# Plot-scale experiments to assess the effects of surface spatial heterogeneity on runoff and soil loss

## Challenges for competitive and sustainable EU-China agricultural systems under increasing pressures on soil and water resources

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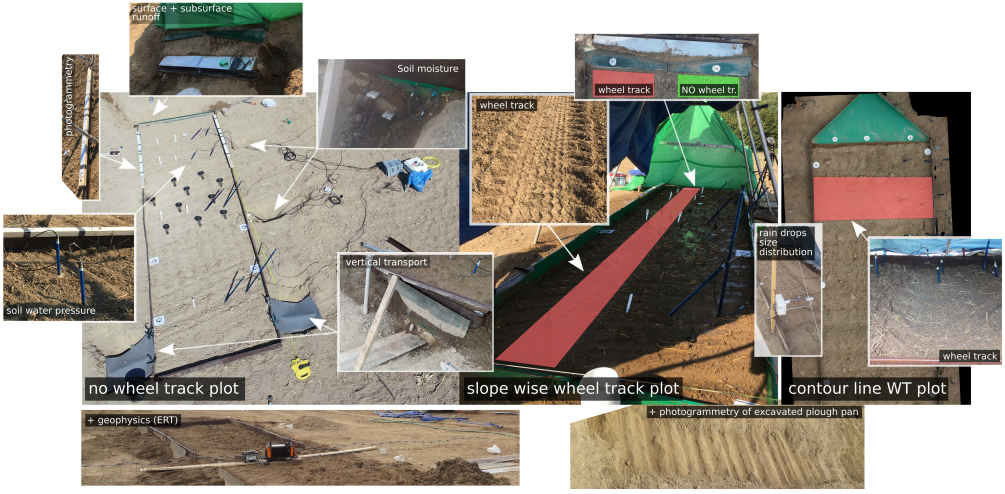
# Plot-scale experiments to assess the effects of surface spatial heterogeneity on runoff and soil loss

## Motivation

Wheel track presence and orientation effect on runoff and soil loss at tilled soil



# Plot-scale experiments to assess the effects of surface spatial heterogeneity on runoff and soil loss

Artificial rainfall experiments were conducted to analyze the wheel track effect (top Figure).

2 wheel track orientations were established alongside no wheel tack situation (top Figure).

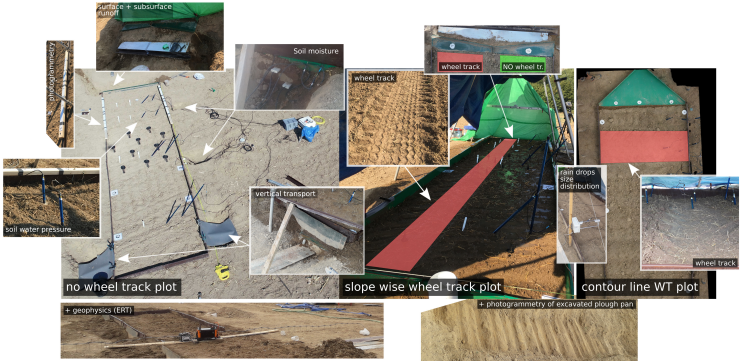
Wheel track were prepared prior experiments (bottom Figure).

## Base information

- Location: Central Bohemia, Czech Republic
- Soil class: loamy (clay = 18 %; silt = 34 %; sand = 48 %)
- Slope: ca 10 %
- Soil profile: Freshly tilled topsoil, plough pan developed at depth of 12-15 cm
- Campaigns: 2018 - vol1; 2019 - vol2
- 3 setups: **noWT** - no wheel track
  **slWT** - slope wise wheel track
  **clWT** - contour line wheel track
- Rainfall intensity: 30 mm/hour
- Plot size: 16 $m^2$

# Plot-scale experiments to assess the effects of surface spatial heterogeneity on runoff and soil loss

- Role of surface topography
  - surface topography changes
  - connectivity of surface topography
- Role of infiltration
  - soil sealing
  - soil layering



