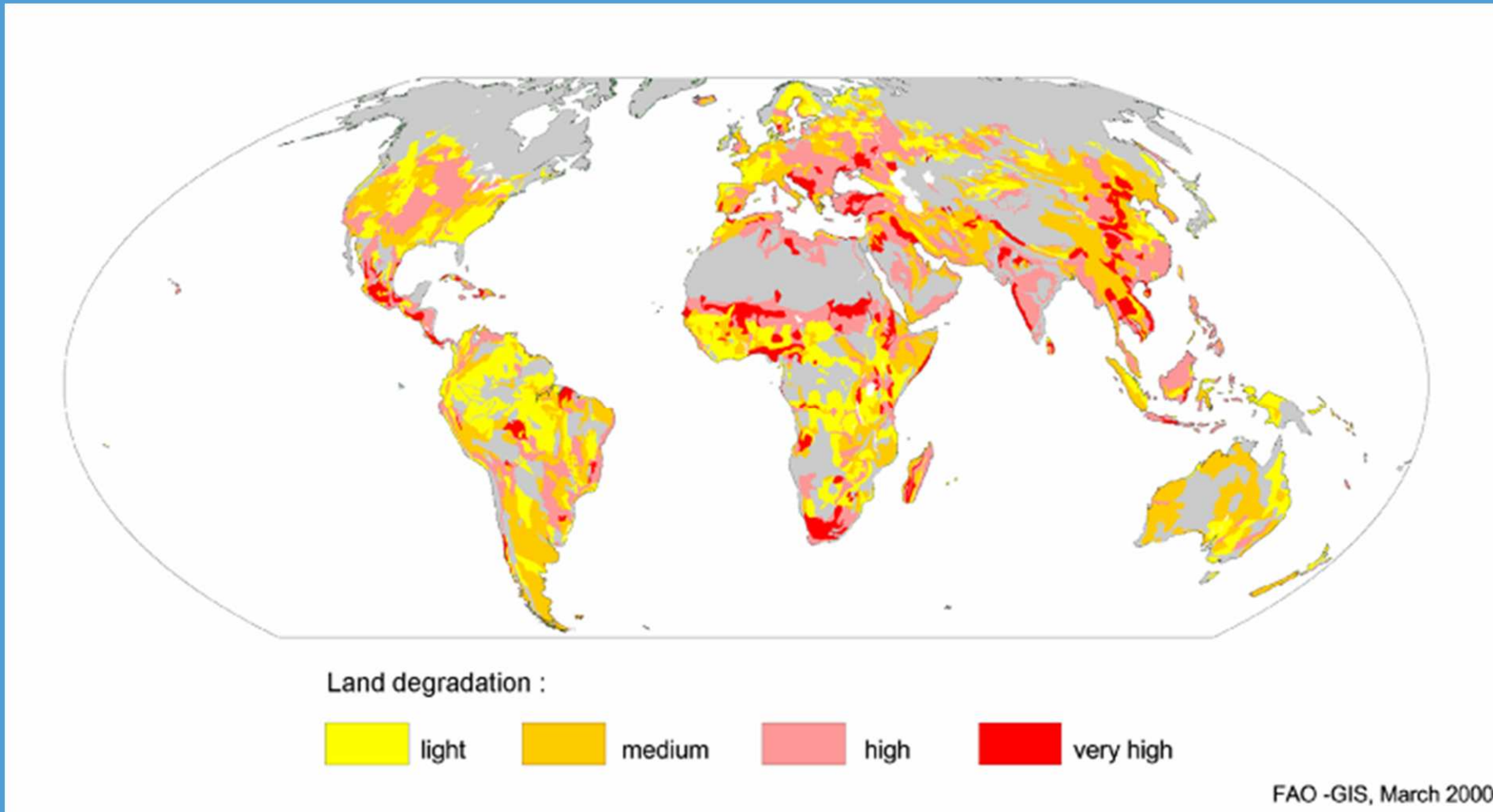
BASIS

Subjects

- Conservation Agriculture
- Advantages and disadvantages
- Soil carbon
- Soil Nitrogen
- Biodiversity
- CA on marine soil in the Netherlands

Conservation agriculture (CA) aims to make better use of agricultural resources through the integrated management of available soil, water and biological resources, combined with limited external inputs. It contributes to environmental conservation and to sustainable agricultural production by maintaining a permanent or semi-permanent organic soil cover. Zero or minimum tillage, direct seeding and a varied crop rotation are important elements of CA (FAO)

Land degradation



World map of severity of land degradation – GLASOD (FAO 2000)

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Total area Conservation Agriculture worldwide 95 Million ha

(Derpsch, 2005)

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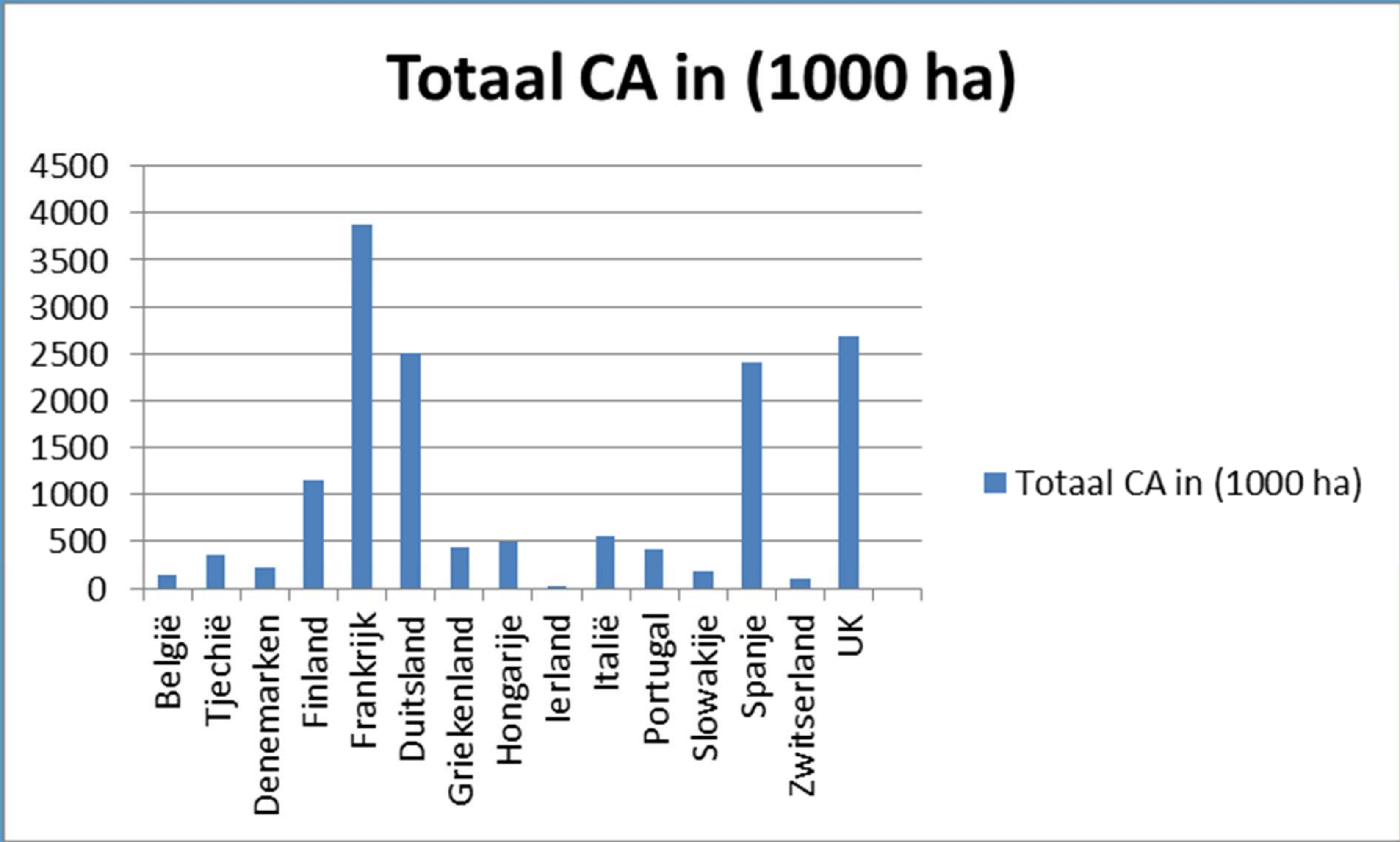
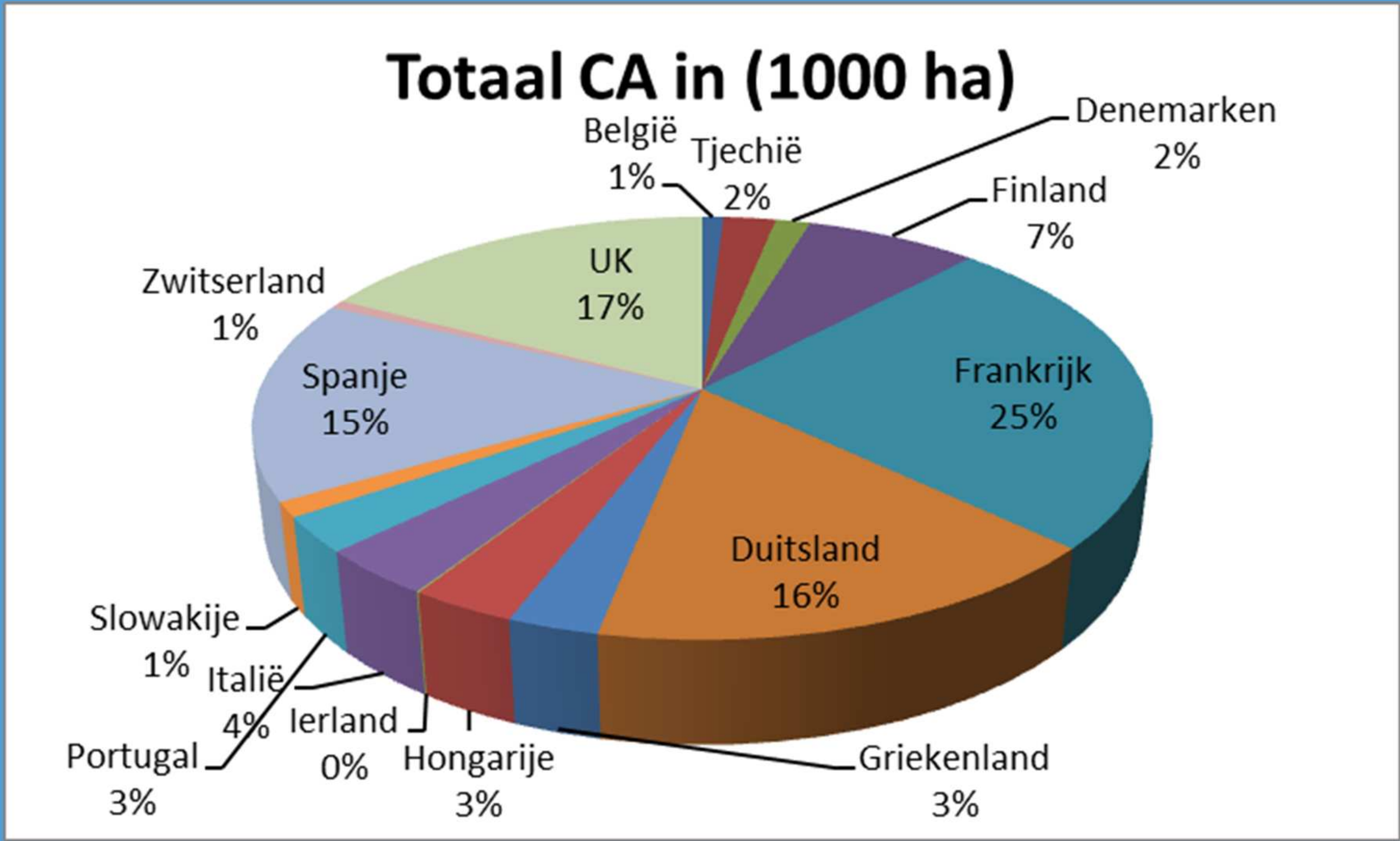
CA in Europa (1)



