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OP Vzdělávání pro konkurenceschopnost

INVESTICE DO ROZVOJE VZDĚLÁVÁNÍ

Phenomena of the climate extremes on agricultural soil – Mitigation steps

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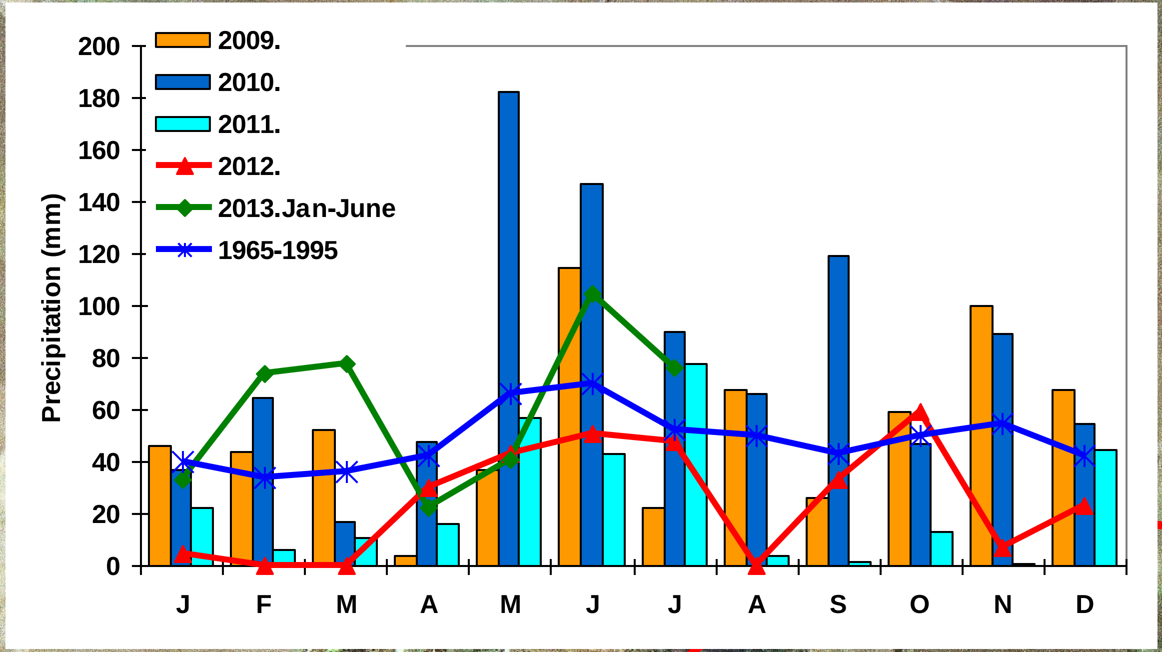
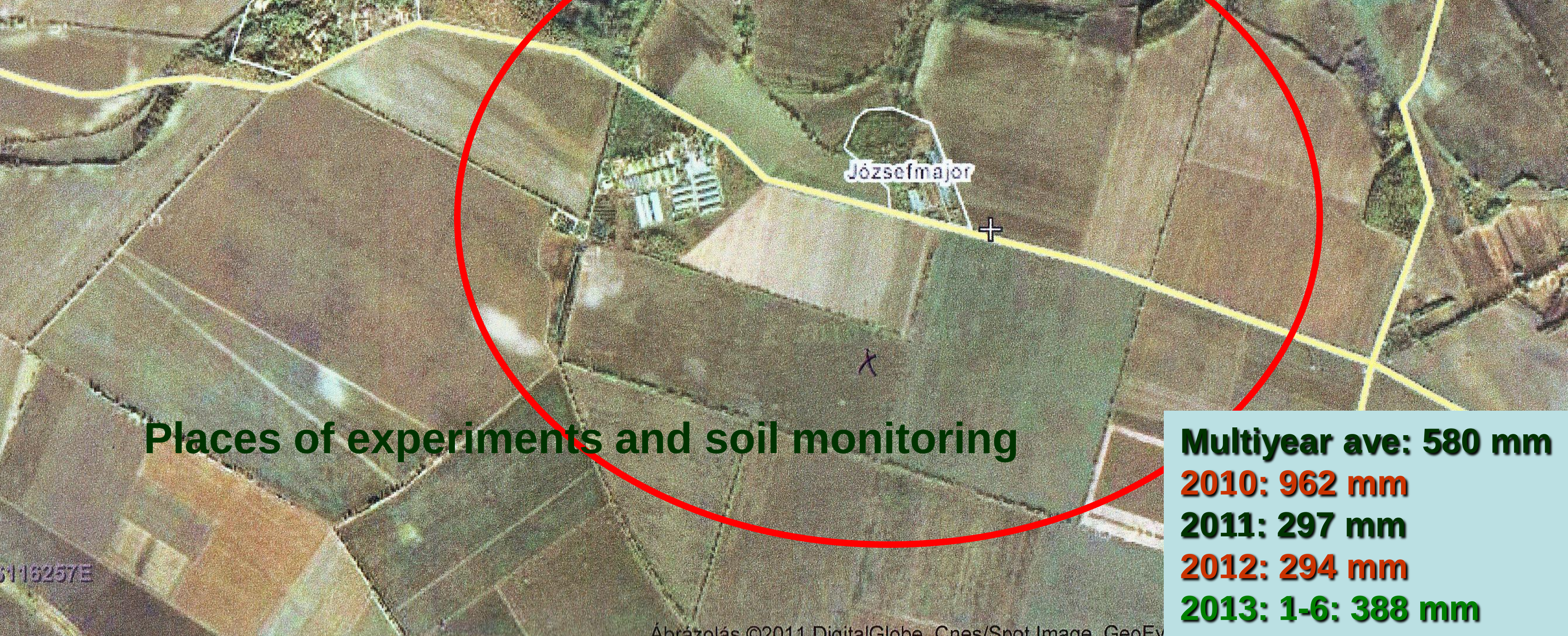
Data and information bases