A direct measurement of runoff and soil loss were undertaken during the experiment

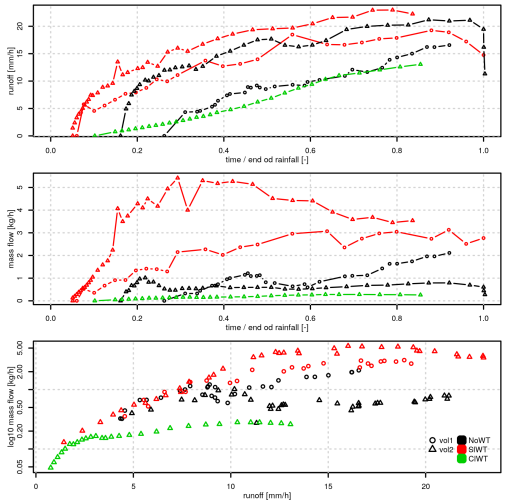
Besides, high resolution DEMs were obtained with photogrammetry

Analysis of DEM were compared to direct measurement.

## DEM analysis consists of:

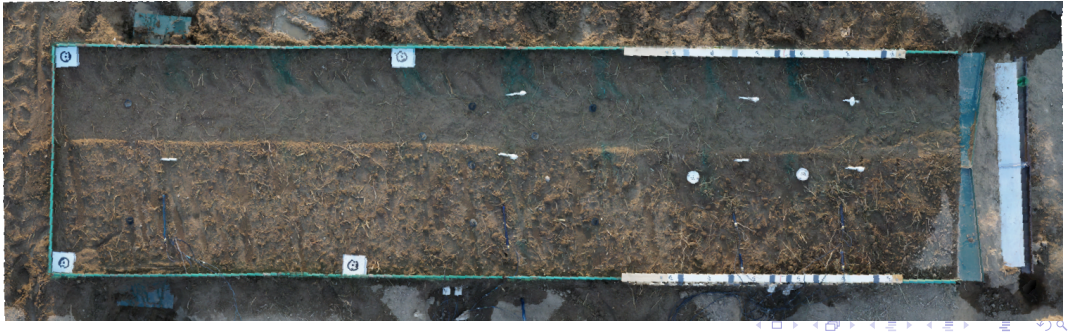
- Temporal surface roughness changes
- Structural connectivity (flow algorithms) $->$ indices
- Functional connectivity (surface runoff model) $->$ indices

## Direct measurement



## DEM was obtained with

- Photogrammetry $->$ Agisoft (done by JK + students)
- DEMs with 1 mm resolution
  - x, y - resampled to **3 mm**, **10mm**, **30mm** and **100mm** res.
- Measured **before** and **after** each experiment



*Random roughness* ($RR$) a *oriented random roughness* ($RR_{x,y}$)
Taconet & Ciarletti (2007)

Surface roughness was calculated for each of the experimental plots based on the before and after rainfall surface conditions.

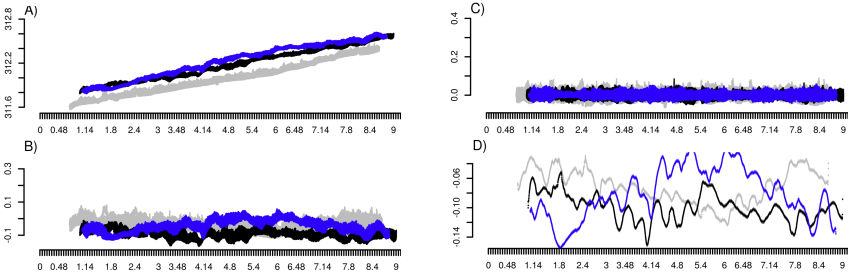
Different kinds of removed trends from the original DEM was tested (Figure BCD)

$$RR = \sqrt{\langle (h(x,y) - \langle h(x,y) \rangle_{x,Y})^2 \rangle_{x,Y}}$$

$$RRx = \langle \sqrt{\langle (h(x,y) - \langle h(x,y) \rangle_{x})^2 \rangle_{x}} \rangle_{Y}$$

$$RRy = \langle \sqrt{\langle (h(x,y) - \langle h(x,y) \rangle_{Y})^2 \rangle_{Y}} \rangle_{x}$$