CA in Europa (2)



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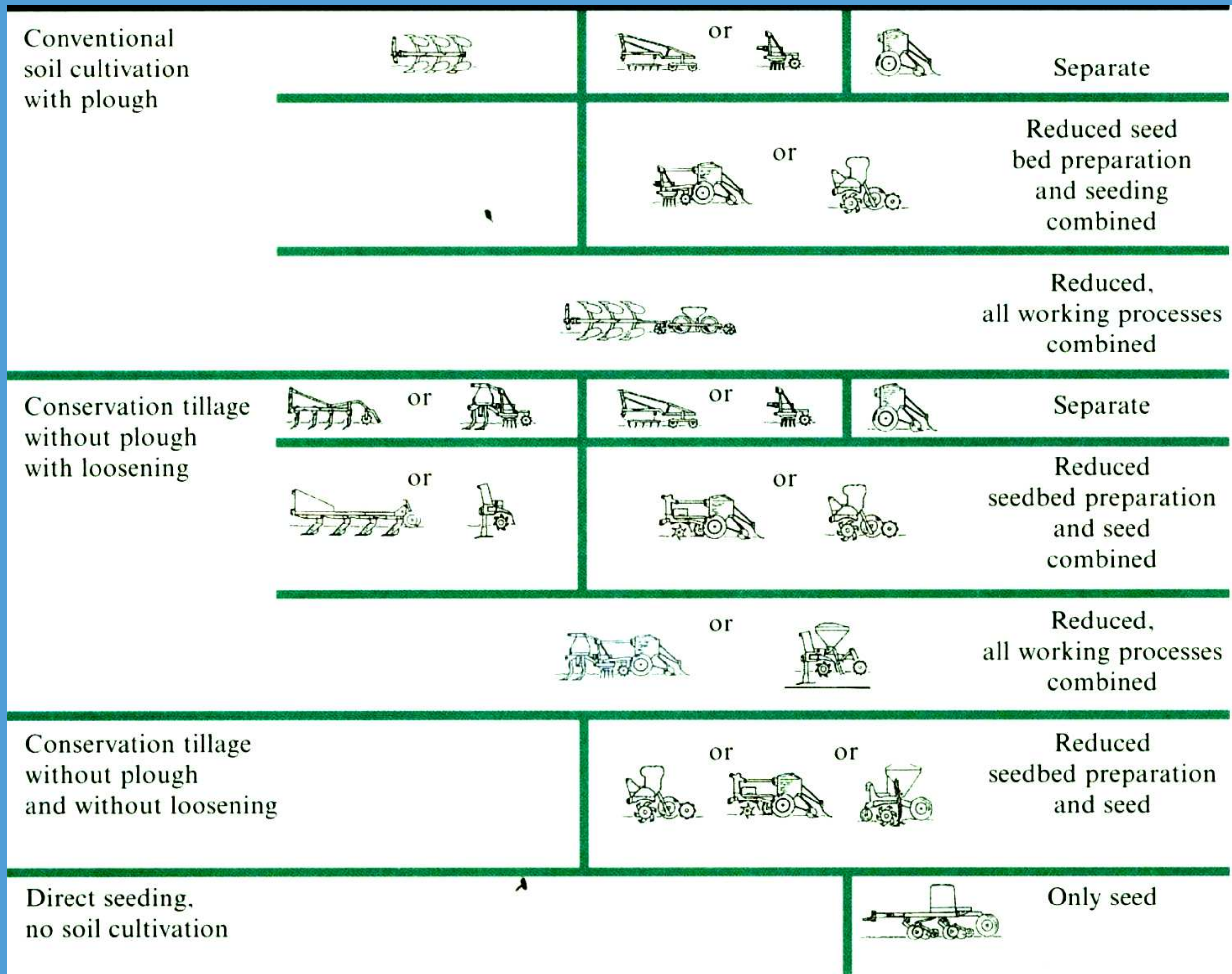
Area of CA per country

Country	Area of no-till[a] (kha)	Total arable land (2008)[b] (kha)	Area of no-till as % of total arable area
Finland[c]	200	2256	8.86
Germany[c]	5	11933	0.42
France[c]	200	18260	1.09
Switzerland[c]	12.5	408	3.06
Spain[c]	650	12500	5.20
Portugal[d]	80	1050	7.62
Italy[d]	80	7132	1.12
Slovak Rep.[d]	37	1382	2.68

[a] Excluding orchard and tree crops.
[b] FAO Statistics Division 2010 (www.fao.com).
[c] Derpsch and Friedrich (2009).
[d] Basch et al. (2008).

CA, Non inverse tillage, reduced tillage



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Potential advantages conservation agriculture

Experiences mainly in other countries

- Lower costs and energy inputs
- Increase of biodiversity (above and in soil)
- Improved soil quality (o.m., structure, resilience, ..)
- Mitigation and adaptation of climate change
- Increasing of water storage and water infiltration
- Better load bearing capacity
- Less erosion

Advantages ploughing

- Getting rid of weeds and crop residues, sanitation
- Better possibilities for seedbed preparation
- Solving problems with soil structure
- More air in the soil

- Whole system, mechanisation and management is adapted for ploughing

Potential disadvantages NIT

- Weed ↑
- Pests and diseases ↑
- First years: yield ↓
- Manure application, organic matter and cover crop?
- *Changing of soilstructure*
- Adaptation of farmsysteem, mechanisation and management is designed for ploughing

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Conservation agriculture in Dutch agriculture?

- Experiences mainly by mowing crops

- Small seeded crops ? (onion and carrot)
- Lifted crops? (potatoes, carrot, …)
- Sea climate?
- Weeds, pests and diseases?
- Period of convertion?

Controlled traffic system

- Better (earlier) opportunities for field activities
- Less compaction
- Less greenhouse gas emission
- Higher efficiency of nutrients

- Combination of conservation agriculture and controlled traffic system has potential!!

Changes and challenges

- More soil cover, winter crops, other green manures, how to manage?
- Crop residues on top
- Changing of N dynamics
- Sowing technique
- How to fertilize (amount and technique)
- Harvest and other activities from tracks?
- Ridge building (potato and carrot)
- Weedcontrol
- Changing of pests and disease

Soil organic carbon

Examples of average annual change in soil organic carbon (SOC) after no-till compared to ploughing in Europe (in ascending order of SOC change).

Country	Number expts.	Depth (cm)	Duration (y)	SOC change ($kg\,C\,ha^{-1}\,y^{-1}$)	Reference
Scotland[a]	1	0–60	6	0	Sun et al. (2010)
Switzerland[b]	1	0–40	19	0	Anken et al. (2009)
Spain[c]	1	0–40	13	158	Hernánz et al. (2002)
France[d]	1	0–20	32	162	Oorts et al. (2007a)
Spain[e]	3	0–40	15–18	20–187	Álvaro-Fuentes et al. (2008)
England[f]	4	0–30	5–9	340	Bhogal et al. (2007)
Scotland[g]	1	0–20	23	510	Ball et al. (1994a)
Portugal[c]	1	0–30	4	750	Basch (2002)
Germany[h]	1	0–30	3	1000	Fleige and Baeumer (1974)
Spain[c]	1	0–30	11	1000	López-Fando and Pardo (2001)
Spain[j]	1	0–30	10	1300	Sombrero and De Benito (2009)

Soil types:
[a] Dystric Fluvic Cambisol.
[b] Orthic Luvisol.
[c] Luvisol.
[d] Haplic Luvisol.
[e] Inceptisol, Calcisol.
[f] Orthic Acrisol, Gleyic Cambisol, Dystric Cambisol.
[g] Eutric Cambisol, Gleysol.
[h] Orthic Podsol.
[j] Typic Calcixerolls.