Soil quality and climate experiment (Hatvan, 2002 -)

Stubble-climate experiment (Hatvan, 2004 – summers)

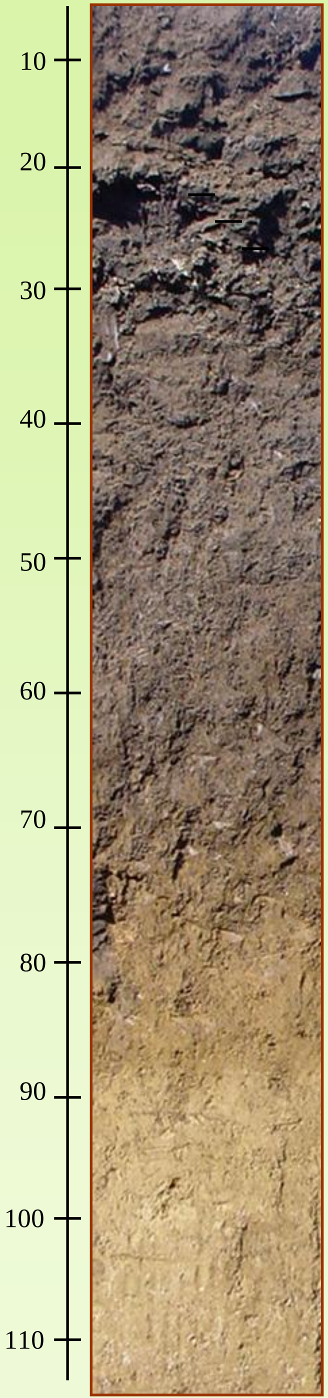
Soil condition monitoring (1976 -): HU, South SK, BiH (6 regions), HR (Slavonia), SRB, North Slovenia





Places of experiments and soil monitoring

Multiyear ave: 580 mm
2010: 962 mm
2011: 297 mm
2012: 294 mm
2013: 1-6: 388 mm



Soil, precipitation, crops

Soil Quality and Climate Experiment (**2002-**) at town Hatvan (47°41'22"N, 19°36'18"E).
Repetition: 4x, in random arrangements
Soil: **Chernic Calcic Chernozem**
Sensitivity to compaction: medium (sand: 23%, silt:42%, clay: 35%)
Field water capacity: 0.37 $m^{-3}m^{-3}$, wilting point: 0.10 $m^{-3}m^{-3}$

Years: **average (2002, 2006), dry (2003: -138 mm, 2004: -101 mm, 2011: - 283 mm, 2012: -286 mm), rainy (2005: +125 mm, 2008: +152 mm, 2010 +371 mm). 2007, 2009 dry in growing seasons**