A) DEM sideview
B) best plane removed
C) micro roughness
D) furrow roughness



Structural connectivity express how long has the water flow until it reaches the bottom of the plot.

Here, the structure is the relief of the soil surface.

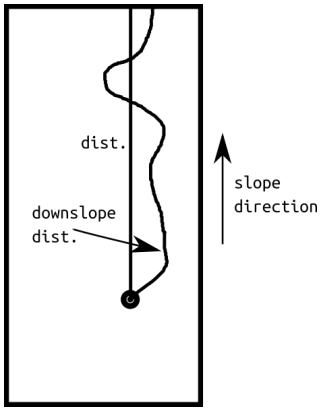
Indices are often used to assess the structural connectivity (e.g. Borselli et al., 2008). Here we utilize the normalized downslope distance.

## Normalized downslope distance (NDD)

NDD express how long is the path of water with respect to shortest downslope distance possible.

- Downslope distance
- TauDEM (Tarboton, 2013)

$$NDD = downslope\ dist./distance$$



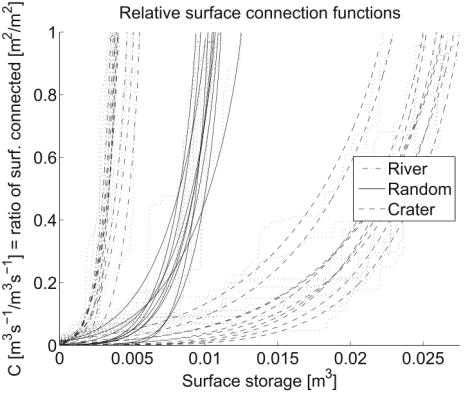
Includes also dynamics of processes in the analysis. It is based on an idea of understanding-oriented modelling (Darboux, et al., 2002)

Here, we used the relative surface connecting function (Antoine et al., 2009). Surface runoff vs. filled surface storage shows how surface contributes to the runoff from some area (see Figure).

### Relative surface connecting function

A surface runoff SMODERP2D model was used for this analysis.

- SMODERP2D
  - surface runoff
  - infiltration
  - surface retention
- surface retention = dem - filled(dem)




(Antoine et al., 2009)

2 campaigns

- vol1 - first round of experiments (09/2018)
- vol2 - second round of experiments (06/2019)

3 wheel track orientations

- NoWT - NO Wheel Track (reference plot)
- SlWT - SLope vice direction Wheel Track
- ClWT- Contour Lines direction Wheel Track

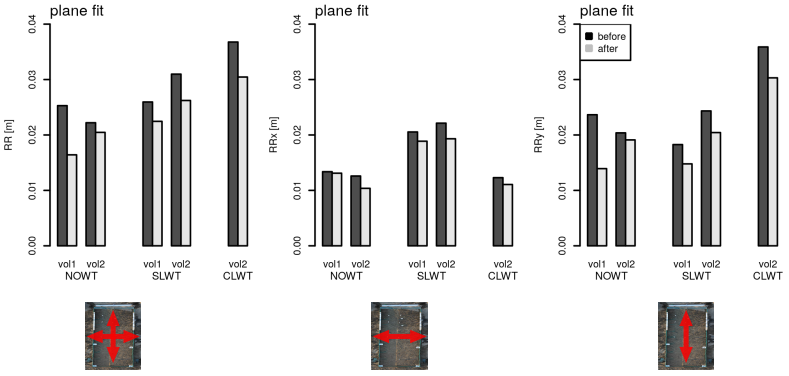
What has been done:

- vol1: NoWT, SlWT
- vol2: NoWT, SlWT, ClWT

Random roughness and oriented random roughness of the before and after rainfall surface conditions.

