CZECH UNIVERSITY OF LIFE SCIENCES

PRAGUE FACULTY OF ENVIRONMENTAL SCIENCES

Landscape Engineering – Landscape Planning

COMPARISON OF DIFFERENT TILLAGE INTENSITIES ON RUNOFF, INFILTRATION AND SOIL LOSSES AND IMPLICATIONS FOR MAIZE PRODUCTION IN KRASNA HORA, CZECH REPUBLIC

DIPLOMA THESIS

Supervisor: Ing. Zdeněk Keken, Ph.D.
Author: Bc. Anežka Stejskalová, MSc.

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Anežka Stejskalová

Landscape Planning

Thesis title

Comparison of different tillage intensities on runoff, infiltration and soil losses and implications for maize production in Krasna Hora, Czech Republic

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Objectives of thesis

To test the implementation of certified technologies to deliver GAEC (Good Agricultural and Environmental Condition)

To investigate the effectiveness of different types of tillage intensity in delivering GAEC, as monitored by: maize productivity, runoff, infiltration and soil loss. This will be achieved from erosion plots located on different fields, where different intensities of tillage have been carried out.

Specific objectives (summarise):To measure and monitor: runoff volume (ml), infiltration volume (ml) soil loss (t/ha) and maize productivity from erosion plots at Krasna Hora, Czech Republic

Methodology

In the project, we have 3 main experimental localities and 1 additional. 3 plots are currently under maize.

The specific treatments / soil conservation technologies include Conventional tillage practice, No-tillage, Strip-till, using active tillage cutter + control variant fallow. Different combinations of treatment and soil management were tested as well, i.e. application of manure, green manure etc.

All localities in the region of Krásná Hora have Cambisols (WRB soil classification system). For all localities, we did detailed soil survey.

Rainfall simulation will be used to generate runoff, infiltration and soil loss from the experimental plots.

Data currently available for analysis includes: data from rainfall simulator – intensity, start of surface runoff, time of duration etc.; measured soil loss; soil description – texture, structure etc.).

The proposed extent of the thesis

40 pages

Keywords

Erosion control, Tillage technologies, Rain simulation, Soil loss, Maize, Erosion mitigation, Infiltration, Surface run-off

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Ing. Zdeněk Keken, Ph.D.

Supervising department

Department of Applied Ecology

Electronic approval: 7. 4. 2017

prof. Ing. Jan Vymazal, CSc.

Head of department

Electronic approval: 10. 4. 2017

prof. RNDr. Vladimír Bejček, CSc.

Dean

Prague on 18. 04. 2017

Declaration

I hereby declare that the thesis titled “Comparison of different tillage intensities on runoff, infiltration and soil losses and implications for maize production in Krasna Hora, Czech Republic” is original work which I have completed independently under the direction of the supervisor. All the sources have been quoted and listed in References at the end of the thesis.

Prague, 18th of April 2017 ______________________________

CRANFIELD UNIVERSITY

ANEZKA STEJSKALOVA

COMPARISON OF DIFFERENT TILLAGE INTENSITIES ON RUNOFF, INFILTRATION AND SOIL LOSSES AND IMPLICATIONS FOR MAIZE PRODUCTION IN KRASNA HORA, CZECH REPUBLIC

SCHOOL OF ENERGY, ENVIRONMENT AND AGRIFOOD
Environmental Engineering

MSc THESIS
Academic Year: 2015 - 2016

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This thesis is submitted in partial fulfilment of the requirements for the degree of MSc.

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ABSTRACT

Legislative incentives have led to a significant increase in maize cultivation for the generation of energy from biomass. As a result, the area under maize production is probably growing faster than any other crop in the UK – from just 8,000 hectares in England in 1973 to 183,000 hectares in 2014. Similar issues have arisen in the Czech Republic. The Research Institute of Soil and Water Conservation in Prague, Czech Republic is testing various tillage practices (TP) and comparing their effectiveness. Maize cultivation is associated with high rates of runoff and soil erosion, which have negative impacts on public goods like soils and fresh water. Soil conservation farming methods are used to mitigate these environmental risks. Field experiments using a rainfall simulator measured the soil loss caused by water erosion under various tillage treatments and intensities of rain. Rain simulations were conducted between 2013-2015 to evaluate the effectiveness of 12 different tillage practices in terms of surface run off, infiltration and soil loss. The results suggest no tillage with maize row widths of 37.5 cm was the most effective tillage practice compared to conventional tillage. This treatment can reduce surface runoff by 30% and soil loss by 93.6%, as well as increase the infiltration rate by 7.9%. The results of the rainfall simulation experiments were also compared with other studies to test if the outcomes agree with those in other locations.

Keywords:

Erosion control, Tillage technologies, Rain simulation, Soil loss, Maize, Erosion mitigation, Infiltration, Surface run-off

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LIST OF ABBREVIATIONS

RISWC	Research Institute for Soil and Water Conservation
CT	Conventional tillage with row widths of 37.5cm
CT 75	Conventional tillage with row widths of 75cm
ST 37.5	Strip tillage with row widths of 37.5cm
ST 75	Strip tillage with row widths of 75cm
NT	No tillage
NT 37.5	No tillage with row widths of 37.5cm
NT 75	No tillage with row widths of 75cm
VT	Vertical tillage
DH	Disc harrow
IC	Intercrop
USB 37.5	Under sowing with barely with row widths of 37.5
USB 75	Under sowing with barely with row widths of 75cm
SR	Surface runoff
IF	Infiltration
SL	Soil loss
GAEC	Good agricultural and environmental condition
TP	Tillage practice
LM	Land management
RS	Rainfall simulator

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Anezka Stejskalova, Jane Rickson, Michaela Hrabalikova

School of Water, Energy and Environment (SWEE), Cranfield University, Cranfield, Bedfordshire MK43 0AL

ABSTRACT

Legislative incentives have led to a significant increase in maize cultivation for the generation of energy from biomass. As a result, the area under maize production is probably growing faster than any other crop in the UK – from just 8,000 hectares in England in 1973 to 183,000 hectares in 2014. Similar issues have arisen in the Czech Republic. The Research Institute of Soil and Water Conservation in Prague, Czech Republic is testing various tillage practises (TP) and comparing their effectiveness. Maize cultivation is associated with high rates of runoff and soil erosion, which have negative impacts on public goods like soils and fresh water. Soil conservation farming methods are used to mitigate these environmental risks. Field experiments using a rainfall simulator measured the soil loss caused by water erosion under various tillage treatments and intensities of rain. Rain simulations were conducted between 2013-2015 to evaluate the effectiveness of 12 different tillage practices in terms of surface run off, infiltration and soil loss. The results suggest no tillage with maize row widths of 37.5 cm was the most effective tillage practice compared to conventional tillage. This treatment can reduce surface runoff by 30% and soil loss by 93.6%, as well as increase the infiltration rate by 7.9%. The results of the rainfall simulation experiments were also compared with other studies to test if the outcomes agree with those in other locations.