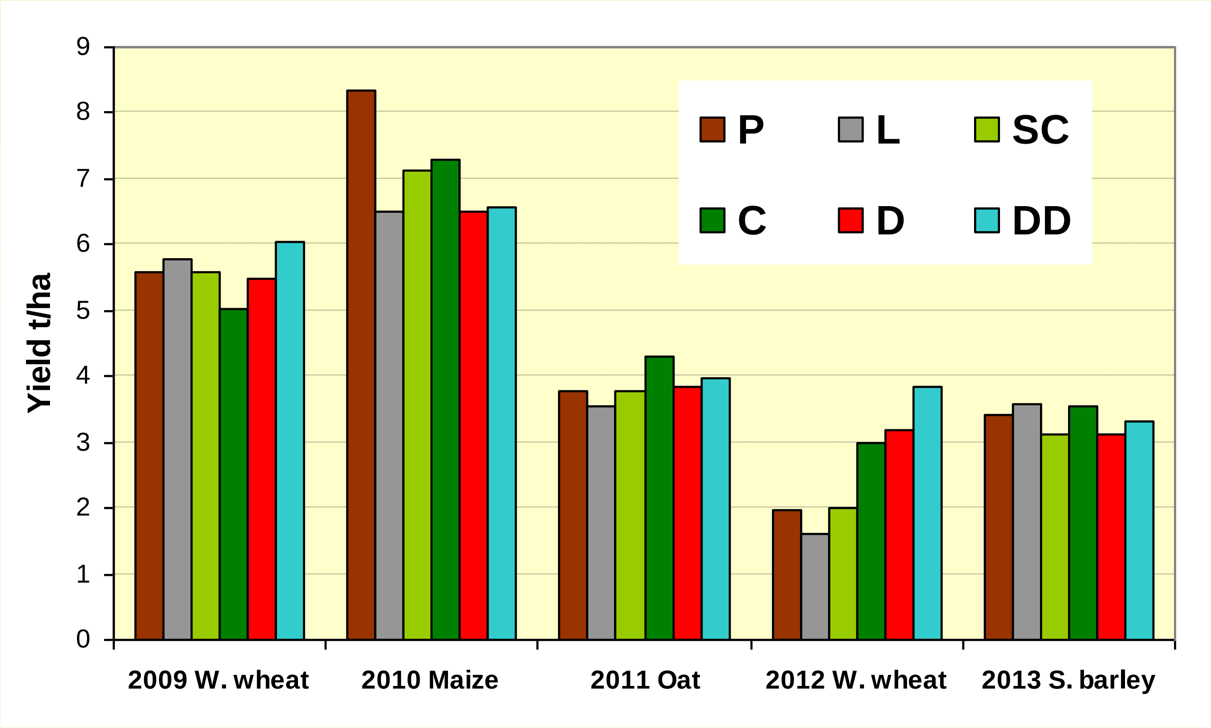
Crop sequence (to increase soil OM content, to protect soil surface and to improve soil quality): 2002: mustard, 2003: **w. wheat**, 2004: **w. rye**, pea, 2005: **w. wheat**, mustard, 2006: **w. wheat**, phacelia, 2007: **maize,** 2008: sunflower, 2009: w. wheat, mustard, 2010: **maize, 2011: oat, 2012: w.wheat, 2013: s. barley**

Soil tillage variants:
Direct drilling (**DD**), **Disking** (15 cm, **D**), **Shallow and medium tine tillage** (15 cm **SC**, 22 cm **C**), **Ploughing** (32 cm,+ **consolidating**, **P**) and **loosening** (40 cm, **L**).

Micro-regions of soil assessment

regular
occasional

Soil tillage (condition) impacts on crop yield in five different seasons (Hatvan, 2009-2013)



$LSD_{0.05}$
2009 (dry): 0.121
2010 (rainy): 0.231
2011 (dry): 0.048
2012 (dry): 0.126
2013 (rainy/dry): 0.142

P: ploughing + pressing
L: subsoiling (40-45 cm)
SC: cultivator (10-12 cm)
C: cultivator use (18-22 cm)
D: disking (10-12 cm)
DD: direct drilling

Rank of soil condition

	Season	P	L	SC	C	D	DD
W. wheat, 2009	dry	2	3	4	5	6	1
Maize, 2010	rainy	1	5	3	2	6	4
Oat, 2011	dry	4	5	4	1	3	2
W. wheat, 2012	dry	5	6	4	3	2	1
S. barley, 2013	rainy/dry	3	1	5	2	6	4

Aims of soil tillage

Crop demand	Soil quality improvement	Reducing climate threats
= plant-focused tillage (to ~1975)	*= soil-focused* tillage (~1975-2000)	*= climate-focused* tillage (2000-)

Background: research results
(35 exp. variants, 35 years + soil monitoring in H, BiH, CZ, HR, SK, SLO):

Since the first years when the alarming signs of climate-change began to appear, it has been a growing need for

adopting a *climate-focused* approach to tillage as well, **since losses caused by climate can be alleviated by conserving and improving the quality of the soil**

Climate-focused soil tillage

Soil is a conditionally renewable natural resource – constant attention and special care are needed to preserve the unique ability of soil resources

Main threats to soil functioning abilities (EU)

1. Erosion
2. Decline in OM
3. Contamination
4. Sealing
5. Compaction
6. Salinisation
7. Floods, landslides
8. Decline in biodiversity

Climate scenarios forecasts

1. Mild winters with somewhat more precipitation
2. Dry and hot summers
3. Extreme distribution of precipitation (2000 → 2013)
4. Increased number of windy and stormy days
5. Other extremities

When long-term effect of climate is rather unfavourable, the adaptability (prevention, alleviation, improvement) gives solutions

Mild winter, more precipitation (?)

1. More water accumulation in soils – Suitable state is to created!
2. Soil moisture storage capacity should be maintained / increased
3. Tillage in wet soils – probable soil damages – Using adaptable tools
4. Mild + windy winter – Water conservation in winter (!)
5. Preserving the soil remaining moisture content after the previous crop will be crucial
6. Create soil state is suitable both to water infiltration and storage and water conservation = water storage for dry seasons

WATER

SOIL STATE

precipitation

infiltrating into the soil

Loss
(20-30 %)

70-80 %

MOISTURE IN SOIL

ratio of storage

ratio of utilisation

ratio of loss

Mild winter, more precipitation

7. Primary tillage aims at minimising the loss of water out of the growing season

   - A root zone free from compaction may increase the chances of minimising yield losses during a dry season

8. Frost impacts may occur less / more frequently

   - Lack of frost may beneficial on pulverised soils (frost' dust is exposed to rain splash and winds)
   - Hard frost: serious dust formation

