poljoprivredni fakultet osijek

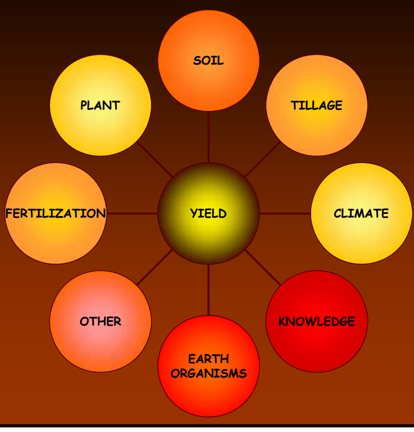
Diplomski studij :: bilinogojstvo
Smjer :: biljna proizvodnja

Comparison conventional tillage and no-tillage according soil chemical, physical and biological properties

Prof. dr. sc. Danijel Jug

Soil tillage in CROATIA

Final goal of any soil tillage is yield



Soil tillage preparation for all arable crops is

90%

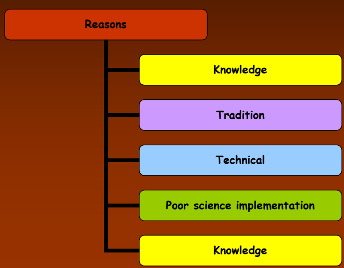
Conventional soil tillage

Official statistics data about land under reduced soil tillage :: NO

First investigations of reduced soil tillage :: seventies of 20. century

Reduced soil tillage today ::

- very restricted (only for winter wheat and soybean)
- limited duration (one year)



Good example	Bad example
- We wonted optimal t/ha of wheat	- We wonted 8 t/ha of wheat
- We needed optimal t/ha of corn	- We needed 12 t/ha of corn
- We have adequately mechanization	- We have only heavy mechanization
- I live on this land	- I am a businessman
- Optimal yields - more money	- Biggest yields - more money
- I need consulting	- I know everything

In Croatia we have a many BAD EXAMPLES

but

CROATIA HAS A BIG POTENTIAL

to adoption a new soil tillage technology

Soil tillage

OLD PARADIGMS

Soil tillage is necessary to produce a crop

- Burying of plant residues with tillage implements
- Bare soil for weeks and month
- Soil heating because of direct solar radiation
- Burning crop residues allowed
- Strong emphasis on soil chemical processes
- Chemical pest control, first option
- Green manure cover crops and crop rotations are options
- Soil erosion is accepted as an unavoidable process associated to farming on sloping land (Erosion is caused by excessive rains)

NEW PARADIGMS

Tillage is not necessary for crop production

- Crop residues remain on the soil surface as mulch
- Permanent soil cover
- Reduced soil temperatures
- Burning mulch prohibited
- Emphasis on soil biological processes
- Biological pest control, first option
- Green manure cover crops and crop rotations compulsory
- Soil erosion is merely a symptom, that for that area and ecosystem unsuited methods of farming are being used (Erosion is caused by soil mismanagement)

Derpsch Rolf, ISTRO-INFO EXTRA, Vol. 4. 1999; available in ISTRO Web page at: http://www.soils.wisc.edu/istro)

What is No-tillage?

No-tillage has different meanings in different parts of the world.

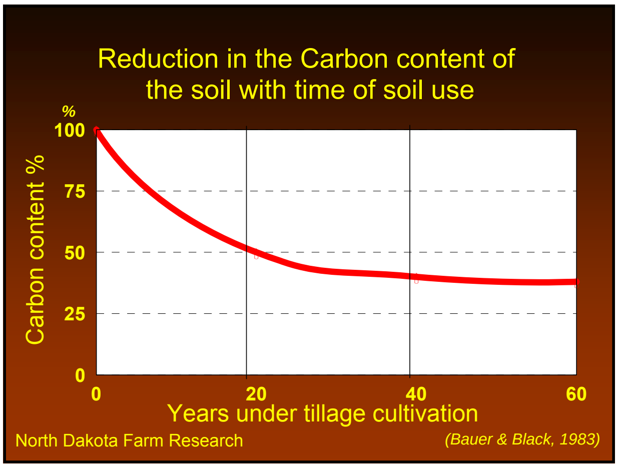
No-tillage is defined as a system of planting crops into untilled soil by opening a narrow slot, trench or band only of sufficient width and depth to obtain proper seed coverage. No other soil tillage is done.