Keywords:

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1 Introduction

Erosion has been considered to be one of the greatest threats to the world's agricultural soils. Soil erosion may have adverse effects on the environment (i.e. water pollution, organic matter loss, reduction in water storage capacity) and cause depressions in crop yield (Prasuhn, 2011). There are a number of current environmental challenges related to climate and demographic change. The agricultural sector plays an important role not only as the producer of food for a rapidly growing world population, it is also relevant for the mitigation of climate change. According to a Fifth Assessment Report (IPCC, 2014), the near future climate change will be mainly embodied in an increase in warm temperature extremes period and an increase in the number of heavy precipitation events. The changes in rainfall and temperature variability may cause a threat to the quality of soil and water resources (Basche et al., 2016). One of possible approaches to mitigate the impacts of increased rainfall variability on a field is to employ soil management practices that enhance infiltration of rainfall into the soil and increase soil structure stability. Both soil and agriculture are key aspects for sustainable land management under future environmental change and require a multidisciplinary approach (Vogel, Deumlich, & Kaupenjohann, 2015). Soil conservation practices are critical for agricultural sustainability (Souza et al., 2013) and conservation tillage practices have been recognised as effective methods for controlling soil erosion (Prasuhn, 2011). The expansion of maize acreage has resulted in an increased risk of water erosion due to the low vegetation soil cover after the drilling of the maize, as well as the linear structure and large widths of the maize rows (Vogel, Deumlich, & Kaupenjohann, 2015). The increase in maize production for bioenergy production has also led to criticisms, most importantly related to increasing food prices as agricultural land is used for bioenergy rather than food production. In addition to these concerns about the negative impacts on global food security, there are also warnings about increased soil erosion risk (Vogel, Deumlich, & Kaupenjohann, 2015). Reviewed papers state that soil erosion can be strongly reduced by soil conserving tillage and there is considerable evidence that conservation tillage can provide a wide range of benefits to the environment. Moreover, satisfactory yields can be achieved when soil conservation tillage methods are applied (Prasuhn, 2011). Vogel, Deumlich, & Kaupenjohann (2015) stated that no-tillage or conservation tillage is the most recommendable erosion control measure – but further research needs to be done on the potential of no-tillage and conservation tillage. However, Townsend, Ramsden, & Wilson (2015) say that the lowest intensity tillage system, zero tillage, demonstrates financial benefits over a conventional tillage system even when the zero tillage system incurs yield penalties of 0–14.2% (across all crops). Several alternative cropping systems have been tested to determine their impacts on soil water dynamics in the Midwestern United States where one-third of global maize (*Zea mays* L.) is grown (Baschea, Kaspar, & Jaynesb, 2016).

Farmers are obliged to maintain their land in good agricultural and environmental condition (GAEC). This concept includes the protection of soil against erosion, the maintenance of soil organic matter and soil structure, and the safe-guarding of landscape features. It is the member states - not the European Commission - which decide the exact specification of these parameters. From the GAEC rules seem to be ineffective and the testing of recommended technologies is essential for sustainable farming methods. Soil conservation technologies eliminating the negative impacts of wide-row crop cultivation should meet the dual requirements of economical crop production and erosion control, to sustain long-term usage of the soil. The highest yield tillage technologies might not be the most economically profitable, but the most efficient soil conserving technology may not reach high yields. When choosing the appropriate tillage technology, it is important to consider all the factors and attest the impacts of the particular tillage on sediment yields in comparison with the conventional tillage. This will determine the actual erosion control effect (VÚMOP, Annual Report - Complex erosion control technologies, 2015).

The present study is part of a more complex research programme at the Research Institute of Soil and Water Conservation in Prague, Czech Republic, which looks at developing soil conservation technologies for *Zea mays L.* maize. The general goal is to analyse quantitative data from experimental rainfall simulations and compare tested tillage practices for their effectiveness under given conditions.

The specific objectives are to test different tillage practices under maize and determine the most effective practice in terms of surface runoff (SR), infiltration (IF) and total soil loss (SL). Eleven various scenarios of tillage practices (TP) were investigated and data analysed: conventional tillage with row widths of 37.5cm (CT 37,5), conventional tillage with row widths of 75cm (CT 75), strip tillage with row widths of 37.5cm (ST 37,5), strip tillage with row widths of 75cm (ST 75), no tillage (NT), no tillage with row widths of 37.5cm (NT 37,5), no tillage with row widths of 75cm (NT 75), vertical tillage (VT), disc harrow (DH), intercrop (IT), under sowing with barely with row widths of 37.5 (USB 37,5), under sowing with barely with row widths of 75cm (USB 75). The study can be used to recommend appropriate tillage technology to farmers to mitigate soil erosion.

2 Material and Methods

2.1 Study site

The study sites investigated are agricultural fields located in central Bohemia, in radius of 9 km from the village of Krasna Hora in Czech Republic. These fields are under the management of the farmers' cooperative, ZD Krasna Hora a.s. The experiment was carried at 5 locations in total. Three of them are near village Krasna Hora and are labelled as Krasna Hora A, B and C. The other location is near village Petrovice and the third by village Skoupy see *Figure 1*.

Figure 1: Localities of the experimental parcels near Krasna Hora village, Czech Republic.

The surrounding terrain is characterised by hilly landscape with dominating peaks, Homole 517 m and Zajicuv Vrch 521 m. The land use of the region is mostly agricultural land (55%), forests (30%) and urban areas (25%). The region is characterised by a continental moderate climate with mild winters and moderate humidity with mean annual temperatures of 7 – 8 C°. Mean annual precipitation is 500 – 600 mm. The nearest meteorological station is located in Svaty Jan, 9.3 km from the experimental parcels. The most intense precipitations during 2013-2015 were recorded in the months of May, June, August and November. The highest total rainfall was 26.1 mm/day. There was no significant erosion recorded on the experimental parcels caused by natural torrential rains. Precipitation values for the year 2015 are displayed in *Table 1*.

Table 1: Monthly total rainfall in the year 2015 - meteorological station Svaty Jan - location Petrovice, Czech Republic.

Monthly precipitation (mm)												Precipitation in veget. period[1]
I.	II.	III.	IV.	V.	VI.	VII.	VIII	IX.	X.	XI.	XII.	IV.-IX.
23.4	1.8	31.8	27	55.7	82.9	9.4	65.1	28.1	52.8	50.7	-	268.2

2.1.1 Experimental plots

The experimental plots are located near the villages of Krasna Hora, Petrovice and Skoupy. The experimental plots have favourable conditions for rain simulation experiments, with moderate slopes (mean slope gradient 15%) with no major terrain divergences. The study field have been used as agricultural land for a long time, with low erodible soils (GAEC classification)

For each simulation scenario was established the field site of 12x20m with maize crop and tillage practices – each of experimental plots was then divided into three parcels – one for each simulation during the vegetation period for obtaining the results from various stages of growth and crop coverage (VUMOP, 2014).

2.1.2 Soil properties

The entire soil profile was examined for soil morphology (layering of soil horizons, character of soil texture and orientation, the location of soil skeleton, organic and moisture content, etc.). Detailed soil survey of experimental plots classified as the main soil type haplic Cambisol (IUSS, 2015) with characteristics such as good infiltration or low water retention. Formation of this soil type is accompanied with the inward weathering and significant dissolution of soil aggregates is typical.