9. Soil surface conservation extending will be crucial

10. Use „new" methods: mulch / strip tillage or DD (calculating the training period)

Frost-effects: serious dust formation in ploughed soils

Hot and dry seasons / areas

1. Crops of longer growing seasons may suffer stress-induced ripening
   - drought resistant varieties and hybrids required
2. Water consumption of weeds and volunteers will draw more attention
3. Germination and growth of volunteers postpone to the new sowing period
4. Hot/drought tolerant pests and diseases gives new tasks to the soil tillage
5. Dry season is the critical period of soil moisture loss – using water conserving methods is crucial


Snow may less and dubious

Soil tillage systems

STUBBLE

STUBBLE TILLAGE

conserving soil moisture, promoting biological mellowing and decreasing heat and rain stress

↓

STUBBLE TREATMENT

weed control

↓

PRIMARY TILLAGE

soil condition improvement to the required depth by different tools (plough, cultivator, subsoiler, disk)

↓

SECONDARY TILLAGE

clod breaking, surface levelling and pressing

SEEDBED PREPARATION

(condition for sowing)

↓

SOWING

surface press

SEEDBED PREPARATION + PLANT + SURFACE PRESS in one pass

Spraying

↓

Direct drilling

STUBBLE TREATMENT

↓

STRIP TILLAGE

↓

STRIP SOWING

Hot and dry seasons / areas

6. Turn to moisture and carbon conserving tillage

7. Creating loosened and consolidated root zone to mitigating climate-induced damages

8. The extreme distribution of rains call for creating or maintaining the soils' water intake capacity and water retention

9. Avoiding the soil surface damages use mulch as straw hat and raincoat

10. Less and well-timing interventions into the soil is/will important

Coherence between tillage induced and climate induced damages

Coherence between tillage induced and rain induced damages

Tillage induced defects	Rain stress		Degree of damage	
	Impacts	Consequences	Unacceptable	Tolerable
Traffic loading	Water stagnation on the surface	Structure collapse, Settling	Field-level	Necessary passes only
Pan-compaction	Water stagnation on the pan layer		Field-level, Below tilled layer (20-200 mm)	Negligible (≤ 15 mm)
Smearing and kneading	Structure deterioration	Limited crumb formation	Field-level, Disturbed layer	Negligible (≤ 10 %)
Dustiness on the surface	Silting	Crust formation	≥ 20 % (except sandy soils)	≤ 10 %
Dustiness in the tilled layer	Dust leaching to the nearest compact layer	Extension of pan layer	≥ 20-25 %	≤ 10 %
Clean/bare surface	Structure deterioration	Crumb degradation	Field-level	≤ 15 %

Rain stress

1. Water stagnation on the surface
2. Water stagnation on the pan layer
3. Structure/crumb deterioration – limited crumb formation
4. Dust silting on the surface
5. Crust formation on the surface – causing airless state
6. Dust leaching to the nearest pan layer
7. Extension of pan layer
8. Soil settling

Possible solutions

1. Natural induced water logging can be managed by hydro-ameliorative interventions
2. Farming induced water-logging is to prevent by regular subsoiling, and avoiding apply pan-forming tools
3. Apply structure preserving tillage tools and surface cover in critical periods

4-5. Avoiding clod formation and no expose soil surface to rains

6-7. Avoiding pan formation, and situations leading to the structure degradation

8. Improve soil resistance by recycling organic materials (e.g. stubble residues)

Coherence between tillage and drought induced damages

Tillage induced defects	Long-term drought stress		Degree of damage	
	Impacts	Consequences	Unacceptable	Tolerable
Traffic loading	Heat stress, Cracking	Inactive soil	≥ 50 %	Necessary passes
Settled state		Water loss, Soil desiccation	Field-level	Min. depth of loosen layer 30-35 cm
Disk pan below 12-14 cm	Over drying, Greater water deficit and drought stress	Unutilised water in the deeper soil layers	Field-level	At most extended of 5 mm
Plough pan below 22/28 cm	Limited water transport	Stress intensifying	Field-level	At most extended of 10 mm
Great, cloddy surface	Serious water loss, Over-drying, Crumb degradation	Limited biological life, Serious water deficit	Field-level	≤ 20-25 %
Cavities in the tilled layer	Great water loss, Desiccation,			≤ 10 %
Dust formation	Crumb degradation, Crusting	Airless state, Greater heat stress	≥ 50 %	≤ 10 %
Clean/bare surface	Great heat stress, Desiccation, Crumb degradation	Limited biological life, Serious water deficit	Field-level	Min. cover ratio of 30-35 %

Drought stress

1. Heat stress
2. Over drying of soils (desiccation)
3. Limited water transport
4. Greater water deficit and drought stress in soils deteriorated by compacted pan
5. Unutilised water in the deeper soil layers (below pan)
6. Crumb degradation – dust formation
7. Crusting – airless state below crusts
8. Limited biological life

Possible solutions

1. Reduce soil warming by sufficient surface cover, mainly in summer
2. Create surface to be adaptable to water retention, and cover the surface to alleviate the heat stress
3. Keep the soil in well-loosened state

4-5. Preserve pan compaction formation and if it occurred loosen the soil carefully

6-7. Prevent the situations may lead to clod (and dust, crust) formation and use crumb conserving tillage tools

8. Create good habitat for earthworms, add stubble residues to the loosened layer (that is food of them)

Climate induced phenomena occurred in arable soils in the first half of year, 2013

Climate induced phenomena in arable soils in the first half of year, 2013

At the end of the winter

- Dust formation in the soil surface as the effect of the periodic frost.
- Silting of the dust in the surface, due to the periodic and heavy rains.
- Dust leaching to the compacted layer formed near to the surface.