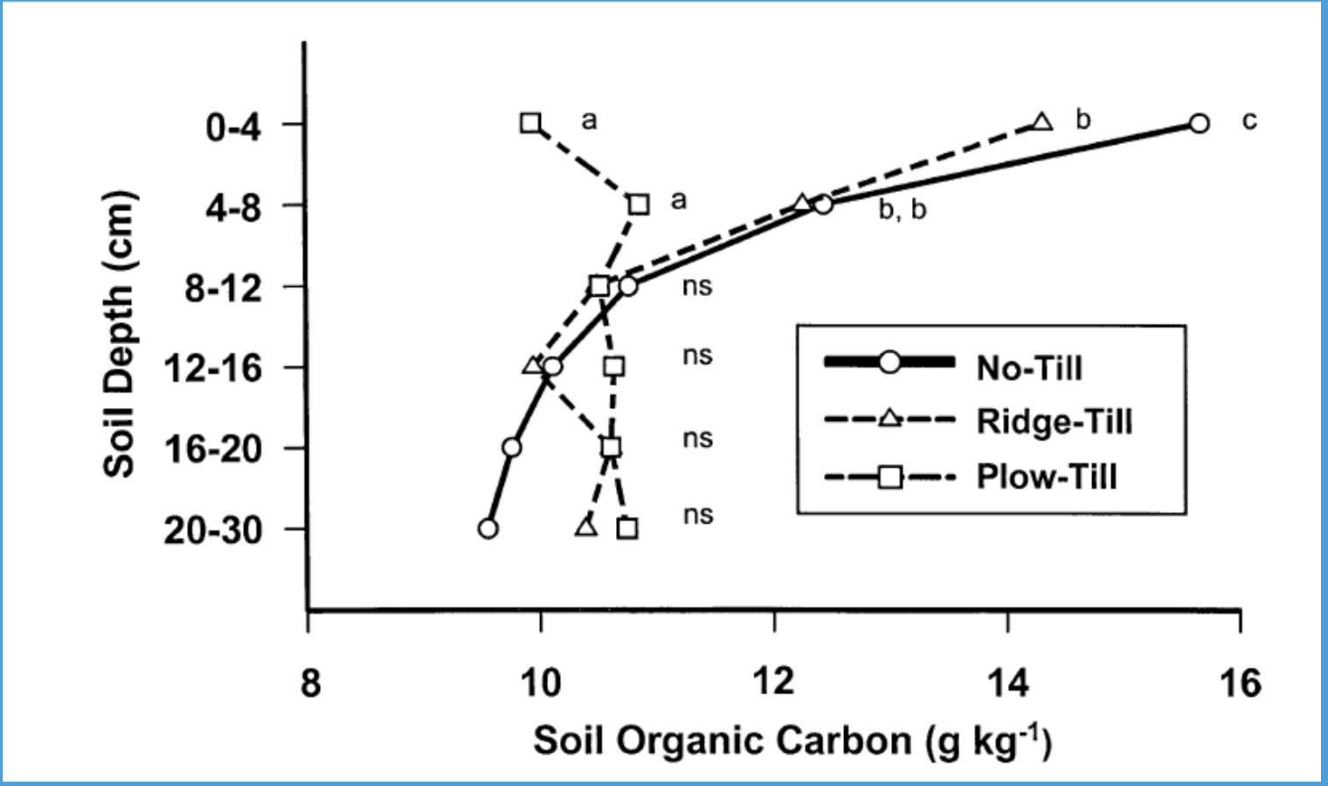
Soil organic carbon influnced by tillage

Bodenbearb. Tiefe [cm]	C_{org}-Gehalt [1] [M.-%] in den Bodentiefen [cm] 0 - 15	0 - 20	0 - 25	0 - 30
C_{org}-Gehalte [M.-%]				
Pflügen 25	1,02	1,02	1,01	0,99
Grubbern 15	1,36	1,24	1,17	1,08
C_{org}-Mengen [t/ha je dm-Schicht]				
Pflügen 25	14,9	15	15,1	14,9
Grubbern 15	19,8	18,5	17,5	16,3

[1] *gewogene Mittel aus C_{org} -Werten bei Probenahme in Abständen von 5 cm*

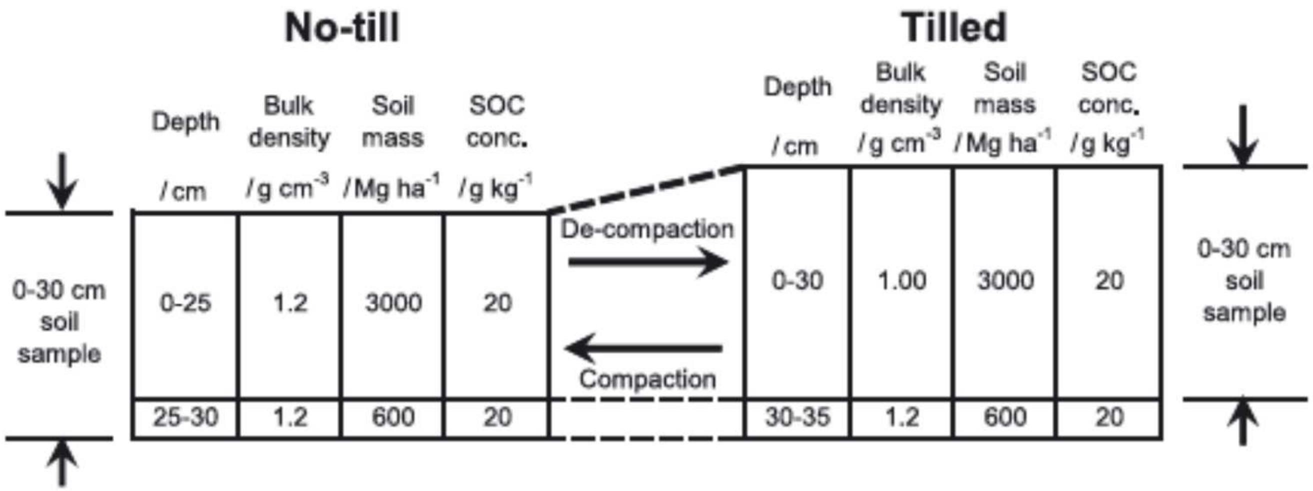
Organische stofverdeling na 9 jaar NKG

Zibilske et al (2002)



Zibilske et al, 2002

J. W. Wendt & S. Hauser



	No-till (compacted)	Tilled (de-compacted)	% error
SOC (kg ha^{-1}) in 30 cm depth layer	72 000	60 000	-16.7
kg SOC ha^{-1} in 3000 Mg soil mass layer	60 000	60 000	0
kg SOC ha^{-1} in 3600 Mg soil mass layer	72 000	72 000	0

Soil structure top layer

- Bulk density – porosity (BASIS)
  - NIT more compact then ploughing, less pores
- Water- en aircontent at FC
  - NIT aircontent FC lower

BASIS, Onion, 2010	Plough		"NIT"	
	2-7 cm	10-15 cm	2-7 cm	10-15 cm
Bulk dens g/cm3	1,35	1,47	1,46	1,59
pores %	47,6	42,8	43,4	38,1
aircont FC %	20,2	11,6	11,2	6,0
watercont FC wght%	20,0	21,2	22,1	20,2

Bearing capacity at onion harvest

Ploughing

Minimal tillage

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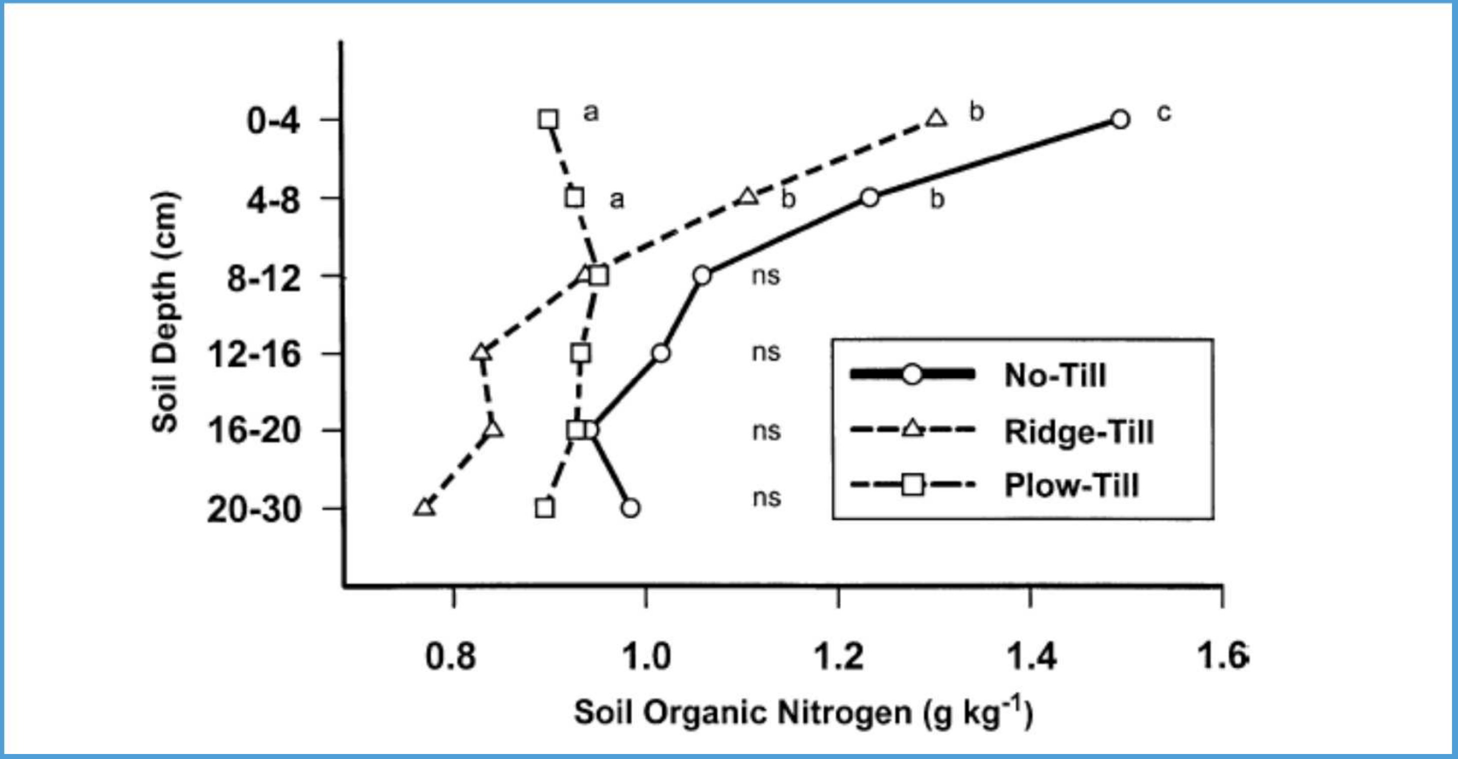
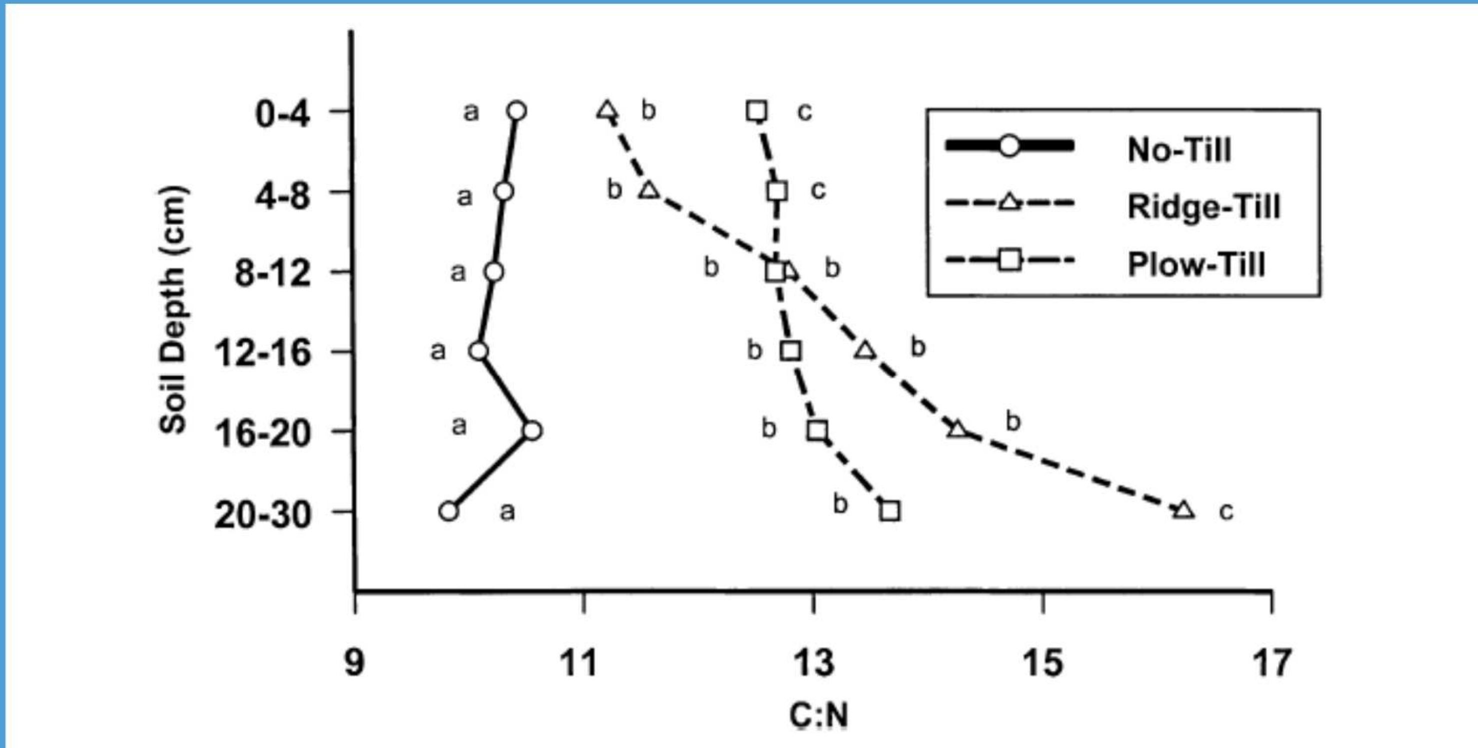
Soil nitrogen