Soil profile investigation showed that the hilly terrain of the region causes truncation of the soil horizons – the soil texture is heavier although the top layer has typical soil texture properties for cambisols. The soil properties indicated

[1] Vegetation period is period from May to September when at the location of experiment were optimal growth condition for maize cultivation

moderate porosity with a relatively stable soil structure, moderate content of organic matter (mean value 2.4%), and the low incidence of soil crusting. These positive physical properties are due to the organic fertilisation in the area.

Surface runoff is predominantly caused by a saturated pore system in the soil, and is highly influenced by the topography and soil moisture content. From the soil sampling and soil analyses, the physical-chemical properties of soil at the various locations were found to be very similar and comparable for all the tested scenarios.

2.2 Experimental approach

The evaluation of different tillage treatment and soil management of *Zea Mays* L. is based on three main parts, which are simulation scenarios, rainfall simulations and soil and water samplings.

The principle of the experiment itself rely in applying water (simulated rainfall) on the defined surface (minimum of 20 m^2) and after that estimation of the beginning of the surface runoff (soil profile saturation) and estimation of the content of the sediment in water under experimental plot.

Due to the high demands on weather conditions and cost of simulation performance there was always only one event of rainfall simulation under specific treatment and stage of growth. There were no replicates for the identical scenarios which is a negative aspect of the experiment.

2.2.1 Simulation scenarios (land management treatments)

The data from the simulations were collected during three years 2013-2015 in total from six experimental study area. Data analysis are presented in this study are results of the experiment under real life field management conditions. The tested technologies – tillage practises (TP) are described in the *Table 2*.

2.2.1.1 Conventional Tillage

Conventional tillage of both widths of rows 37.5 and 75cm – at the beginning of November the crushed grass sod was cultivated into the soil by the farm machinery, followed by the deep tillage in depth of 25-30cm without compaction and over the winter stayed in rough furrow. In spring (mid to the end of May) the soil was once compacted (in case of wide rows), and twice compacted in case of narrow rows.

2.2.1.2 Strip Tillage (ST)

Strip tillage (ST) practice use the non-tillage seeding machine and the fore crop organic residues of are intercorporated into the soil in September, followed by vertical hoeing (depth 20cm). The soil is compacted once before the seeding. As a fore crop the rye is seeded – non-tillage seeding machine in September. At the end of November strip tillage is done to depth of 25cm. In spring the desificcation of the crop cover by total herbicide and in May the strip tillage is done (depth of 20cm) followed by the maize seeding in the mid May (with width of rows 37.5cm or 75cm).

2.2.1.3 Intercrop (IC)

Intercrop (IC) practice – for this experiment Lacy phacelia was investigated as an intercrop and its influence on the erosion rates under maize. At this plot the main crop was wheat (fertilized by the digestate – incorporated into the soil 20m^3). The wheat was harvested in August and followed by sowing of intercrop Lacy Phacelia (10kg/ha) – over the winter the intercrop freezes and leaves organic residues which are incorporated into the soil, vertical tillage is done afterwards (depth of 20cm). Soil was once compacted before sowing the maize by no tillage machine in the row width of 37.5cm.

2.2.1.4 Direct Sowing – No Tillage (NT)

Direct sowing (no tillage) – grass sod crashed and incorporated into the soil (middle of September) followed by vertical hoeing in depth of 20cm. The soil preparation includes compaction by compacting machine once before the sowing. The rye is sowed (end of September) by the non-tillage sowing machine. In spring the crop is desiccated by total herbicide and followed by direct sowing of maize (non-tillage sowing machine) to the rows of width of 37.5cm or 75cm.

2.2.1.5 Under sowing with barley (USB)

Under sowing with barley (USB) practice – winter barley is used as under sowing crop to reduce the weed (natural herbicide) and increase the organic matter in soil. The harvest residues of winter barley were incorporated into the soil, followed by shallow tillage – 20-22cm deep and sowing of winter barley (September/October). Winter barley harvested in May, followed with ploughing to prepare the soil surface for maize seeding by no tillage sowing machine.

2.2.1.6 Disc Harrow (DH)

Disc harrow (DH) practice – plot coved with grass (harvested for hay at the end for October); stubble was done in November and organic residues were incorporated into the soil by disking and immediately followed with winter rye. Total herbicide was applied after winter rye harvest in May and soil cultivated by disc harrow machine followed with maize sowing.

2.2.1.7 Vertical Tillage (VT)

Vertical tillage (VT) – the basic concept is to work the soil vertically with the vertical tillage machine. VT tillage practice is used to break the horizontal barriers in soil for better growth of root system and consequently increase the yields. In November, the grass sod was incorporated in soil by discing and followed by vertical hoeing by in depth of 25 cm. Before the maize sowing (no tillage machine) in May the soil was compacted once.

Table 2: Description of the tested TP.

Scenario	Rill width (cm)	Description	Yield
CT 37.5	37.5 cm	• In autumn grass incorporated in soil by disking (Lemken-Rubin) • followed with deep tillage 25 – 30 cm in October • no surface smoothing • compaction in spring – 2 times in May • Maize sowing in mid-May	23.3 t/ha fresh biomass – 28% of dry matter
CT 75	75	• In autumn grass incorporated in soil by disking (Lemken-Rubin) • followed with deep tillage 25 – 30 cm in November	

		• no surface smoothing • soil compacted 2x in spring • maize sowing in wide rows from mid to end of May	
ST 37.5 ST 75	37.5 75	• In autumn on the grass cover is applied total herbicide • Strip tillage until the end of October in depth of 25 cm • In spring one more strip tillage done in depth of 20 cm • No tillage sowing machine in mid-May • Selective herbicide applied	26.8 t/ha fresh biomass
IC		• Digestate incorporated in soil (20m3) - after the main crop harvest (wheat) – technology for incorporating: Horsch-terrang FX) • Intercrop sowing Lacy phacelia – 10kg/ha • Lacy phacelia freezes over the winter • Weed desiccation	
DS 37.5 (no tillage) DS 75 (no tillage)	37.5 75	• Sowing directly to frozen intercrop • Maize seeded mid-May – no tillage sowing machine Kinze 3500 • N fertilizer (DAM 390) applied straight after the seeding – 200 l/ha	26,1 t/ha biomass - 28 % dry matter
DH	62.5	• Plot with grass cover cut for hay harvest • Total herbicide applied and residuals immediately incorporated into soil by disking • Mineral fertiliser applied	18.4 t/ha fresh biomass
USB 37.5 USB 75	37.5 75	• In Autumn – shallow tillage and post-harvest residue of fore crop incorporated into the soil – hoeing machine Hosch – Joker • Soil surface preparation by ploughing Vario Köckerling – followed with winter barley – harvested in May 2015 • Maize seeding – no tillage sowing machine Kinze 3500 in rows of widths either 37.5 or 75cm	
VT	75	• In autumn grass incorporated in soil by discing • Followed with vertical hoeing by Terraland in depth of 25 cm • In spring soil compaction 1 time • No tillage sowing of maize by Kinze 3500	18.9 t/ha fresh biomass

2.2.2 Soil sampling and laboratory analysis

Samples of sediment are taken during the rainfall simulation as well in the pycnometer which is cleaned and wiped with a dry towel before weighing. First sediment sampling is done exactly 1 minute after the beginning of the surface runoff – followed by sampling every 2 minutes of surface runoff duration. Samples of the sediment are immediately weighed on the scale with 0.1g accuracy.