The plain of best fit is removes from the original DEM (bottom diagram). Small diagrams below barplots depict the direction orientation of the roughness.

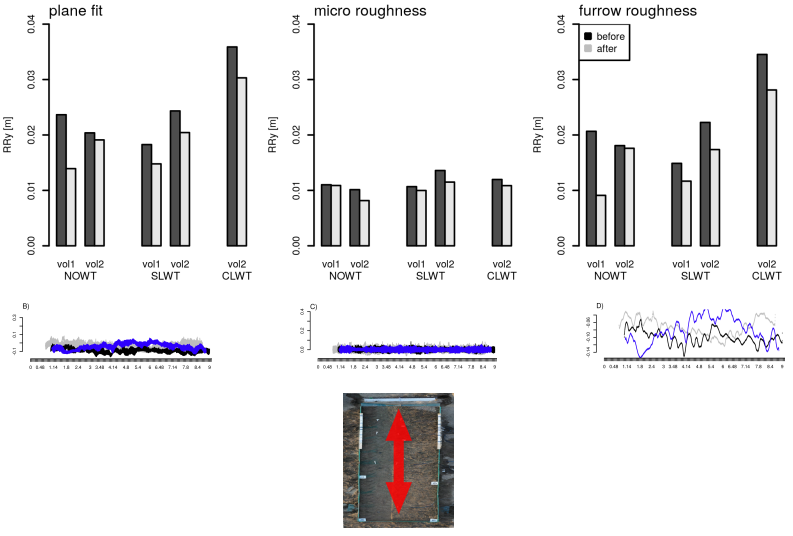
Random roughness decreased after the rainfall for all orientation of wheel track and all random roughness coefficients.



Y-direction odiented random roughness of the before and after rainfall surface conditions.

The plain of best fit, furrows and microtopograpohy was removes from the original DEM (bottom diagram). Small diagrams below barplots depict the shape of used surface topography

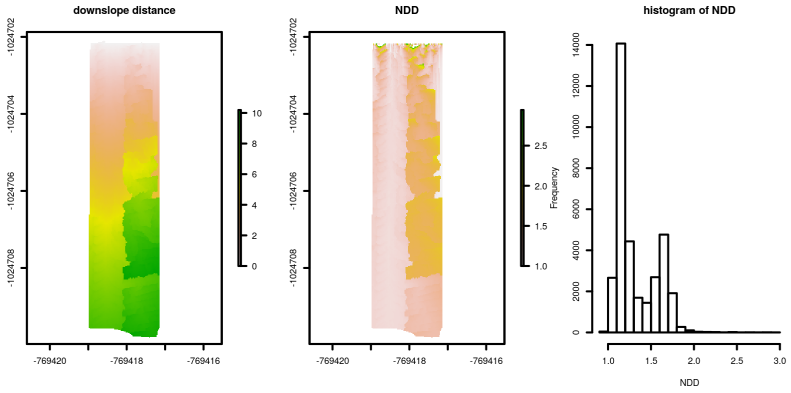
Random roughness decreased after the rainfall for all types of the surface curvature.



Example of downslope distance and NDD of before-rainfall stepwise wheel track.

The (normalized) distance distance was higher for the surface outside the wheel track. No evidence of water flow in the wheel track.

NDD histogram exhibited bimodal distribution. Two modes for wheel track soil and the soil outside the wheel track.



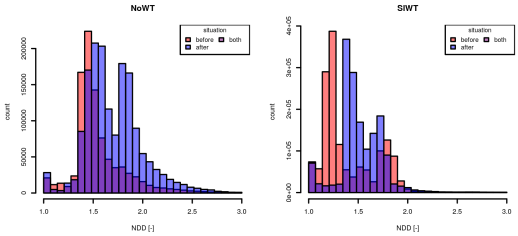
# Results - Normalized downslope distance - structural connectivity

Histogram of before and after NDD of the campaign vol1

The downslope distance increased for the after-rainfall conditions at the NoWT plot.