Zibilske et al, 2002

C/N ratio



Zibilske et al, 2002

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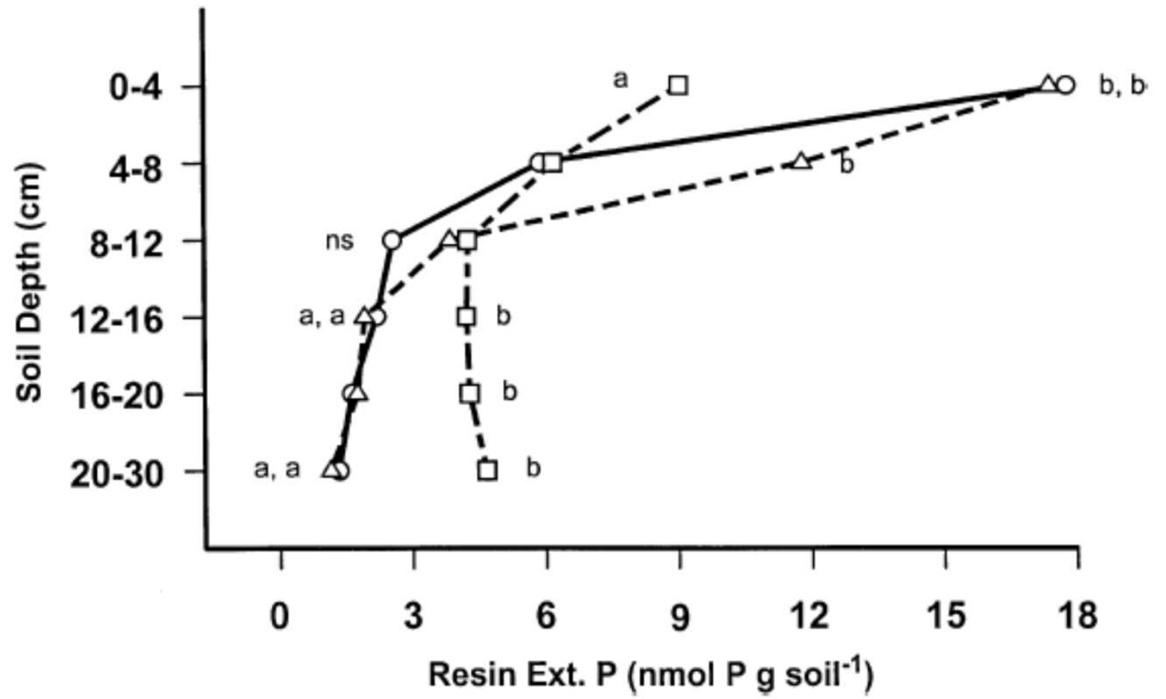


Zibilske et al, 2002

Tillage effects, energy

Carbon costs of the variables that intervene in the CA and the TA systems

Variables	Cost of the variable under CA as compared to TA
fuel consumption per unit area per unit output	35 - 80% less
number of passes	50 - 54% less
size of machinery	50% lower power requirement
depreciation rate of machinery	2 - 3 times lower (i.e. 2 - 3 times longer lifetime)

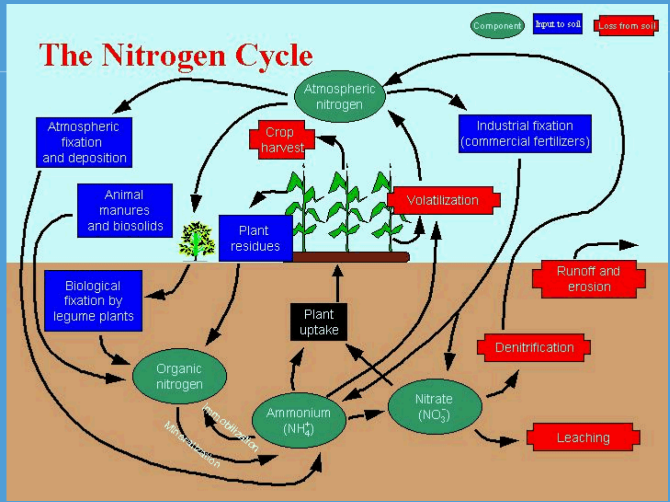
FAO, 2012

Tillage effects, carbon

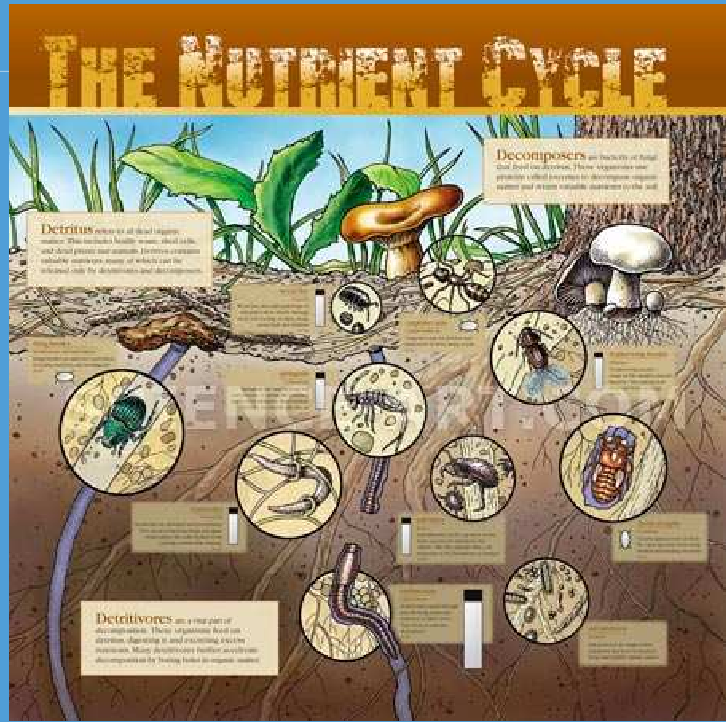
Percentage of carbon in the crop residues released from the soil after different treatments (Reicosky, 1997).