Data from soil and water samples are added and fulfilled in the SDZ software (developed in RISWC). Samples of the soil and sediment are also taken to the laboratory for further analyses (content of insoluble particulates and soil organic content).

2.2.3 Rainfall simulations

Rainfall simulations set up is using two different rain intensities of precipitation to simulate saturated and unsaturated soil conditions – 30 minutes' rain (to saturate the soil) with the precipitation intensity of 1.28 mm/min and volume of precipitation 38.4 mm, the pressure of the precipitation intensity 50 bars, followed with 15 minutes' rain with the same precipitation intensity of 1.28 mm/min and volume of precipitation 19.2 mm and pressure of 50 bars, in between the storms is 15 minutes break.

2.2.3.1 Choosing the dates for simulations

Simulations are applied at the same locations many times of the year however, according to the actual weather conditions not all of the planned experiments were carried see *Table 3*. The dates for the experiment were chosen according to two methodologies (a) the appropriate cover crop – stage of the crop growth and surface coverage, (b) particular phases of agro technology operations - where vegetation period is divided into 5 phases (defined below). Both methodologies (a) WISCHMEIER, W. H. & SMITH, D. D. (1978) and (b) Janeček et al. (2012) were taken into account for the purpose of this experiment to designate appropriate dates of simulations:

2.2.3.1.1 WISCHMEIER, W. H. & SMITH, D. D. (1978) methodology

Period F (rough fallow) – Inversion ploughing to secondary tillage.

Period SB (seedbed) – Secondary tillage for seedbed preparation until the crop is developed 10% canopy cover.

Period 1 (establishment) – End of SB until crop has developed a 50% canopy cover.

Period 2 (development) – End of period 1 until canopy cover reaches 75%.

Period 3 (maturing crop) – End of period 2 until crop harvest.

Period 4 (residue or stubble) – Harvest to ploughing or new seeding (Wischmeier & Smith, 1978).

2.2.3.1.2 Janeček et. al. methodology

Period F (rough fallow) – Turn ploughing to seeding.

Period 1 (seeding) – Seedbed preparation to 1 months after planting.

Period 2 (establishment) – From 1 to 2 months after spring of summer seeding. For fall-seeded grain, period 2 includes the winter months, ending about May 1 in the Northern States, and April 1 in the Southern States.

Period 3 (growing and maturing crop) – End of period 2 to crop harvest.

Period 4 (residue or stubble) – Crop harvest to ploughing or new seeding (Janeček et. al., 2012).

Table 3: Dates of simulation during years 2013-2015.

Year	Location	Dates
2013	**Petrovice**	2.7.2013, 22.8.2013, 9.10.2013
2014	**Krasna Hora**	22.5.2014, 9.6.2014, 27.6.2014, 14.7.2014, 8.8.2014, 14.8.2014
2015	**Petrovice**	2.6.2015, 4.8.2015
	Skoupy	26.5.2015, 2.6.2015, 30.6.2015, 25.8.2015, 21.10.2015

2.2.3.2 Description of rainfall simulator

Rainfall simulator (RS) is designed to perform experiments in terrain and can measure actual soil losses caused by the water erosion during the simulation of precipitation at various rain intensities. The rainfall simulator can also generate other soil hydrological parameters such as infiltration rates and the behaviour of soil at different saturation conditions. The rainfall simulator structure consists technical parts (e.g. electrical core and pumping system), water regulation elements, water storage and nozzles. The basic components of a sprinkler rainfall simulator are the nozzle, a structure in which the nozzle is housed, and the connections with the water supply and the pumping system. To avoid interference by wind to rainfall distribution during the experiment, the rainfall simulator is equipped with a wind shield. The principles of measurements are the equal distribution of water on the defined soil surface, collecting the time data of beginning of the surface runoff, sampling of the sediment yield and determination of the total soil loss. The rainfall simulator is controlled by the software “SDZ” – developed in the RISWC.

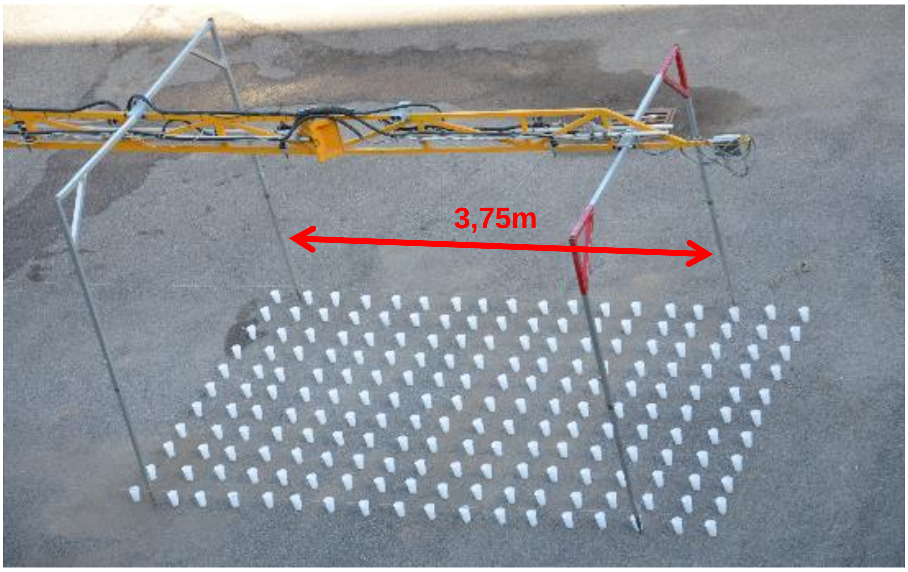
2.2.3.2.1 Calibration

The simulator was calibrated before every session – the objective of the calibration is to set up the right pressure, orientation and height of nozzles, these parameters influence the drop dispersion, their kinetic energy and final effect on the soil surface. The Christiansen coefficient is used to assess the uniformity of applied rainfall by evaluating the deviation from each measurement (in percentage) from the total amount of measurements from the arithmetic mean value of all measurements. If these deviations are small (the distribution of the rainfall is equal) the coefficient is close to 1 (100%). The uniformity coefficient is given by (Christiansen, 1942):

$$C_u = \left(1 - \frac{\sum_{i-1}^{N} |x_i - \bar{x}|}{N\bar{x}}\right) \cdot 100$$

Where x_i is height at the location i, $\bar{x}$ is mean precipitation height, N is number of points where the precipitation was measured. Uniform rainfall application has coefficient of 100%.