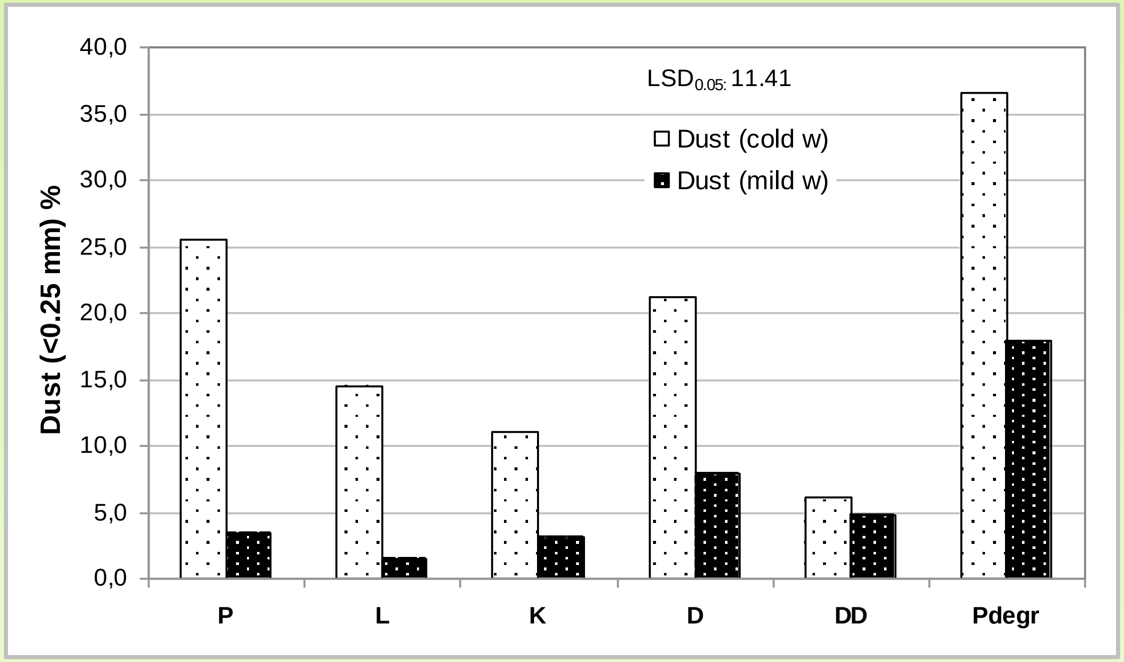
In the beginning of the spring (thereafter rainy period)

- Soil settling due to the repeatedly precipitation.
- Strong crust formation in the silted surface (unsown, sown).
- Over compaction of the seedbed base at time of seedbed preparation
  Soil surface was dry and crusty (soil drying has been lasted) and soil was wet below 5-6 cm
- Natural induced water logging: in lowlands and along the underground water veins.
- Tillage induced water stagnation: above the compacted pan layers.

In the beginning of the summer (following May rain)

- Remaining crusty structure in the narrow-row crops.
- Crust formation in the soil surface in the wide-row crops.
- Declining crumb formation in soils due to hot, dry and windy weather.
- Defects of the crop rooting in the over settled soils and in soils having over compacted seedbed base.