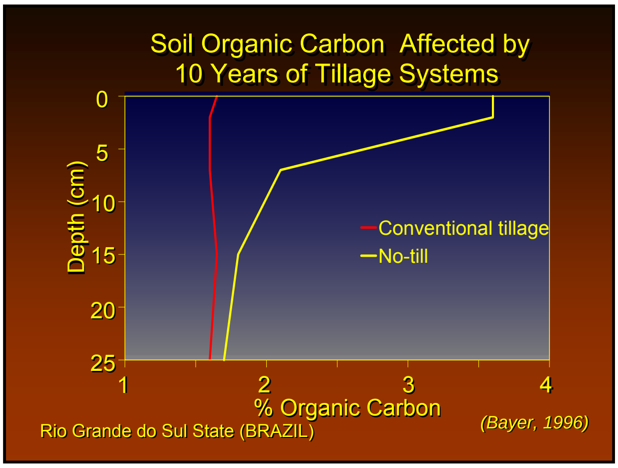
All crop residues remain on the soil surface!

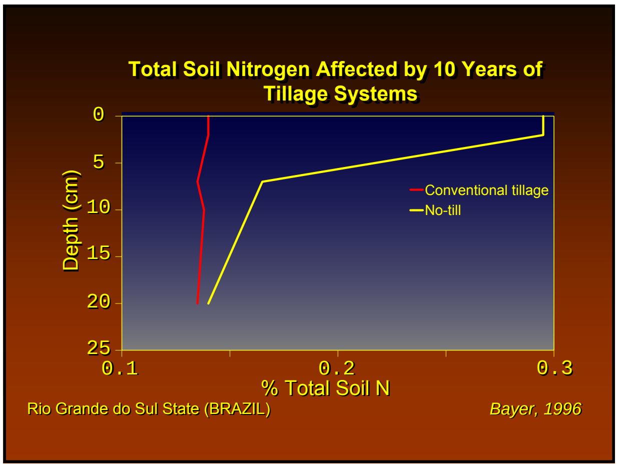
Influence No-tillage on soil chemical properties

> Organic matter	*+ (positive)*
> Nitrogen	*+*
> Phosphorus	*+*
> Potassium	*+*
> Calcium and Magnesium	*+*
> pH	*+*
< Al saturation	*+*
> CEC (Cation exchange cap.)	*+*

Improves soil quality *(Derpsch, 2007)*


Reduction in the Carbon content of
the soil with time of soil use
%
100
75
50
25
0
Carbon content %
0
20
40
60
Years under tillage cultivation
North Dakota Farm Research
(Bauer & Black, 1983)


Soil Organic Carbon Affected by
10 Years of Tillage Systems
Depth (cm)
0
5
10
15
20
25
Conventional tillage
No-till
1
2
3
4
% Organic Carbon
Rio Grande do Sul State (BRAZIL)
(Bayer, 1996)


Total Soil Nitrogen Affected by 10 Years of
Tillage Systems
Depth (cm)
0
5
10
15
20
25
Conventional tillage
No-till
0.1
0.2
0.3
% Total Soil N
Rio Grande do Sul State (BRAZIL)
Bayer, 1996

Influence No-tillage on soil physical properties

< Erosion	+ (positive)
> Water infiltration	+
< Soil temperature	- +
> Soil moisture	+
> Aggregate stability	+
> Soil structure	+
> Soil density	- +

Improves soil quality

(Derpsch, 2007)