The calibration coefficient is measured by the so called “cup” method (*Figure 2*) where plastic cups are placed in the regular square net on the test surface and trial rainfall is applied – each cup is labelled and weighed before and after testing. The weight of each cup can be converted into the volume of the water captured – then with the knowledge of the cup area the height of the precipitation at each point (mm) can be calculated. From the total rainfall (mm) the cover coefficient (*Table 4*) and rainfall intensity (*Figure 2*) can be ascertained. The highest uniformity coefficient identifies the best possible applicable height and pressure of the nozzles.



176	164	153	143	132	121	110	99	88	77	66	55	44	33	22	11	187	198	Y (m)
175	164	153	142	131	120	109	98	87	76	65	54	43	32	21	10	186	197	1.08
174	163	152	141	130	119	108	97	86	75	64	53	42	31	20	9	185	196	0.75
173	162	151	140	129	118	107	96	85	74	63	52	41	30	19	8	184	195	0.5
172	161	150	139	128	117	106	95	84	73	62	51	40	29	18	7	183	194	0.25
171	160	149	138	127	116	105	94	83	72	61	50	39	28	17	6	182	193	0
170	159	148	137	126	115	104	93	82	71	60	49	38	27	16	5	181	192	-0.25
169	158	147	136	125	114	103	92	81	70	59	48	37	26	15	4	180	191	-0.5
168	157	146	135	124	113	102	91	80	69	58	47	36	25	14	3	179	190	-0.75
167	156	145	134	123	112	101	90	79	68	57	46	35	24	13	2	178	189	-1
166	155	144	133	122	111	100	89	78	67	56	45	34	23	12	1	177	188	-1.25
3.75	3.5	3.25	3	2.75	2.5	2.25	2	1.75	1.5	1.25	1	0.75	0.5	0.25	0	-0.25	-0.5	
X (m)																		

Figure 2: Rainfall simulator calibration - cup method.

2.2.3.2.2 Nozzles and precipitation regimes

The area where the rainfall was applied is defined by the borders of the simulator and where the sprayed water reaches the ground, water is applied with nozzles 30WSQ spraying the water under the pressure 0.5 bar, placed 2.2 m above the ground surface with precipitation intensity of 1.02 mm/min - 1.28 mm/min delivering 38.4 mm of rainfall. The nozzles used were tested for purpose of appropriate height, pressure and orientation. All surface runoff from the plot is captured in the catchment area which is protected from wind. Catchment area is rain fed area by simulator 20m^2 (*Figure 6*). The software is controlling the pressure demand corresponding with the recommended precipitation intensity (Czech Hydrometeorogical Institute) based on the mean rainfall intensity of torrential rain in Czech Republic – **60 mm/hour**.

2.3 Data analyses

Data from individual simulations (from years 2013-2015) were recorded and compiled in Excel spread sheets, where each tested LM scenario had description of: height of crop, height of surface runoff (mm), infiltration (mm), total soil loss (t/ha), beginning of surface runoff, moisture content (%), location and date of simulation see the *Figure 7* in appendix.

As a default tillage practice was CT with width of row 37.5 cm (CT) and the mean value of all the CT results was indicated as **100%** (this mean value was calculated from 25 measurements from years 2014-2015) and then all the other treatments mean values were computed and presented as a percentage of the conventional tillage by the simple proportion calculation.

$$TP_x = \frac{\text{control treatment(mean value)}}{\text{conventional tillage(mean value)}} * 100$$

Where TP_x is the particular tillage practice,

As the data from tested practices were calculated we can compare particular TP and estimate which of the tested TP is the most effective in term of surface runoff (SR), infiltration (IF) and total soil loss (SL) in **comparison to the conventional tillage**.

To obtain the mean value of erosion rates of specific scenarios – the data in Excel had to be firstly filtered (to get the data from all the simulations in years 2013-2015 under the **same treatment**) and secondly out of all the simulations with similar scenarios (where only the height of crop varied) computed the mean value of them. When particular TP was filtered in the Excel spread sheet (eg. “no tillage 37.5”) and filtered by the stage of growth (either early: 5-50cm or late: 260-290cm). The values of SR, IF and SL from all simulations were computed and mean value generated from minimum of 2 values and maximum of 13 values – depended on how many experiments were carried and availability of data.

The stage of growth significantly influences the erosion rates, that is the reason to divide the data outcomes into 2 stages of growth – early and late. The reason is the different coverage of the bare soil and plant water demand. For example, when the maize plant is at the early stage (5-50cm) the area of bare soil is quite big and the bigger amount of soil particulates are washed away. Although the stage of growth is at its peak and the maize plant reaches 260-290cm the area of bare soil is much smaller, but the top soil layer can be compacted and water run off high. There are other factors as well, such as the compaction of the top soil layer, content of organic matter, size and velocity of the raindrops, time of infiltration etc.

3 Results

The results are presented in percentage of effectiveness to the conventional tillage at the early and late stage of growth of maize – early stage considered as 10 - 50 cm and late stage as 260 – 290 cm of crop cover height. *Table 5* and *Table 6* displays the mean values of the SR (mm), IF (mm) and SL (t/ha) and percentage of the rates in comparison to the CT. *Table 5* summarise the results from the early stage - the highest erosion reduction observed under the NT 37.5 where SL reduced by 93.6%, in contrary the least effective TP was ST 37.5 where SL increased by 28.3%. Promising TP in term of SL are IC with 60.4% soil erosion reduction and DS 37.5 (no tillage) saved 80.5%. The data presented in *Table 6* are incomplete due to unsuitable weather conditions. The results data always represents at least two events under similar conditions – identical TP and stage of growth, the height of crop and date of simulation vary (e.g. the soil saturation may vary for recent natural rain event or in contrary dry weather).