Tillage practice	Percentage of carbon in the crop residues released as CO_2
mouldboard plough	134
mouldboard plough and disc harrow	70
disc harrow	58
chisel plough	54
sod seeding	27

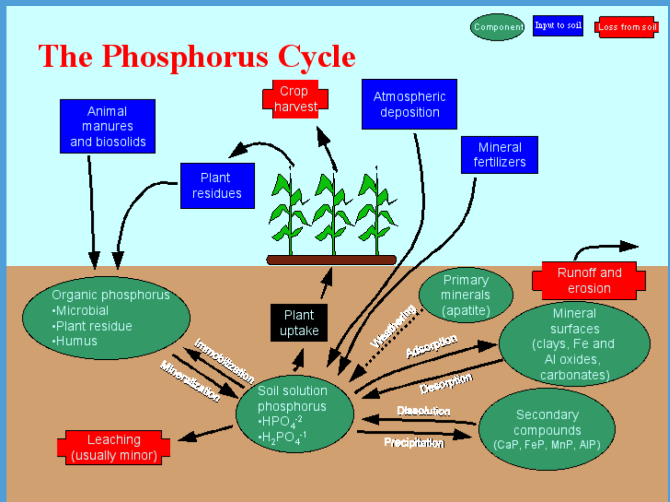
FAO, 2012



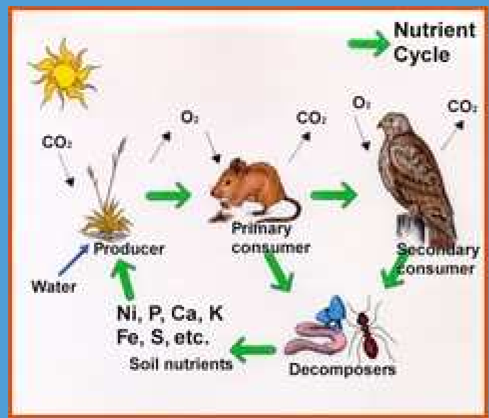
Component
Input to soil
Loss from soil
The Nitrogen Cycle
Atmospheric nitrogen
Atmospheric fixation and deposition
Industrial fixation (commercial fertilizers)
Crop harvest
Animal manures and biosolids
Volatilization
Plant residues
Runoff and erosion
Biological fixation by legume plants
Plant uptake
Denitrification
Organic nitrogen
Ammonium (NH_4^+)
Nitrate (NO_3^-)
Leaching
Immobilization
Mineralization



THE NUTRIENT CYCLE
Detritus
Decomposers
Detritivores



Component
Input to soil
Loss from soil
The Phosphorus Cycle
Crop harvest
Atmospheric deposition
Animal manures and biosolids
Mineral fertilizers
Plant residues
Runoff and erosion
Primary minerals (apatite)
Organic phosphorus
•Microbial
•Plant residue
•Humus
Plant uptake
Mineral surfaces (clays, Fe and Al oxides, carbonates)
Weathering
Adsorption
Immobilization
Desorption
Mineralization
Soil solution phosphorus
•HPO_4^{-2}
•$H_2PO_4^{-1}$
Dissolution
Secondary compounds (CaP, FeP, MnP, AlP)
Precipitation
Leaching (usually minor)



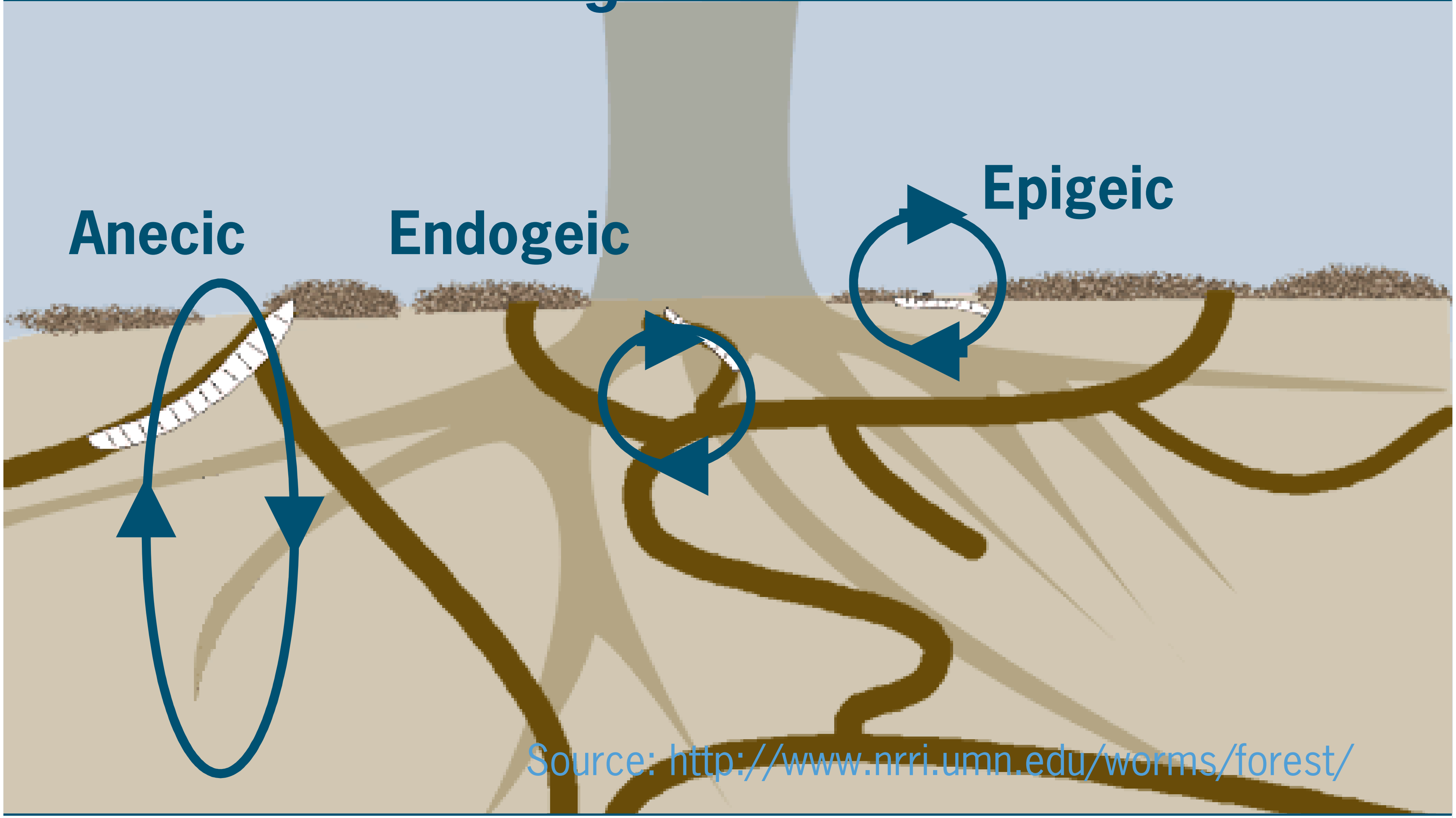
Nutrient Cycle
CO_2
O_2
CO_2
O_2
CO_2
Producer
Primary consumer
Secondary consumer
Water
Ni, P, Ca, K
Fe, S, etc.
Soil nutrients
Decomposers

Tillage effects, soil biodiversity

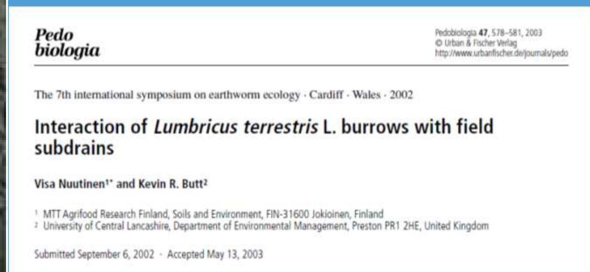
Indicator	Soil tillage system		
	Conventional	CA (NIT)	Direct seeding
Earthworm (in/m²)	35,4	56,1	125,4
Enchytraeidae (ind 10²/m²	5658,7	6797,2	1050
Mytes (in 10²/m²)	16,4	11,2	0,9
Collembola (ind 10²/m²	13,1	11,2	5,4
Nematodes (ind 10²/100 g TS)	1,8	2,3	2,1
Microbial biomass (µg C_{mic} /g TS	335,1	372,1	394,2

LOP magazine

Earthworms: background



Earthworms: *L* *tris*


Pedo
biologia

Pedobiologia **47**, 578–581, 2003
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http://www.urbanfischer.de/journals/pedo

The 7th international symposium on earthworm ecology · Cardiff · Wales · 2002

Interaction of *Lumbricus terrestris* L. burrows with field subdrains

Visa Nuutinen[1*] and Kevin R. Butt[2]

[1] MTT Agrifood Research Finland, Soils and Environment, FIN-31600 Jokioinen, Finland
[2] University of Central Lancashire, Department of Environmental Management, Preston PR1 2HE, United Kingdom

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Steve Crittenden

Earthworm impact on water infiltration

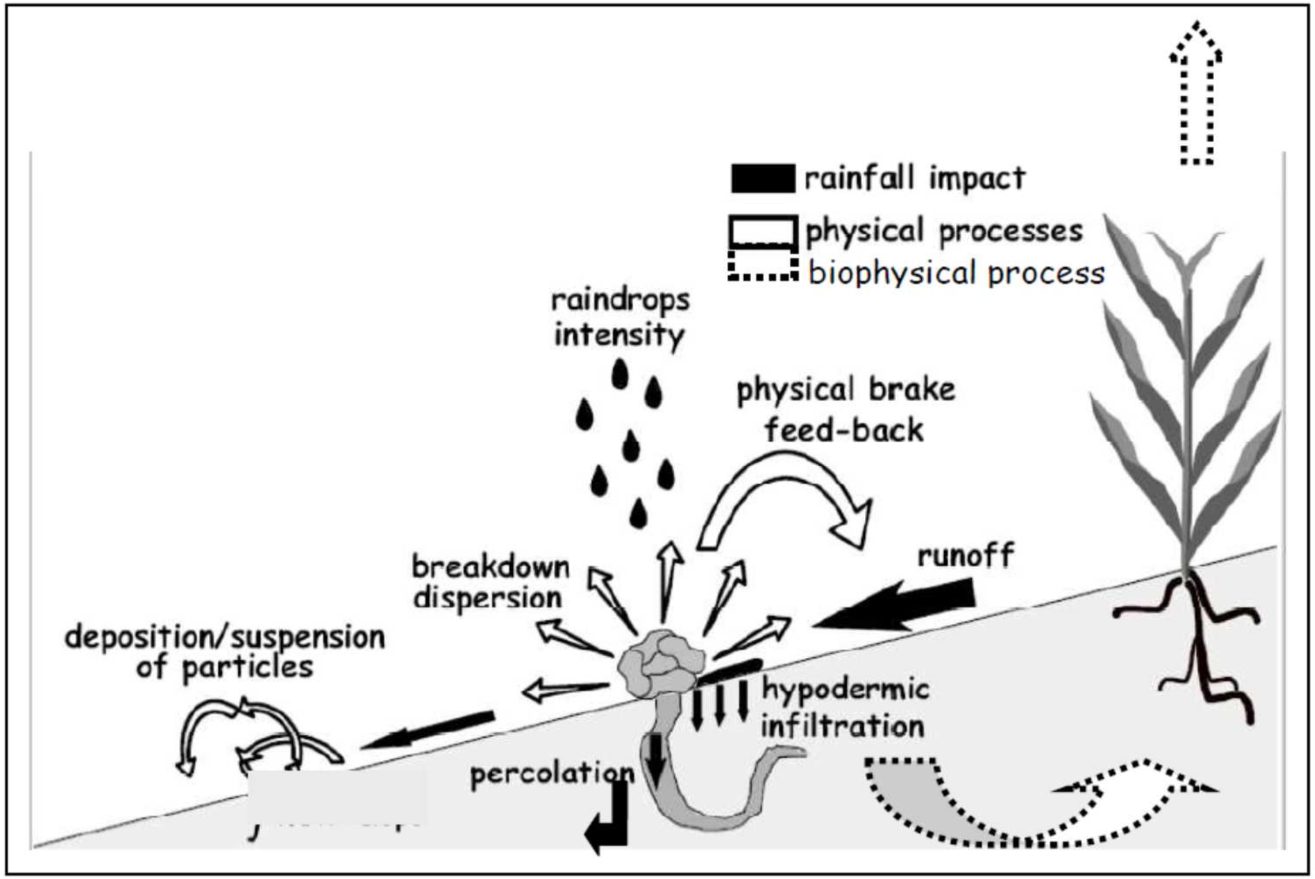

Fig. 1. Earthworm impact on water infiltration. Modified after (Le Bayon and Binet, 2001).