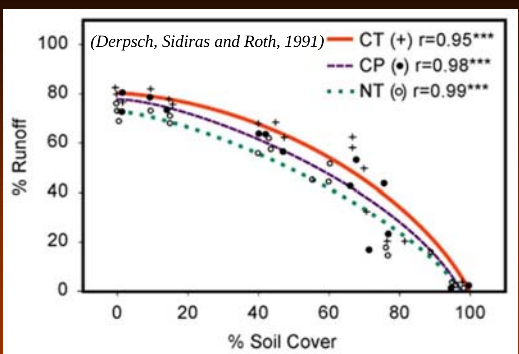
Erosion research under extreme conditions.

In 2 days we had 186 mm of rain
Research on 4000 m^2 plots with 8% Slope.

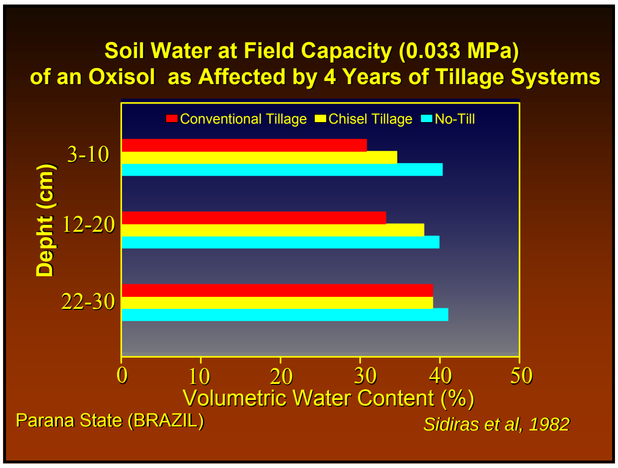
	Soil losses
Conventional tillage	46.500 kg/ha
No-tillage	99 kg/ha

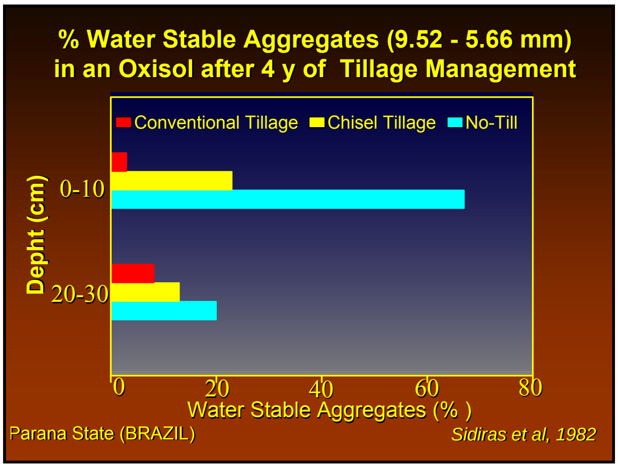
(Venialgo, 1996)

Water infiltration in different tillage systems



Total runoff after 60 minutes of simulated rainfall (60 mm/h) as afected by % soil cover and tillage system