3.1.1 Surface runoff results

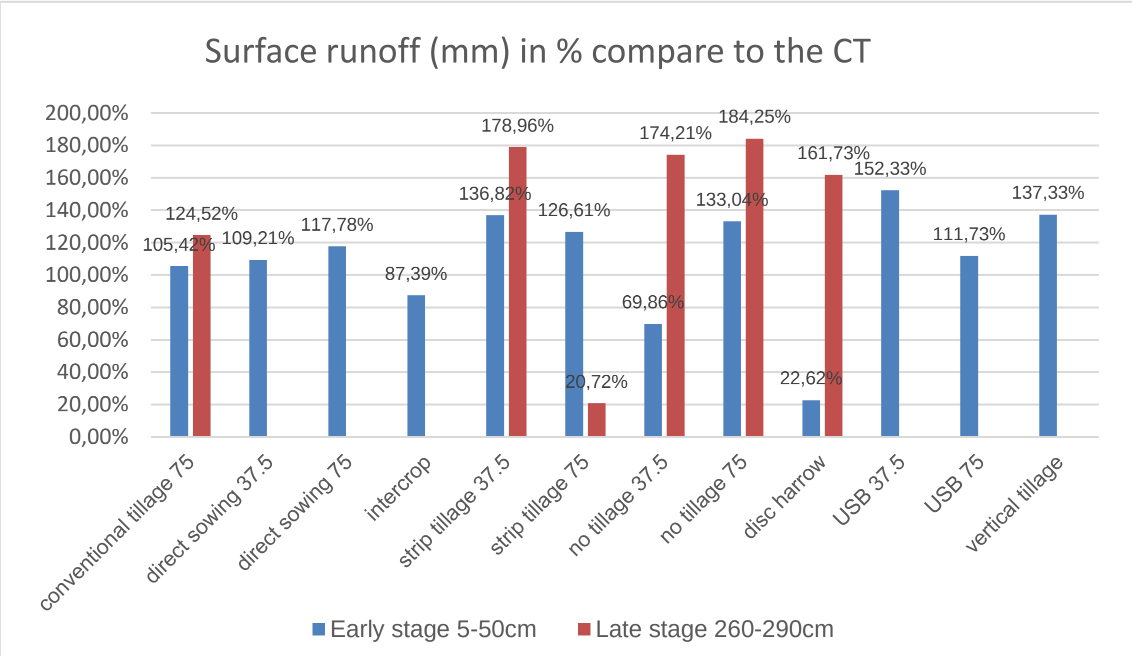
Surface runoff values present total amount of sediment yield and water caused by water erosion, it is the suspension of water and detached soil particles. The experiment has shown very positive results in term of SR under the NT 37.5 where SR coefficient was lower by 30%, however this treatment was not very effective at the late stage of growth where the SR is higher by 74.2% than CT – comparison in *Graph 1*. The highest SR mitigation was observed at the DH practice where SR is lower by 77.4% in comparison to CT however, at the late stage of growth the SR increased by 61.7%. 12.6% of SR can be saved by intercropping the maize with Lacy phacelia. From the simulations the ST 37.5 and ST 75 were not very effective treatments in term of SR. ST 37.5 has increase the SR by 36.8% and ST 75 by 26.6%. ST 37.5 resulted high sediment yield at the late stage of growth where SR increased by nearly 79%. The highest SR contrary to expectations observed at the USB 37.5 (no tillage) and USB 75 (no tillage) – but need to take into account that the simulation was run when height of crop was only 4cm – SR resulted higher compare to the CT by 52.3% (USB 37.5) and 11.7% (USB 75). Resulted data summarised in *Table 4.*

Table 4: SR results for early stage of growth (5-50cm) – where CT 37.5 is 100% and other TP are computed in comparison to CT 37.5 expressed in percentage where higher total sediment yield is always more than 100%.

TP	*SR (mm)*	*SR reduction/increment (%)*
Early stage		
conventional tillage 37.5	7.93	100.00%
conventional tillage 75	8.36	105.42%
direct sowing 37.5	8.66	109.21%
direct sowing 75	9.34	117.78%
intercrop	6.93	87.39%
strip tillage 37.5	10.85	136.82%
strip tillage 75	10.04	126.61%
no tillage 37.5	5.54	69.86%
no tillage 75	10.55	133.04%
disc harrow	4.40	22.62%
USB 37.5	12.08	152.33%
USB 75	8.86	111.73%
vertical tillage	10.89	137.33%
Late stage		
conventional tillage 37.5	9.46	100%
conventional tillage 75	11.78	124.52%

strip tillage 37.5	12.15	128.44%
strip tillage 75	16.93	178.96%
no tillage 37.5	16.48	174.21%
no tillage 75	17.43	184.25%
disc harrow	15.3	161.73%
vertical tillage	9.46	100%

Graph 1: Results of SR in percentage in comparison of TP considering that CT is 100 % - Early and late stage of growth of maize (due to the unsuitable weather conditions for rainfall simulations some data are missing).



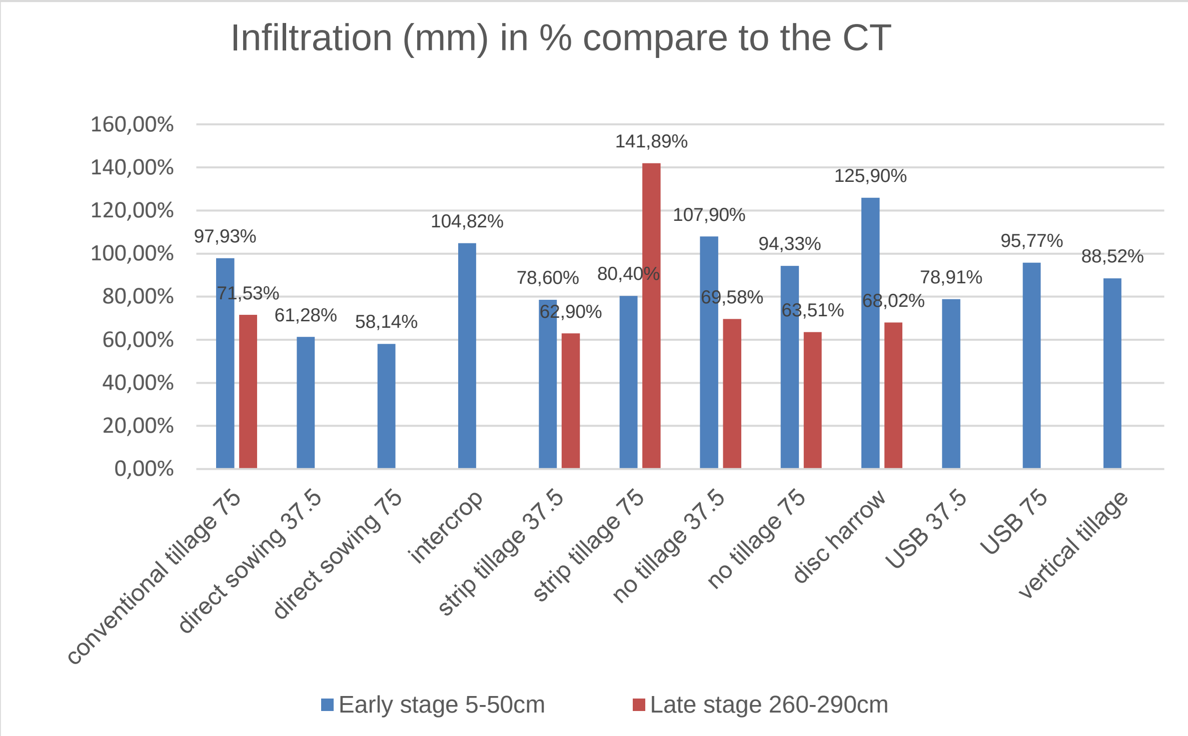
3.1.2 Infiltration results

Infiltration (mm) represents the saturation capacity of the soil and is the difference of water consumption and total surface runoff, resulted values are presented in *Table 7*. High infiltration rates observed under the IC practice where IF increased by 4.8% (*Graph 2*). The best TP in term of IF is DH where IF coefficient is higher by 25.9% at the early stage, however the late stage of growth under DH has mitigated IF rate by 32% and is one of the least effective TP. If we compare NT 37.5 and NT 75 – better results have appeared under the NT 37.5 where IF was positive by 7.9%, neither NT land management was effective in term of IF at the late stage of growth where both TP has shown negative rates by 30.4% (NT 37.5) and 36.5% (NT 75). The effect of DS was negative in both drill row widths where IF lowered by 38.7% (DS 37.5) and 41.9% (DS 75). Lowest infiltration coefficient observed under the ST 37.5 technology at both stages of growth (21.4-37.1%), but noticeable results shown at the late stage of growth under ST 75 where IF is higher by nearly 42% although at the early stage the results are unsatisfactory and IF is lower by 19.6% than CT. The comparison of TP presented in *Graph 2*.