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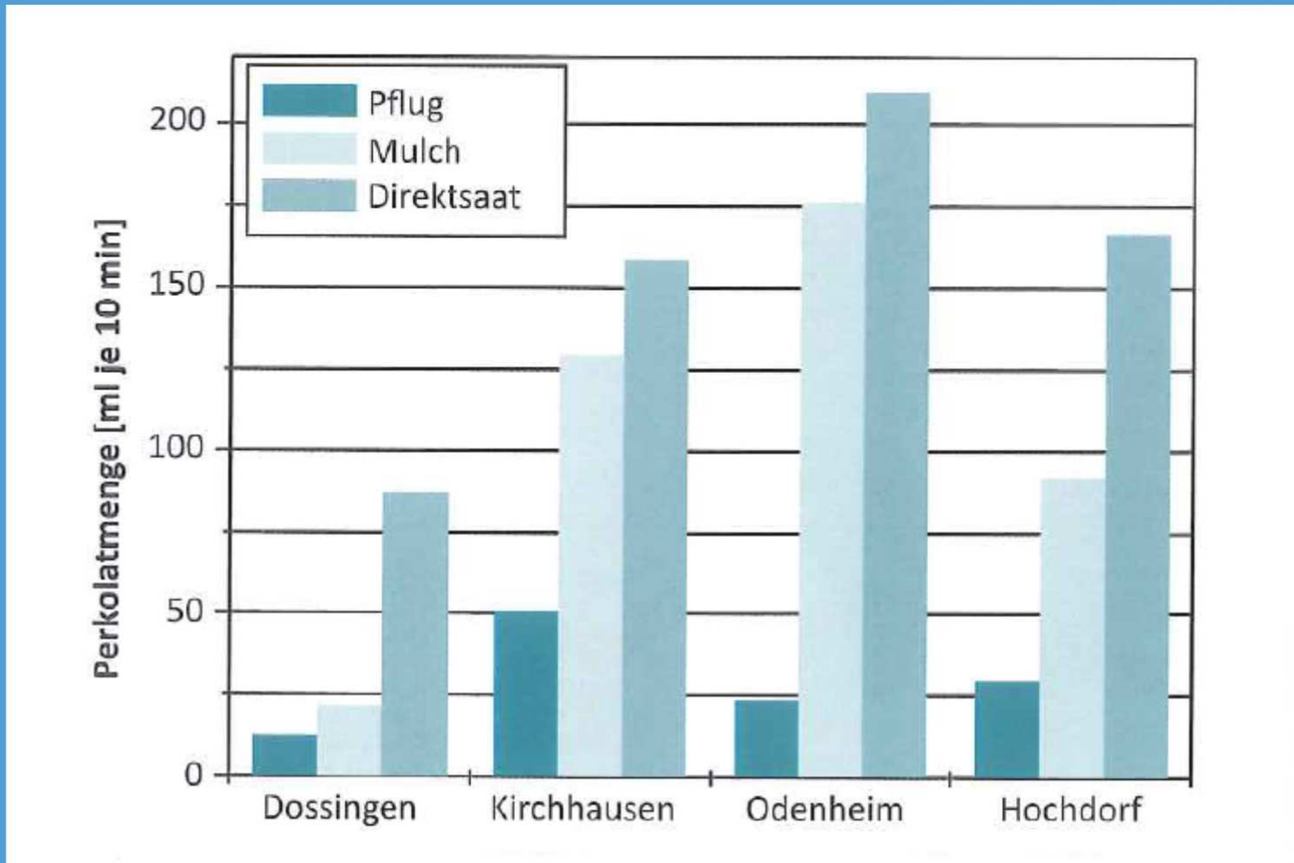
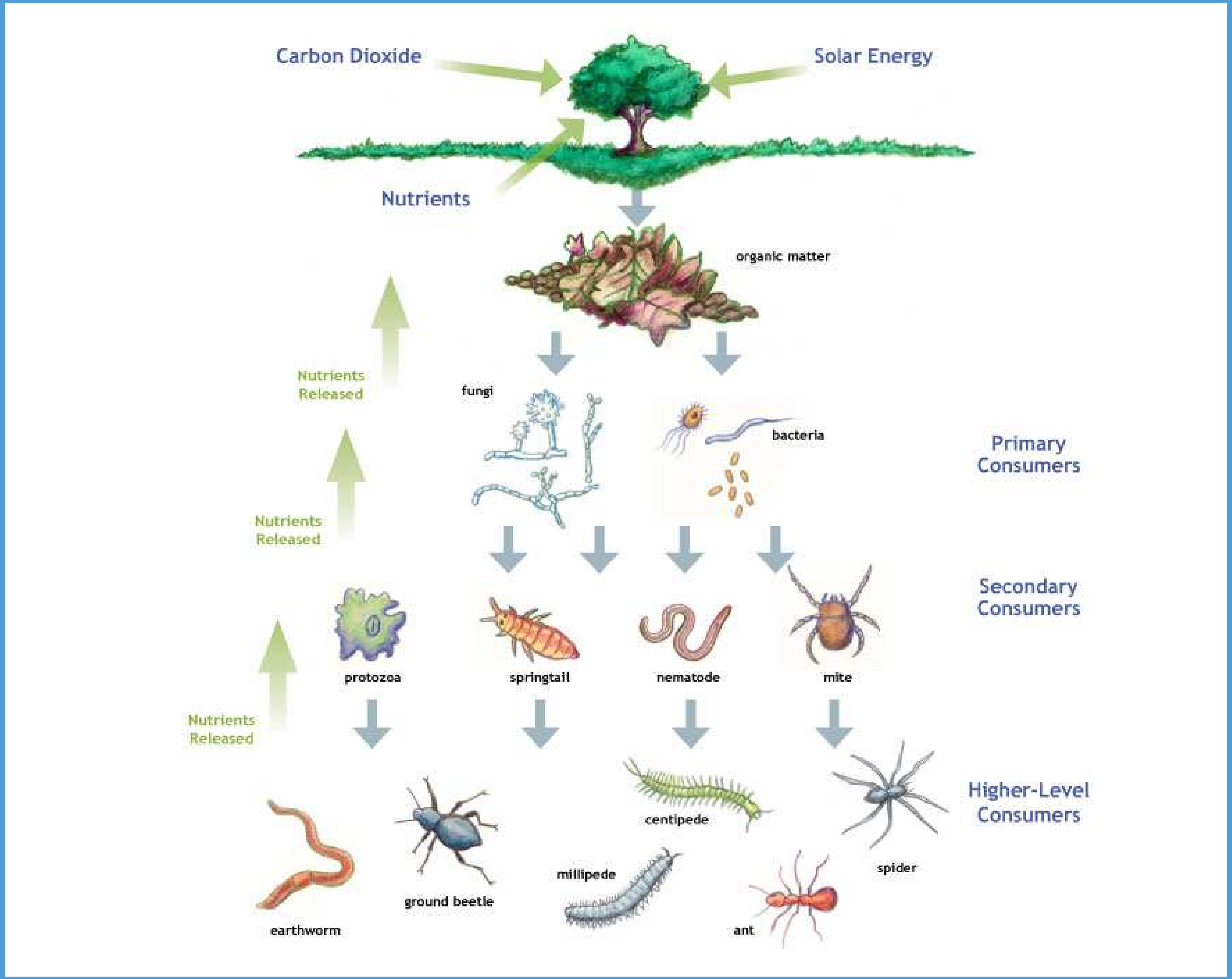
LOP magazine



Source: LOP magazine

Soil life



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BASIS

Conservation Agriculture on marine clay soil

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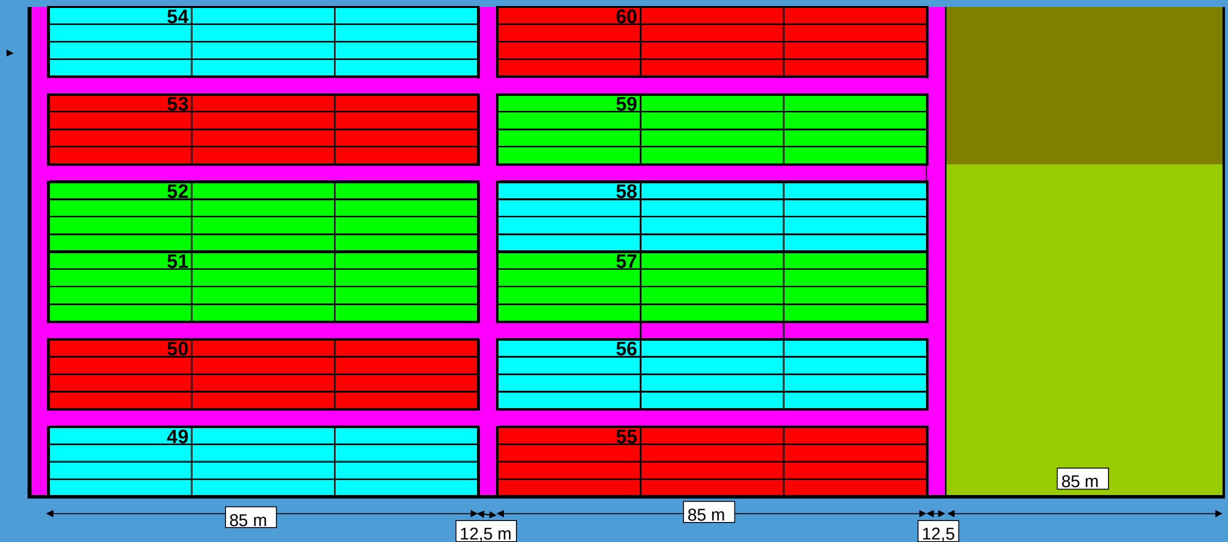
BASIS setup (started autumn 2008)

- CTF 3,15 meter tracks
- 5 fields of 2,5 ha
- Conventional 4-years rotation
- Organic 6-years rotatie
- 3 treatments
    - Ploughing 25 cm (ST)
    - Non inversed tillage (T)
    - Minimal, only subsoiling when necessary
- 4 replicates
- 1/3 field for testing machines, other experiments etc.