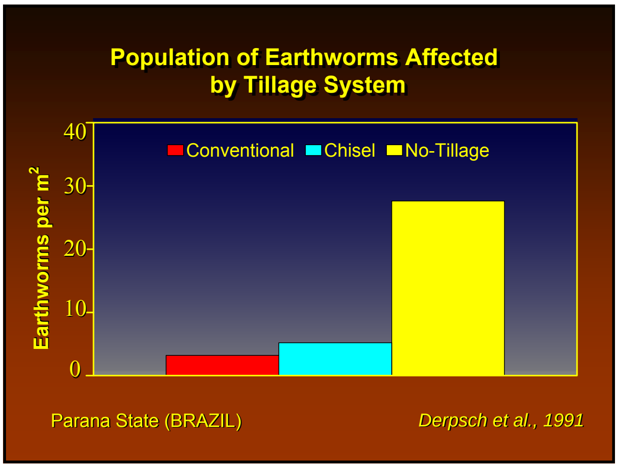


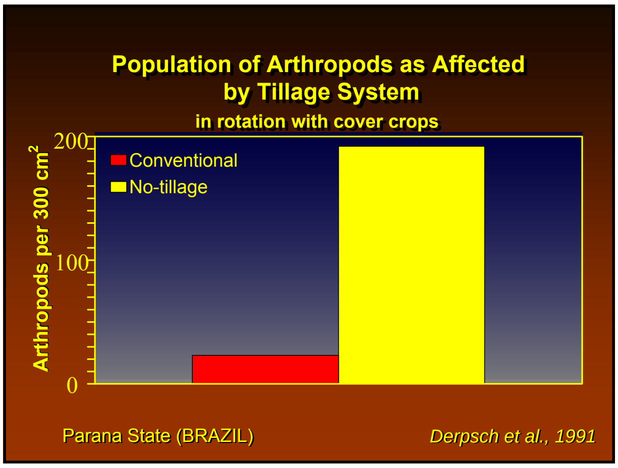


Influence No-tillage on soil biology

- > *Earthworms* + *(positive)*
- > *Arthropods (soil animals)* +
- > *Nodules (Legumes)* +
- > *Micorrhyza* +
- > *Cellulose degradation* +
- > *Microbial biomass* +

Improves soil quality *(Derpsch, 2007)*



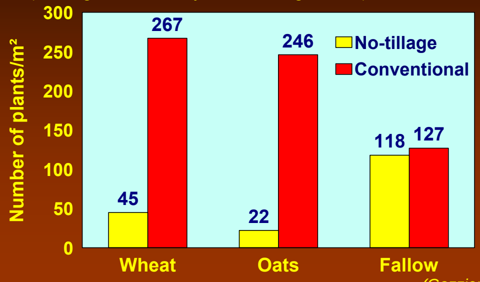


Influence No-tillage on crop sanitary aspects

> *Biological pest control*	*+ (positive)*
> *Pests* <	*- +*
> *Diseases*	*- (negative)*
< *Weed germination*	*+*

(Derpsch, 2007)

Number of weeds (Brachiaria plantaginea) per m²
in soybeans under two tillage systems
and three different crops
(Average of three soybean sowing dates (18/10, 18/11, 12/12)



(Gazziero, 1991)

Influence No-tillage on other factors

- < Fuel consumption + (positive)
- < Mechanization hp/ha +
- > Life of tractors +
- < Labour +
- < Traficability +
- > Yields +
- > Profitability +
- > Time for recreation and management

(Derpsch, 2007)

Fuel consumption is reduced by 66%

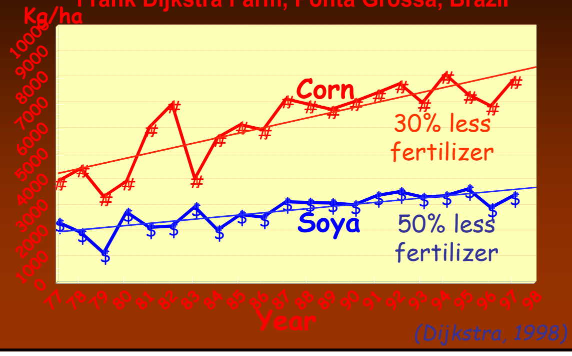
Conventional tillage	42.3 l/ha
Heavy disc harrow	34.3 l/ha
No-till	13.9 l/ha

(Sorrenson, 1984)