Table 5: IF results for early (5-50cm) and late (260 – 290cm) stage of growth– Infiltration rates under CT 37.5 is expressed as 100%, positive IF rates in comparison with CT 37.5 are higher than 100%, negative than lower than 100%.

TP	*IF (mm)*	*IF (mm)*
Early stage		
conventional tillage 37.5	19.45	100.00%
conventional tillage 75	19.05	97.93%
direct sowing 37.5	11.92	61.28%
direct sowing 75	11.31	58.14%
intercrop	20.39	104.82%
strip tillage 37.5	15.29	78.60%
strip tillage 75	15.64	80.40%
no tillage 37.5	20.99	107.90%
no tillage 75	18.35	94.33%
disc harrow	24.49	125.90%
USB 37.5	15.35	78.91%
USB 75	18.63	95.77%
vertical tillage	17.22	88.52%
Late stage		
conventional tillage 37.5	17.95	100%
conventional tillage 75	12.84	71.53%
strip tillage 37.5	7.15	39.83%
strip tillage 75	11.29	62.90%
no tillage 37.5	12.49	69.58%
no tillage 75	11.4	63.51%
disc harrow	12.21	68.02%
vertical tillage	17.95	100%

Graph 2: Results of IF in percentage - comparison of TP considering that CT is 100 %



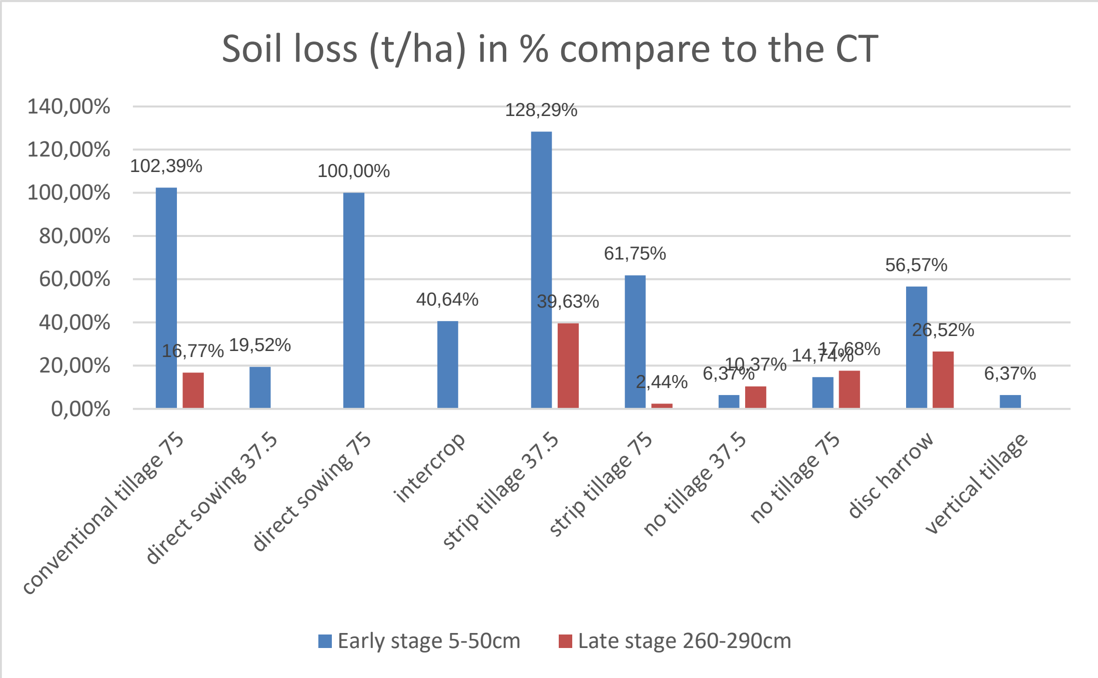
3.1.3 Soil loss results

Only two of tested TP had higher total SL than CT – except USB where the extreme resulted values are caused by low crop coverage where height of maize was 4cm (*Table 6*). At the early stage of growth ST 37.5 shown higher SL by 28.3%, however this TP was effective when height of crop is 260-290cm when can mitigate SL by 60.4%. CT 75 increase SL by 2.4% compare to the CT. We observed best SL results under the NT 37.5 – mitigation by 93.6% and VT, where SL lowered by 93.6%. Positive results also shown NT 75 where SL is reduced by 85.3%. Promising TP in term of SL is DS 37.5% - SL reduced by 80.5%.

Table 6: SL results for early (5-50cm) and late (260 – 290cm) stage of growth– the table represents resulted data from experiment rainfall simulations where CT 37.5 is always expressed as 100% of soil loss – other tested TP are computed as percentage of SL reduction or increment.

TP	*SL (t/ha)*	*SL reduction/increment (t/ha)*
Early stage		
conventional tillage 37.5	2.51	100.00%
conventional tillage 75	2.57	102.39%
direct sowing 37.5	0.49	19.52%
direct sowing 75	2.51	100.00%
intercrop	1.02	40.64%
strip tillage 37.5	3.22	128.29%
strip tillage 75	1.55	61.75%
no tillage 37.5	0.16	6.37%
no tillage 75	0.37	14.74%
disc harrow	1.42	56.57%
USB 37.5	13.9	553.78%
USB 75	9.29	370.12%
vertical tillage	0.16	6.37%
Late stage		
conventional tillage 37.5	3.28	100%
conventional tillage 75	0.55	16.77%
strip tillage 37.5	0.77	23.48%
strip tillage 75	1.3	39.63%
no tillage 37.5	0.34	10.37%
no tillage 75	0.58	17.68%
disc harrow	0.87	26.52%
vertical tillage	3.28	100%

Graph 3: Results of SL in percentage - comparison of TP considering that CT is 100 %



4 Discussion

As already mentioned maize is one of the most important cereal crops, which plays an important role in expanding overall grain production capacity, during the past 30 years, maize yield was significantly improved by optimizing management practices (Piao, Qi, & Zhao, 2016). CT with one crop per year is the common practice, maize is fairly sensitive to water stress and highly demanding for nutrients, management of available water resources and soil fertility is crucial to ensure a sustainable productivity (Scopel, Findeling, Chavez-Guerra, & Corbeels, 2011). Results show that conservation farming techniques have the highest erosion reduction potentials and appear promising in terms of reducing both surface runoff and total soil loss. We have especially focused on the early stage of growth where the potential erosion risk is highest due to the low crop coverage.