- Comparison and development of the systems



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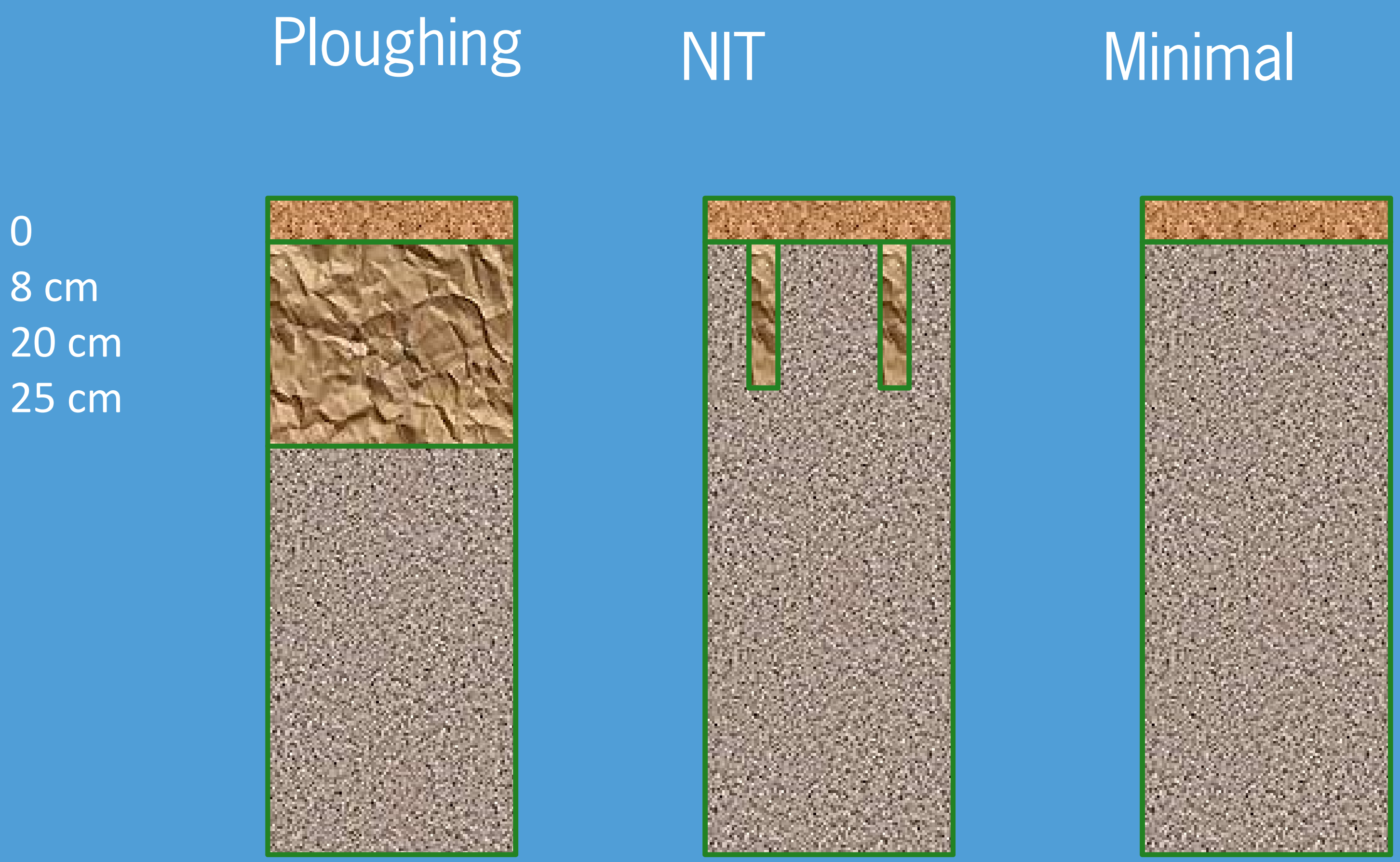
BASIS soil tillage



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Multifunctional crop rotation conventional

ploughing

ST standard

Year	winter			spring			summer			autumn		
	jan	feb	mar	apr	may	jun	jul	aug	sept	oct	nov	dec
1				seed potato					winter rye			
2			sugar beet							winter wheat		
3	winter wheat							radish				
4			onion						yellow mustard			

T non inverse tillage

Year	winter			spring			summer			autumn		
	jan	feb	mar	apr	may	jun	jul	aug	sept	oct	nov	dec
1	yellow mustard			seed potato					winter rye			
2	winter rye		sugar beet							winter wheat		
3	winter wheat							radish				
4	radish		onion						yellow mustard			

Multifunctional crop rotation organic

ploughing

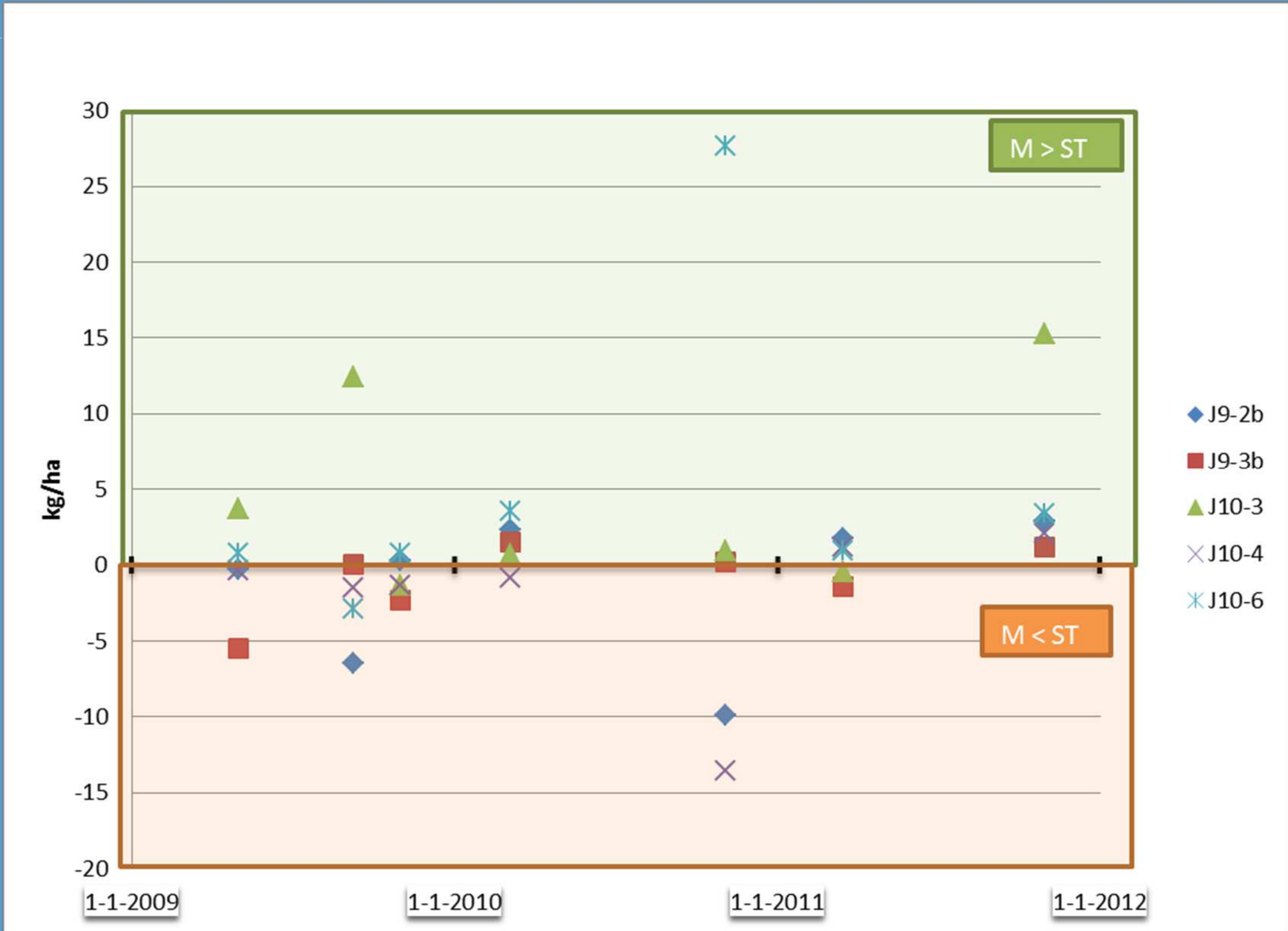
ST standard

Year	winter			spring			summer			autumn		
	jan	feb	mar	apr	may	jun	jul	aug	sept	oct	nov	dec
1				potato					Grass clover			
2	Grass clover											
3						white cabbage						
4			spring wheat					white clover				
5						carrot						
6					leguminous crop			yellow mustard				

T non inverse tillage

Year	winter			spring			summer			autumn		
	jan	feb	mar	apr	may	jun	jul	aug	sept	oct	nov	dec
1				potato					Grass clover			
2	Grass clover											
3						white cabbage						
4			spring wheat					white clover				
5						carrot						
6					leguminous crop			yellow mustard				