Yields

Crop Productivities in No-tillage

Frank Dijkstra Farm, Ponta Grossa, Brazil



Influence No-tillage on the environment

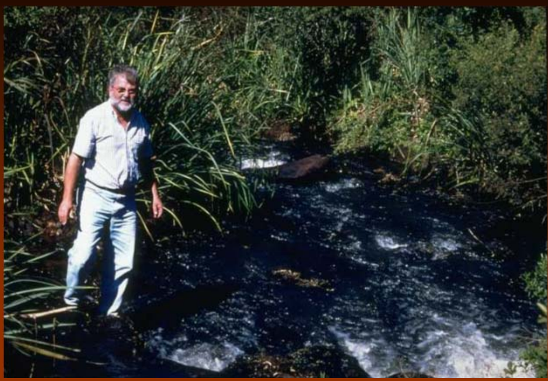
- < CO_2 emissions + (positive)
- > < Herbicides + -
- > Water quality +
- > Wildlife (birds) +
- > Sustainability +

(Derpsch, 2007)

Sediment loaded water in conv. tilled watershed

(Derpsch, 2007)

Clear water in a no-tillage watershed



(Derpsch, 2007)

Birds come back to no-till fields = > environment

(Derpsch, 2007)

Residue covers

Residue Cover

Intensive (conventional) tillage systems
- leave less than 15% crop residue cover or less than 550 kg/ha of small grain residue.

Reduced tillage systems
- leave between 15 and 30% residue cover on the soil surface or 550 to 1100 kg/ha of small grain residue.

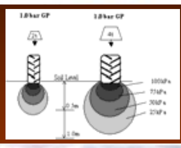
Conservation tillage systems
- are methods of soil tillage which leave a minimum of 30% of crop residue on the soil surface or at least 1100 kg/ha of small grain residue on the surface.

% of crop residue on the soil surface – after tillage preparation for the next crops.

Conservation soil tillage :: Conservation tillage is defined as any tillage planting system that leaves at least 30% of the field surface covered with crop residue after planting has been completed *(Eck i Brown, 2004).*

Why residues are so important ???

Some Benefits of Conservation Tillage
•reduced wind erosion
•reduced water erosion
•erodible land brought into production
•increased options for multiple cropping
•improved soil moisture management
•flexible timing for field operations
•improved soil structure
•better humus management
•carbon sequestration
•moderation of soil temperature
•improved soil biogenity
•generaly :: improved MECHANICAL – CHEMICAL – BIOLOGICAL properties of soil



❖ Soil loss due to water erosion in relation to percent residue cover

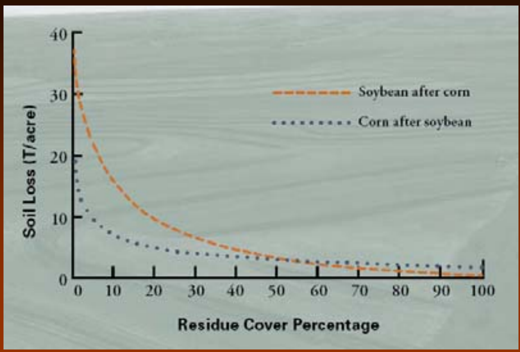
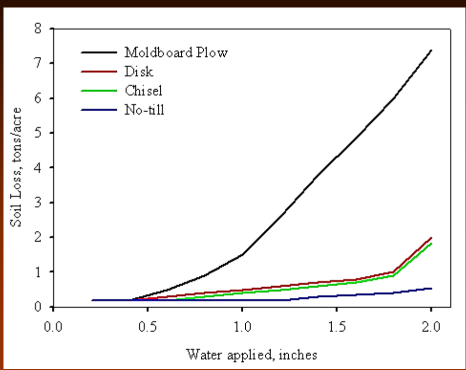
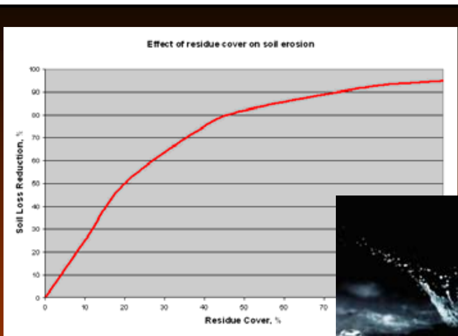


Image by Iowa State University

❖ Soil loss associated with tillage systems used for planting corn into corn residue on a silt loam soil



University of Nebraska-Lincoln, USA



University of Nebraska-Lincoln, USA

The total energy for a 760 mm annual precipitation occurring over 2.6 square kilometers is equivalent to the energy of 9.100 metric tons of TNT (Meyer and Renard, 1991)!!!