(Frost) dust formation

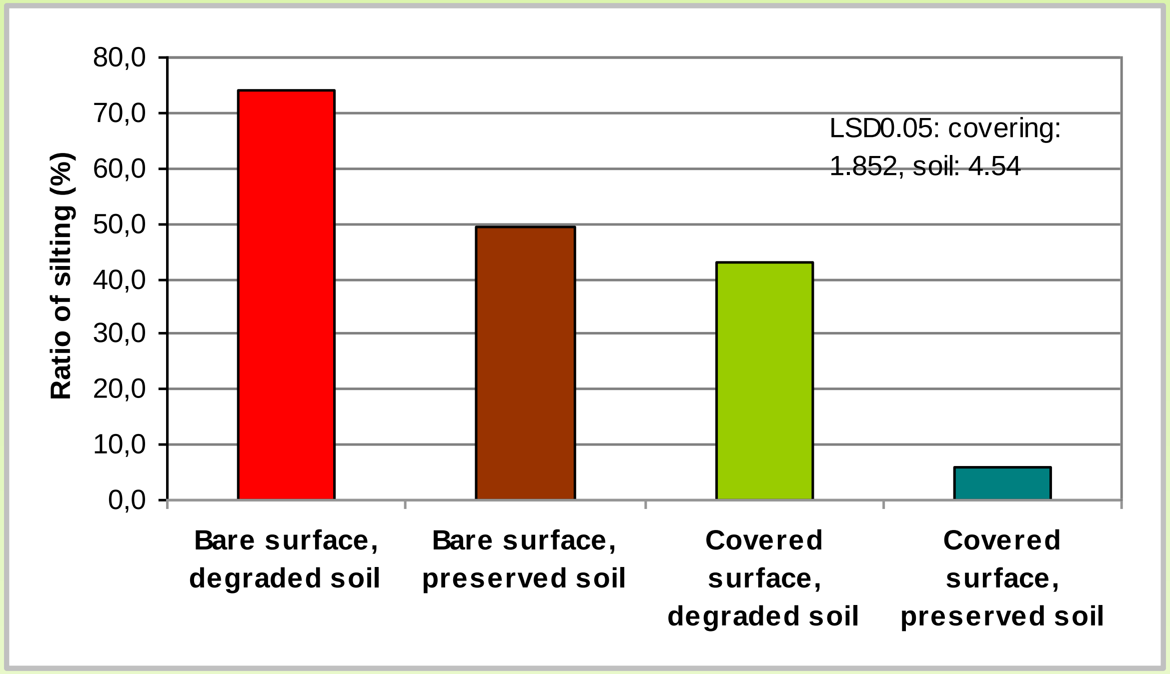


Ranking by the degree of the damage:

<10 %: slight (negligible)
11-30%: conspicuous
31-50 %: risky
51-70 %: serious
71-100 %: very serious

Dust ratio in soils following a cold (2013) and a mild (2010) winter, Hatvan
Legend: P: ploughing and levelling, L: loosening. K: cultivator use, D: disking, DD: direct drilling, Pdegr: ploughing, no levelling, in degraded soil

Surface soil silting



Ranking by the degree of the damage:

<10 %: slight (negligible)
11-30%: conspicuous
31-50 %: risky
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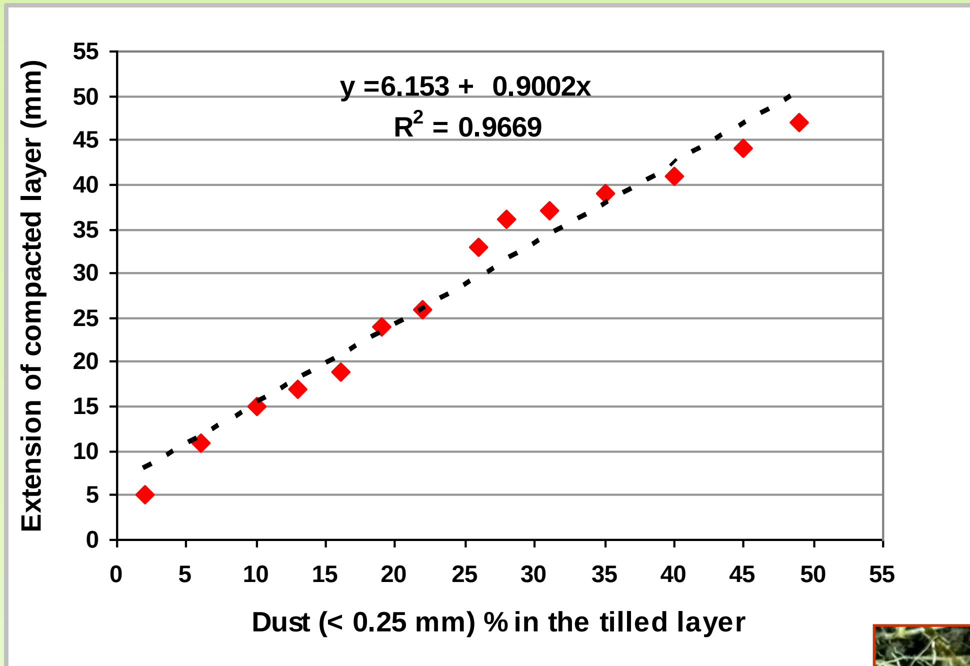
Impacts of surface cover and soil quality on soil surface silting in a rainy period (Hatvan, April, 2013)

Dust leaching to the first compact layer



The leached dust mixed with soil mineral particles constitutes a most firm condition.
This phenomenon explains the formation of large clods at any loosening tillage and higher resistance of soil.

Relations between surface dust ratio and the extension of the compacted layer
(Hatvan, 2009-2012)