Difference in Nmin in kg/ha 0-15 cm



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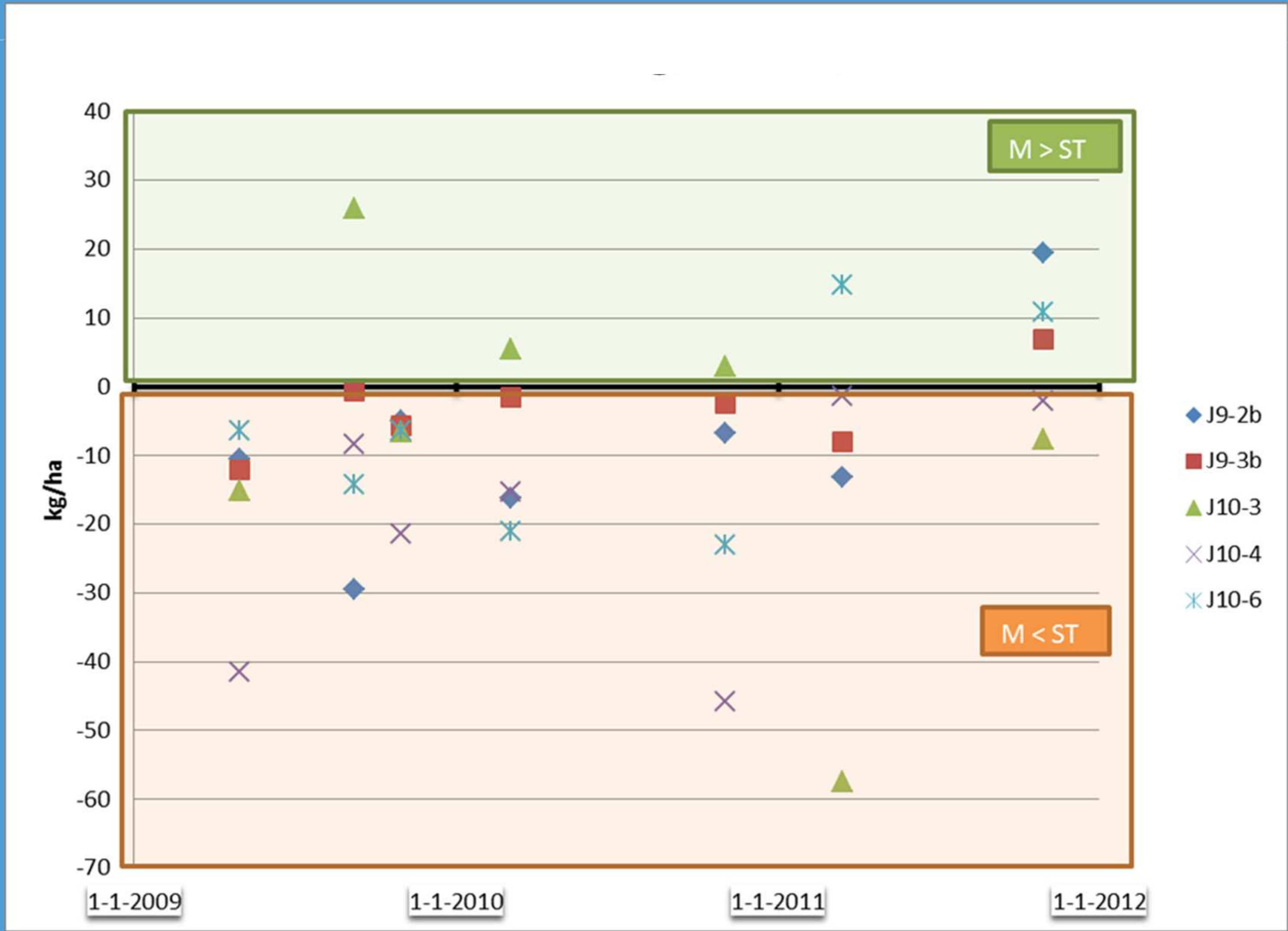
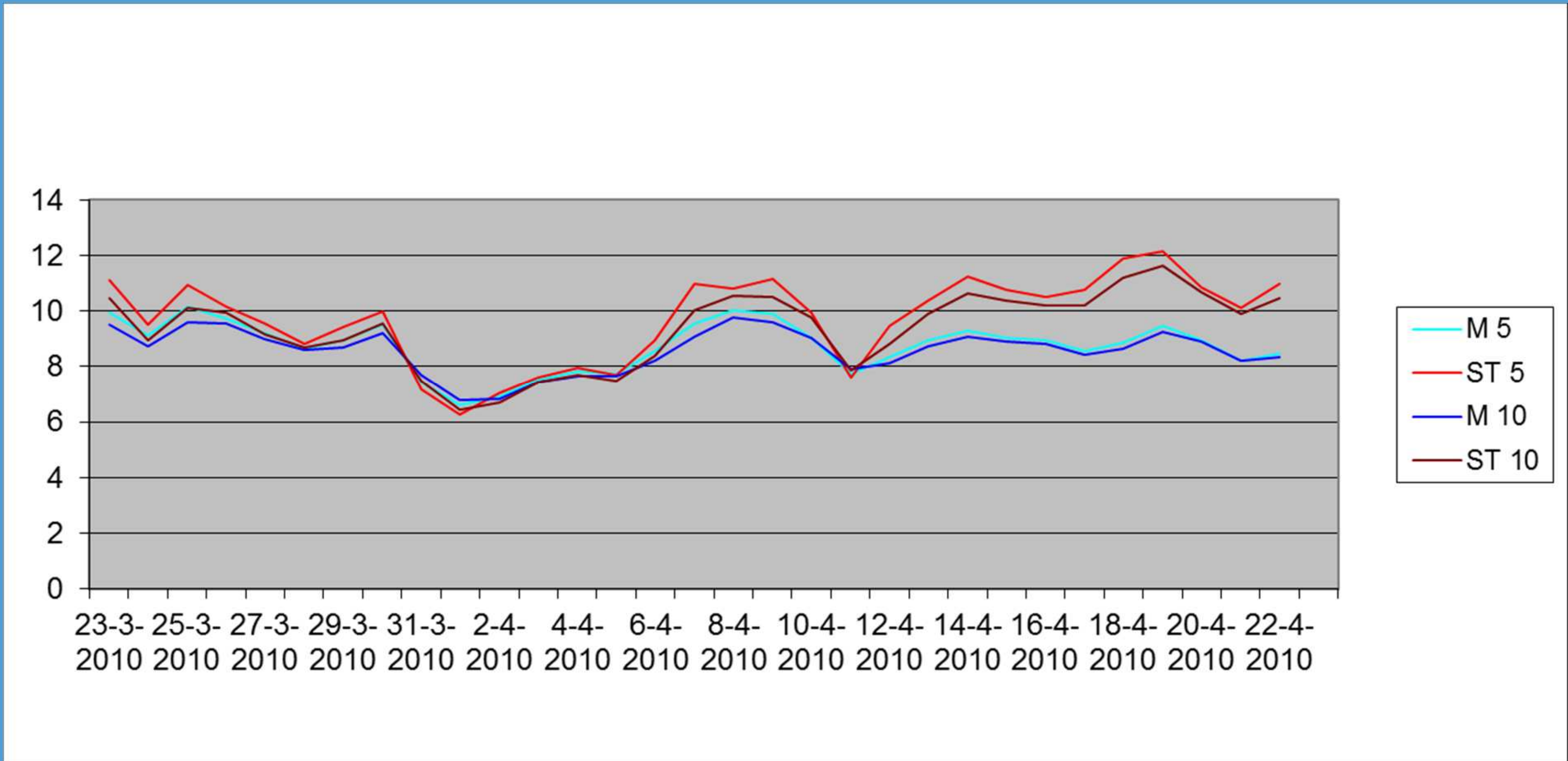
Difference in Nmin in kg/ha 0-60/0-90 cm



Average soil temperatuur (one parcel) 2010



Mechanisation

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Yield potato (organic)

Behandeling	Bruto opbrengst		Netto opbrengst 28-55 mm		ds gehalte in %		ds opbrengst bruto		ds opbrengst netto 28-55 mm	
ST	21.76	a	20.16	a	15.53	b	3.381	a	3.132	a
T	22.91	a	20.17	a	14.93	a	3.427	a	3.018	a
M	22.63	a	20.19	a	15.15	ab	3.431	a	3.062	a
Lsd	2.209		1.905		0.544		0.353		0.333	
F pr.	n.s.		n.s.		<0.10		n.s.		n.s.	
s.e. mean	0.638		0.551		0.157		0.102		0.0963	
sd	1.277		1.101		0.314		0.204		0.193	
nrep	4		4		4		4		4	

Yield Spring Wheat

Behandeling	Totale opbrengst plant in ton/ha		stro opbrengst in ton/ha		korrel opbrengst in ton/ha		ds % plant		ds % zaad		ds opbrengst totaal in ton/ha		ds opbrengst korrel in ton/ha	
ST	13.63	a	7.485	a	6.049	a	95.43	a	83.43	a	12.28	a	5.041	a
T	13.69	a	7.190	a	6.571	a	95.18	a	83.58	a	12.29	a	5.493	a
M	13.46	a	7.219	a	6.441	a	95.10	a	83.33	a	12.06	a	5.363	a
Lsd	0.937		0.942		0.831		1.221		0.360		0.877		0.708	
F pr.	n.s.		n.s.		n.s.		n.s.		n.s.		n.s.		n.s.	
s.e. mean	0.239		0.272		0.212		0.353		0.104		0.223		0.180	
sd	0.413		0.544		0.367		0.706		0.208		0.387		0.312	
nrep	3		4		3		4		4		3		3	

First experiences

- First 2 year little difference in yield, except carrot and onion (20% less)
- Crop development varies per treatment
- Non inverse tillage: more weeds
- Non inverse tillage: more mice, slugs and seed corn maggot

- Optimalization of tillage system and CTF

Some preliminary results

- Minimal tillage more organic matter in 0-15 cm, less in 15-30 cm
- M lower Nmin during the year
- M higher total N
- High excaust of CO_2 after ploughing
- Ghg emmission differs, tendency to lower emmission ghg in M

Preliminary conclusions soil physical

- Minimum tilled soil was colder in spring compared with ploughed soil, probably because of uninterrupted capillary rise (and vaporization) of soil water.
- 2 years after start of treatments, minimum tilled soil was clearly harder and denser and had less macropores than ploughed soil. As a consequence, the load bearing capacity in autumn was better.
- The relative root density was equal for minimum tillage and ploughing, despite the denser structure of minimum tilled soil.
- At ploughing depth in autumn, the stable water infiltration capacity on minimum tilled soil was certainly not lower than on ploughed soil.

Challenges vegetable crops

- Sowing in stubble (especially onion and carrot)
- Grass clover >cabbage
- Clover in spring before sowing of carrot.
- Weed control.
- Sead corn maggot in onion.
- Application of manure.
- Allelopathic properties of cover crops