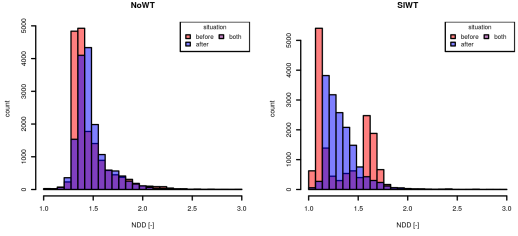
The distribution reduced number of modes from two to one at the SlWT plot for both spatial resolutions.

**3 mm** resolution.




NA

**30 mm** resolution.




NA

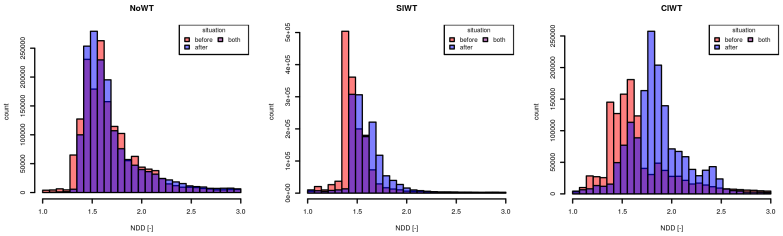
# Results - Normalized downslope distance - structural connectivity

Histogram of before and after NDD of the campaign vol2.

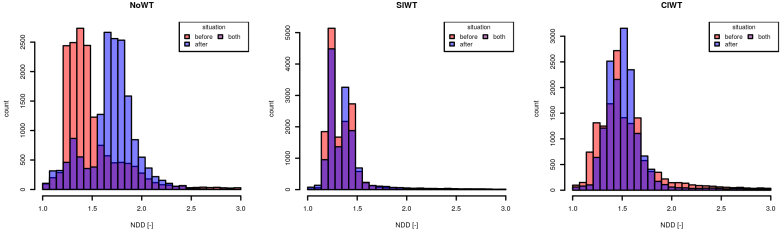
The increase of NDD was observed at the CIWT plot for 3 mm resolution and for NoWT plot with 30 mm spatial resolution.

The bi-modality of the SIWT plot was less pronounced compared to previous year campaign (previous slide).

**3 mm** resolution.

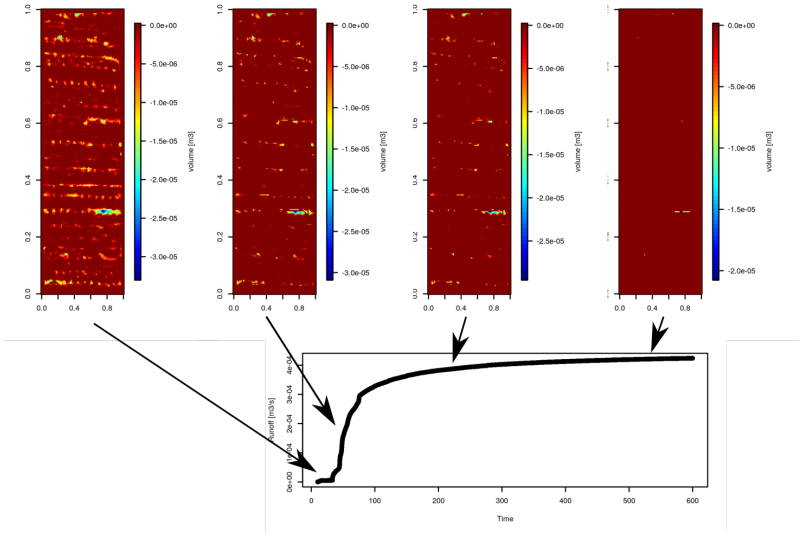



**30 mm** resolution.



# Results - Relative surface connecting function - Functional connectivity

To recapitulate: The surface retention (expressed with four plots in the upper part of the Figure) are being filled while the runoff, and hence the runoff coefficient, increases (bottom graph).