Soil settling

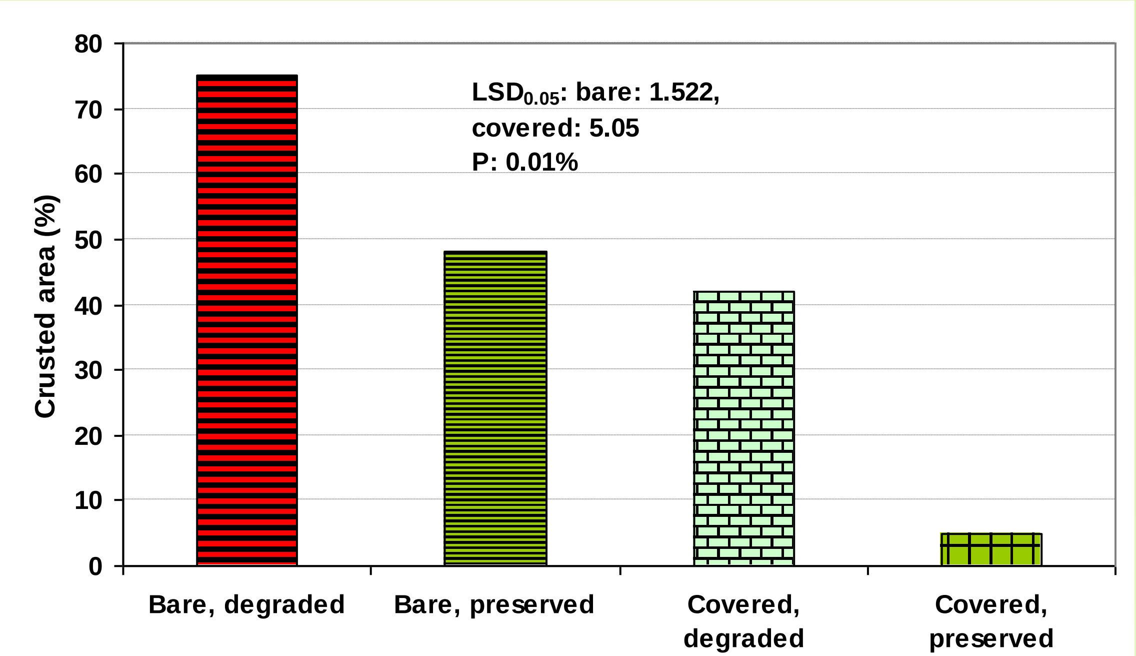
Degree of the soil settling (mm) in different sites *(average, min-max)*
(November, 2012 – April, 2013)

Chernozem soil (Hatvan)		Forest soil (Northern Hungary)		Forest soil (South-Hungary)		Gley (Slavonia)	
Prevented	Degraded	Prevented	Degraded	Prevented	Degraded	Prevented	Degraded
11 2 – 14	37 26 – 41	19 11 – 22	43 38 – 46	21 18 – 25	50 45 – 61	19 15 – 22	36 28 – 41

Ranking:
<15 mm: slight (normal)
16-25 mm: conspicuous
26-45 mm: risky
46-75 mm: serious
75-100 mm: very serious

Crust formation

Ranking of crusted area:
<10 %: slight (negligible)
11-30%: conspicuous
31-50 %: risky
51-70 %: serious
71-100 %: very serious