❖ Soil water conservation accordance to residue cover on soil surface

Cover of the surface (%)				
< 10	25-30	45-50	70-75	95-100
slight	good	good	very good	good
				
Insufficient in dry and average seasons	Sufficient in dry and average seasons	Effectual in dry and average seasons	Very effectual in dry and average seasons	Total cover of soil is not recommended in arable fields
Aggregate conservation in rainy season				
poor	adequate	good	very good	????

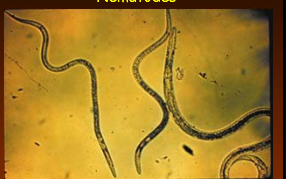
Birkás et al., 2008., Zagreb

Earthworms

One of the most important advantages of conservation soil tillage is a higher soil biogenity.

Rhizobium bacteria (Nitrogen-fixing Bacteria)

Nematodes



Mycorrhizal fungi

Predators

Earthworms (number and condition) may be used as one of criteria for evaluation of healty soils.

Earthworms :: facts

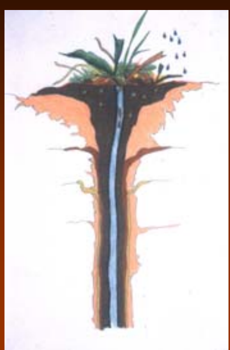
- Shred residues, stimulating microbial decomposition and nutrient release;
- Produce casts rich in N, P, K, and other nutrients;
- Improve soil stability, air porosity and moisture holding capacity by burrowing and aggregating soil;
- Turn soil over and may reduce the incidence of disease by bringing deeper soil to the surface and burying organic matter;
- Improve water infiltration by forming channels and promoting soil aggregation;
- Improve root growth by creating channels lined with nutrients for plant roots to follow.
- etc.

Strong correlation of earthworms and amount of harvest residues at the soil surface.

Earthworms play a major role in overall soil fertility and productivity and may alter the physical, chemical, and biological properties of a crop production soil ecosystem.

Earthworm burrow

Earthworm vertical burrow



Earthworm cast

Important factors of the soil environment to earthworm abundance

- *Organic matter (food sources) ::*
- *Soil type ::*
- *Depth to a restrictive layer ::*
- *Soil pH ::*
- *Moisture holding capacity and internal drainage ::*
- *Rainfall and temperature ::*
- *Predation and parasitism ::*
- *Earthworm introduction ::*

Soil tillage is the main technical factor to earthworm abundance

- less and shallower tillage is better,

-worm numbers can be reduced by deep and frequent tillage,

- tillage reduces earthworm populations by drying the soil and burying the plant residue they feed on, and making the soil more likely to freeze,

- tillage destroys vertical worm burrows and can kill and cut up the worms,

- worms are dormant in the hot part of the summer and in the cold of winter. Young worms emerge in spring and fall-they are most active just when farmers are likely to be tilling the soil,

- as a rule, earthworm numbers can be increased by reducing or eliminating tillage (especially fall tillage), not using a moldboard plow, reducing residue particle size (using a straw chopper on the combine), adding animal manure, and growing green manure crops.

- single tillage event will not drastically reduce earthworm populations, repeated tillage over time will cause a decline in earthworm populations.