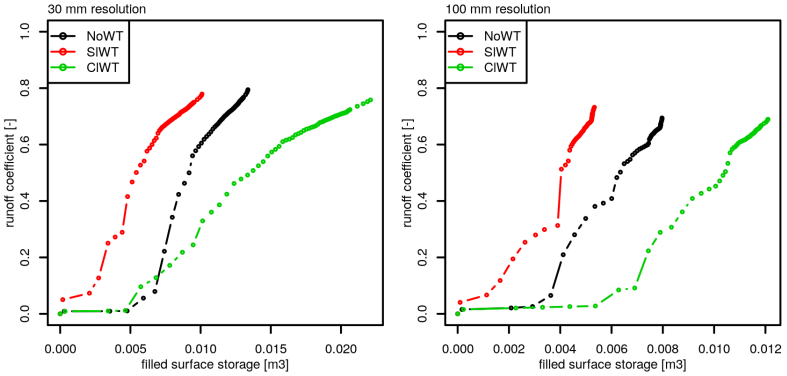


The CIWT plot had the largest and SIWT plot the smallest storage for both, before- and after-rainfall surface conditions.

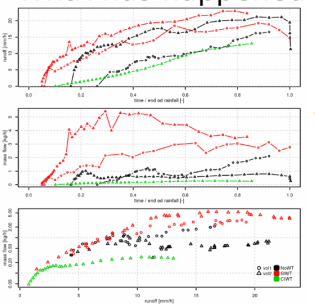
The most gradual increase of runoff coefficient was observed for the CIWT plot. The threshold behaviour was pronounced the most at the NoWT and SIWT plot.

Larger effect of spatial resolution on total surface storage capacity and the overall behaviour was observed.

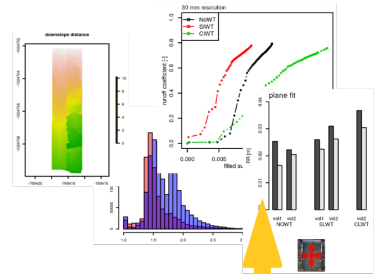
Relative surface connecting function of the **vol2** experiments at two spatial resolutions.



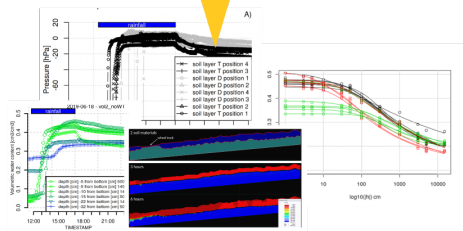
## What has happened



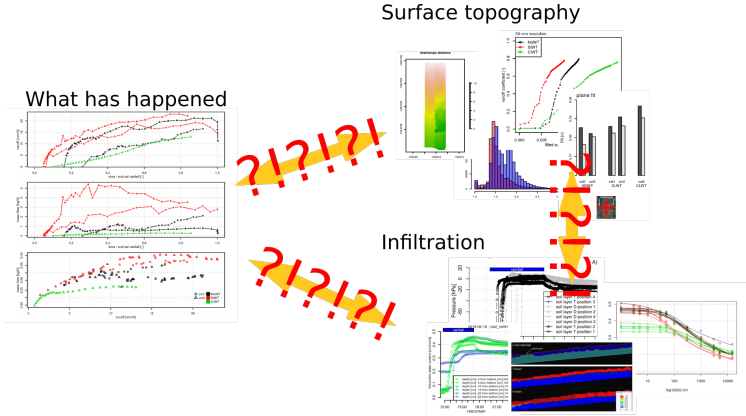
## Surface topography



## Infiltration



Thank you for your attention.

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