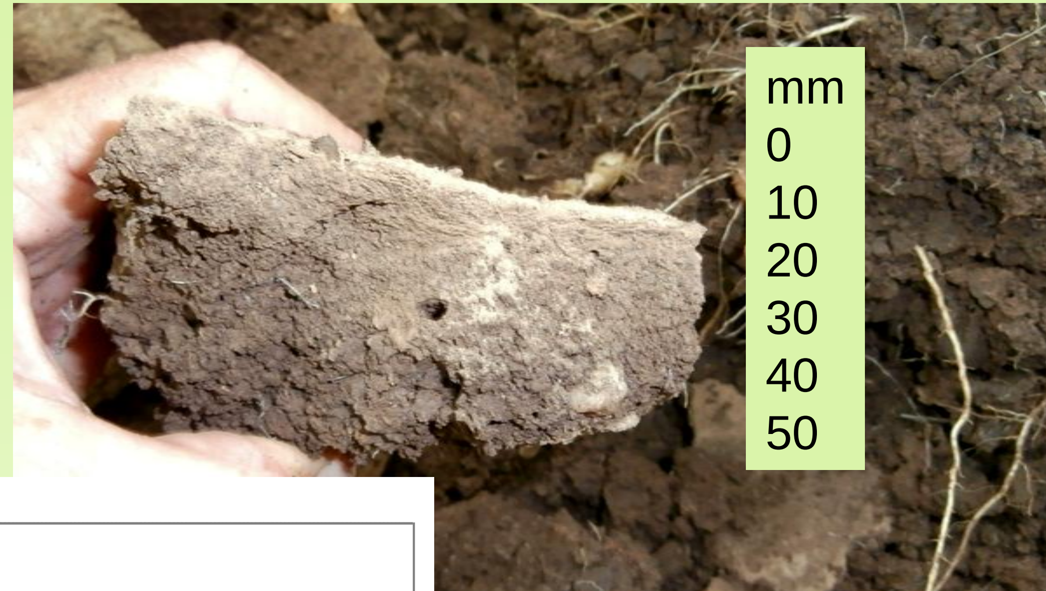


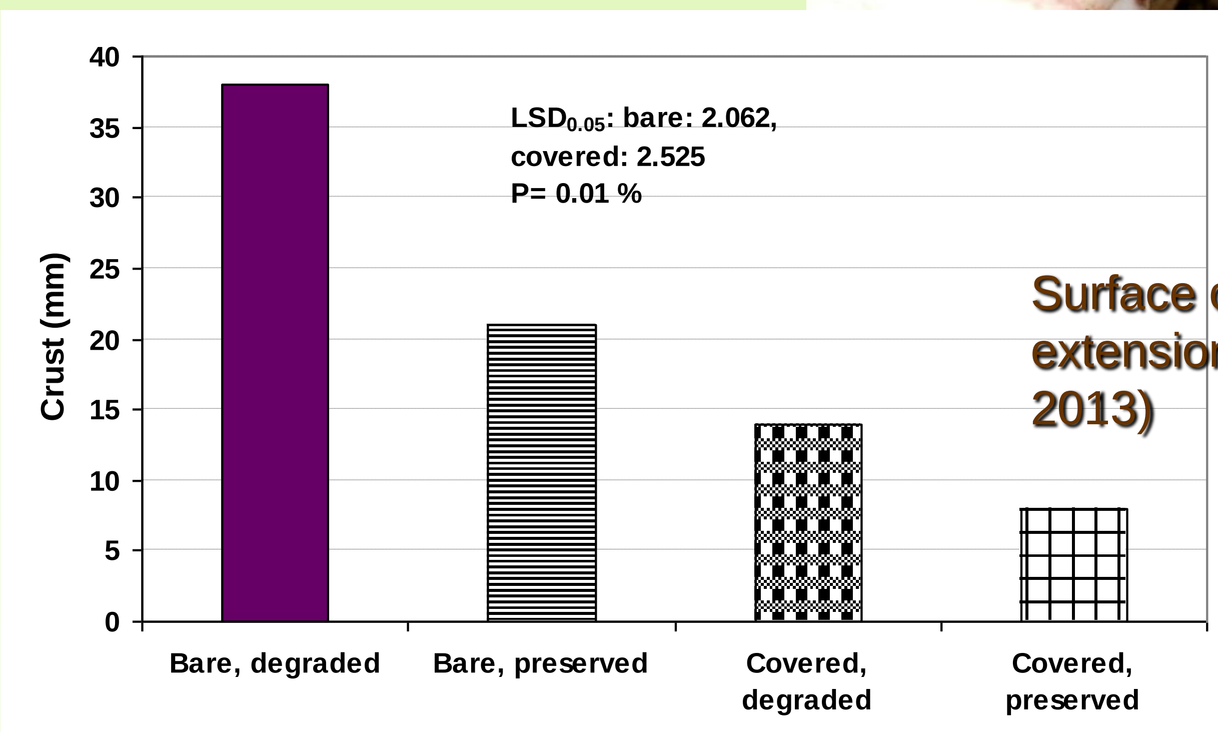
Surface cover and soil quality impact on crusting (Chernozem soil, 2013)

Crust thickness

Ranking of crust thickness:

<5 mm: slight
6-15 mm: conspicuous
16-25 mm: risky
26-35 mm: serious
>35 mm: very serious





Surface cover and soil quality impact on extension of the crust (Chernozem soil, 2013)

Over-consolidation of the seedbed base

Sunflower

- Seedbed preparation was completed in soils were dry and crusty in the surface and wet below 5-6 cm, so seedbed was over-compacted.
- Natural drying of soils was lasted considering the hard and thick crust and by this means preparation tools have kneaded and thickened the seedbed base.
- Main roots have penetrated the compacted layer, but lateral roots has grown horizontally (mostly above the seedbed base).

Special rooting of maize in 2013

Cracking

Deep cracking in clayey soil and root tearing

Maize sank into the crack

Farming induced water logging

Prevention and alleviation

1. Soil quality improvement / maintenance
2. Water management and water regulation
3. Covering the surface in the required rate – min. 45 % but it may vary between 45-65 %
4. Long-term crumb conservation, avoiding clod and dust formation
5. Rational stubble residue management
6. Soil organic material preservation and applying carbon conserving tillage
7. Estimating the degree of the probable damage and then taking the initial steps in prevention and later in soil remediation

Threats – Weaknesses – Opportunities – Strengths

related to climate 'change'

Threats	Weaknesses	Opportunities	Strengths
- extremities - thinning ozone layer - higher temperature = more CO_2 in atmosphere = decreasing fito-production - new pests, diseases and weeds (hardly controllable) - land shortage - limited water resources - soil sealing - soil / water contamination - food shortage	- hardly manageable water deficit or water surplus - poor arable sites - continuous soil deterioration - OM decline - loss of soil biodiversity - neglected soil state - salinisation - acidification - lack of knowledge	- moderated temperature rise (+ 2 ^oC) = moderated CO_2 in the atmosphere = better fito-production - adaptable technique - soil filtering, buffering capacity - water recycling - soil is a conditionally renewable natural resource	- advanced sciences - regional cooperation - skills in water + C management - skills in soil management - effectual land / site / soil conservation - efficacious climate threat mitigation

Definitions*

Soil preserving tillage

No additional damage is done to the soil or its physical and biological condition is even improved while creating conditions to meet the requirements of the crop

Adaptable tillage

Improving or conserving the quality of the soil in harmony with site, mechanisation and farming conditions. Creating a soil condition providing reliable groundwork for cropping through alleviating harmful climate impacts

Climate stress mitigation tillage

Alleviation of soil sensitiveness by reasonably controlling the soil water transport and the carbon balance

*From M. Birkás

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Thank you for your attention – **Děkuji za pozornost**