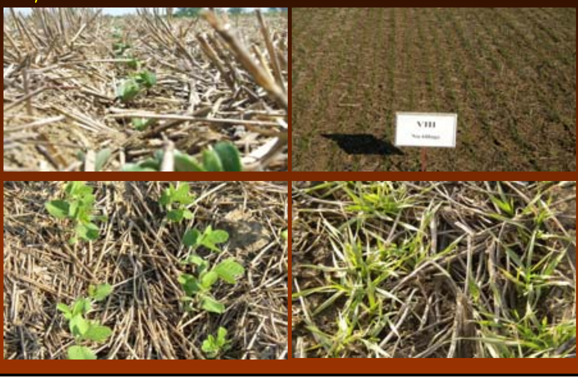
Example

Experiment

::

Residue covers and *Earthworms*

- The objective of this research was to establish differences in soil surface coverage by soybean harvest residues among soil tillage systems, together with its influence at earthworm population beneath different soil tillage systems.



Material and methods

- **The Field experiment**
  - cultivar :: w. wheat - soybean crop rotation
  - location :: eastern Croatia – experimental site near Kneževo
  - experimental period :: 2002-2005
  - soil tillage treatments :: CT – conventional tillage
    DH – diskharrowing
    RH – chiseling + diskharrowing
    NT – no-tillage
  - Basic experimental plot :: 900 m^{-2}
  - fertilization :: $N:P_2O_5:K_2O$ = 121:130:130 kg ha^{-1}

- sowing :: in October (w. wheat) – in May (soybean)
  John Deere 750A
  interrow spacing 16.5 cm (w.w.) – 33 cm (soybean)
  deep of sowing 2-3 cm (w.w.) – 4-6 cm (soybean)

Soil characteristics

- calcareous chernozem on loess substrate
- chemical properties ::
  pH (H_2O) - 8.1
  pH (KCl) - 7.5
  Humus - 2.6%
  $CaCO_3$ - 2.1%
  P_2O_5 - 18.7 mg 100 g^{-1} tla (AL-soluble)
  K_2O - 28.4 mg 100 g^{-1} tla (AL-soluble)

Soil tillage treatments

CONVENTIONAL TILLAGE --- [CT]

- Ploughing --- 25-30 cm (autumn)
- Diskharrowing (autumn)
- Seedbed preparation --- rototiler (spring)
- Standard sowing---John Deere 750A

DISKHARROWING --- [DH]

- Diskharrowing --- 10-15 cm (autumn)
- Seedbed preparation --- rototiler (spring)
- Standard sowing---John Deere 750A

Soil tillage treatments

CHISELING --- [RH]

- Chiseling --- 25-30 cm (autumn)
- Diskharrowing (autumn)
- Seedbed preparation --- rototiler (spring)
- Standard sowing---John Deere 750A

NO-TILLAGE --- [NT]

- Without any tillage treatments
- Direct seeding ---John Deere 750A

➢ CT - *Conventional tillage - in autumn*

➢ DH - *Diskharrowing - in autumn*

➢ RH - *Chiseling + diskharrowing – in autumn*

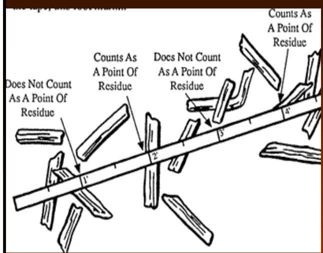
➢ NT - *early season*

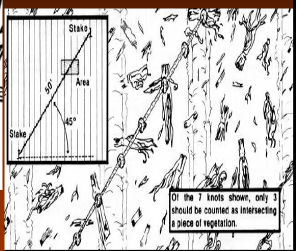
Winter wheat

Soybean

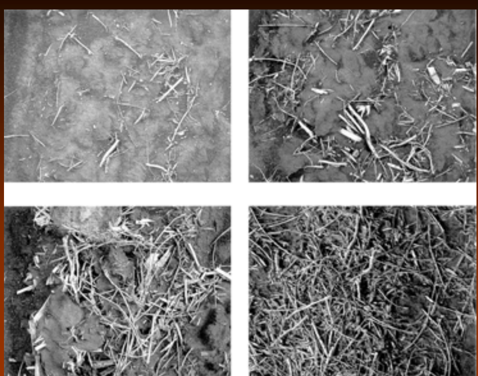
Methods for Estimating Residue Cover

➢ **Line-Transect Method**





➢ **Photo-Comparison Method**



✧ **Earthworm populations**

Earthworms (*Lumbricus terrestris L.*) were hand-sorted from each 10 cm layer up to 50 cm depth. They were collected each spring in 3 years (02. May 2003; 21. May 2004; 11. May 2005), after sowing soybean. Densities were determined on a per square meter basis.

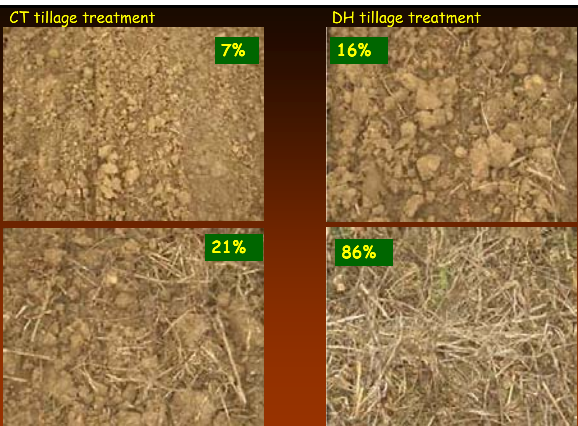
Without *Lumbricus terrestris* — With *Lumbricus terrestris*

➢ Influence of soil tillage treatments on residue covers (%) in period 2002/2003-2004/2005. year.

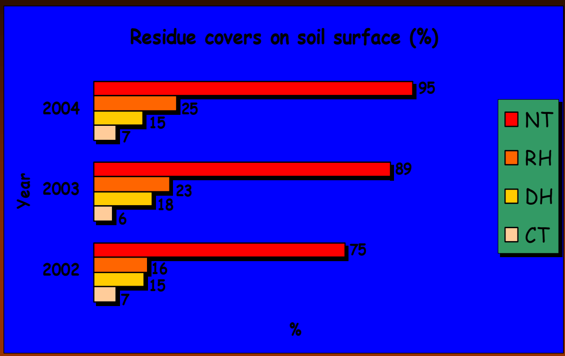
Soil tillage (T)		Year (Y) 2002	2003	2004	Average (T)
CT		7a	6a	7a	7a
DH		15b	18b	15b	16b
RH		16b	23c	25c	21c
NT		75c	89d	95d	86d
Average (Y)		28 A	34 B	36 C	33
LSD (T)	0.05	2,49	3,4	4,74	1,92
	0.01	3,57	4,88	6,81	2,59
F-test		1646,45**	1234,26**	752,37**	3047,24**
LSD (Y)	0.05		1,04		
	0.01		1,57		
F-test			156,39**		

Means with the same lowercase letter(s) are not significantly different at P<0.01 level (T)
Means with the same uppercase letter(s) are not significantly different at P<0.01 level (Y)

CT tillage treatment — DH tillage treatment



RH tillage treatment — NT tillage treatment



Earthworm populations (*Lumbricus terrestris*) on four different tillage treatments in period 2003-2005.

Tillage (T)	Soil depth, cm (D)	Year (Y) 2003	2004	2005	Average (D)
CT Sum (C)	Earthworms/m^2	20	44	48	37 *A*
RH Sum (C)	Earthworms/m^2	32	60	68	53 B
DH Sum (C)	Earthworms/m^2	44	80	96	73 *C*
NT Sum (C)	Earthworms/m^2	64	112	132	103 D
Average Across Soil Tillage	00 - 10				17 b
	10 - 20				23 c
	20 - 30				15 b
	30 - 40				9 ab
	40 - 50				3 a
LSD (T) 0.05					4
0.01					5
LSD (D) 0.05					5
0.01					6

Means with the same lowercase letter(s) are not significantly different at P<0.01 level (D)
Means with the same uppercase letter(s) are not significantly different at P<0.01 level (T)