4.1 Surface runoff

NT 37.5 resulted positive SR rates and mitigated total sediment yield by 30% when height of cover crop is 5-50cm, but we observed that NT 75 had higher SR that CT by 33% - the reason can be wider rows and bigger surface of bare soil before the crop is well established. However, both NT 37.5 and NT 75 are not effective at the late stage of growth where SR is higher by 74.2% (NT 37.5) and 84.2% (NT 75) than CT, which can be caused by compaction of soil as there is minimal disturbance. Highest SR mitigation was observed at the DH practice where SR is lower by 77.4% in comparison to CT, residuals of grass cover were incorporated into soil, which can improve infiltration and SR mitigation. DH considered as ineffective at the late stage of growth where SR increased by 61.7% - soil disturbance leads to breakdown and reduction in soil aggregate size consequently, the total soil porosity and pore sizes are reduced and soil retention lower, so as well nutrient availability and thus impact negatively on the productive capacity of the soil (Phiria, Amézquitab, Raob, & Singha, 2001). Strip tillage is a conservative technique widespread overseas with recognized environmental, agronomical and economic benefits (Trevini, Benincasa, & Guiducci, 2013), but carried simulations has shown high increment of SR under ST of both drill row widths where generated 26-36% more than under CT, as result of frequent disturbance of soil and compacted soil from machinery. Interesting results from the simulations occurs under ST 75 where SR at the early stage of growth showing high sediment yield (26.6% more than CT), but very low soil loss – SL reduction by 38.3% assuming that the detachment of soil particles is lower and generated water don't carry the sediment, in contrary ST 37.5 resulted high SR and high SL (*Table 5*) which can cause the higher disturbance of soil when the drill rows are narrower. This experiment has resulted highest SR rates under the USB practises which is surprising because the post-harvest residuals incorporated into soil and maize seeded by no-till machinery and shallow ploughing, but simulation were carried when cover crop height was only 4cm – that explains very unsatisfactory results.

4.2 Infiltration

Reduced tillage combine with cover crop can increase infiltration rates and lower sediment yield which can have positive impact on potential soil erosion in comparison to conventionally tilled systems (Alliaume et al., 2014), we can support this statement by real data results from simulations where IC positively influences the infiltration by 4.8% as expected – the reasons can be: plant water uptake, higher density of root system or higher content of organic matter, disadvantage of intercropping the maize can be the additional seeding cost, plant nutrient and radiance competition. Initially, tillage may have a positive impact on infiltration but this effect is usually transitory and typically leads to a decline in infiltration rates on tilled surfaces as a result of reconsolidation and aggregate disintegration after repeated rainstorms (Schwartz, Baumhardt and Evett, 2010) besides biological activity is commonly greater and both microbial and soil-dwelling fauna populations are higher under no tillage practises relative to full tillage (Horne, Ross and Hughes, 1992). Despite the contrasting findings about the performance of NT (Mhazo, Chivenge and Chaplot, 2016) we observed positive results under NT 37.5 where infiltration increased by 7.9% - results are unexpected because although the drill of rows is narrower the disturbance of soil is minimal – but ST 37.5, where drill is also narrow and soil is tilled in autumn and spring the water retention is very low and infiltration rate increase by 21.4% compare to CT – ST 37.5 also resulted low infiltration rate at the late stage of growth where the coefficient is lower by 37.1%. Low infiltration rates occurred under the DS – which is surprising – considering that DS is minimum tillage treatment without seedbed preparation, the reason can be undisturbed top soil layer, lower content of OM or low porosity.

NT practises has shown low IF rates at the late stage of growth (*Table 6*) which can be initiated by compacted top layer of soil or crust occurred for minimal surface disturbance. Highest IF rates observed under the DH where drill row width is 62.5 cm and grass residuals were incorporated into the soil – which could have increased the organic matter content and consequently increase the IF rates, also the soil disturbance by discing can have positive impact on infiltration but exposure of moist soil to the atmosphere by tillage can accelerate evaporative losses during the initial few days after tillage (Schwartz, Baumhardt and Evett, 2010). Soil quality deterioration and fertility decline caused by agriculture due to intense tillage, high erodible crops, loss of organic matter, and frequent cultivation (Alliaume et al., 2014) including changes in soil properties and influence infiltration, redistribution of water within the profile, subsequent evaporation rates, and water availability to crops (Schwartz, Baumhardt and Evett, 2010).

4.3 Soil loss

Excessive tillage in conventional agricultural systems triggers soil movement that leads to higher soil losses and environmental degradation (Shahzad & Farooq, 2016). The topsoil under NT is usually cooler and moister, with a higher bulk density (BD) and, thus, presents greater soil strength than under CT (Quin, Stamp, & Richner, 2004) which can be one of the reasons of low SL coefficients under NT 37.5 which proved soil erosion reduction by 93.6% and NT 75 by 85.3%. Although Pitelkowa et. al. (2015) designated NT lower in yield for maize production compare to the CT: no-till yield (kg ha^{-1}) - 5323±8462, conv. tillage yield (kg ha^{-1}) 5672 +/9071 (weighted mean ± weighted standard deviation), furthermore in all cases of other tested crops except maize, the negative effects of no-till, where present, decreased with time – but rainfall simulations clearly prove that NT 37.5 under maize can save 2.35 t/ha of soil, and NT 75 2,14 t/ha. Besides equipment, fuel and initial costs related with seedbed preparation are higher, traffic in field is more frequent, which increase the risk of compaction and the spreading of weeds in the field, risk of soil erosion by wind and water as well as crusting are greater with inadequate surface residue and frequent tillage diminishes organic matter content (Wisconsin, 2014) and numerous studies have reported lower soil temperature during early spring under NT, due to residues left on the soil surface, with adverse effects on crop growth (R., Stamp, & Richner, 2014).

(Trevini, Benincasa, & Guiducci, 2013) concluded that strip tillage allowed a seedbed preparation not different from minimum tillage but moved less soil volumes, data from this experiment resulted 3.06 t/ha more soil loss under the ST 37.5 than NT 37.5 and 1.18 t/ha more under ST 75 than under NT 75. Intercropping maize with *Phacelia tanacetifolia* common name Lacy phacelia has shown positive impact on erosion rates, soil loss reduction was more than 59%. Due to intensification of agricultural production most soils are low in humus as its content does not exceed 2% incorporation of intercrop plant improve the soil humus balance, limit erosion processes, protect waters against agricultural pollution (Zaniewicz-Bajkowska, Franczuk, Rosa, & Kosterna, 2013). However, the disadvantage can be the nutrient competition and initial sowing cost of Lacy. Dhima, Vasilakoglou, Gatsis, Panou-Philotheoua, & Eleftherohorinosc in 2009 concluded that incorporating Lacy phacelia could be used as cover crop green manures to suppress susceptible weeds grown in crops like maize in order to minimise herbicide usage, which proves additional positive impact on maize cultivation. Numerous studies have reported lower soil temperature during early spring under NT, due to residues left on the soil surface, with adverse effects on crop growth (R., Stamp, & Richner, 2014).

5 Conclusions

The present study provides a quantitative assessment of the effectiveness of different tillage intensities in comparison to the conventional tillage - to be used to reduce erosion rates in maize cultivation assuming that erosion control measures should always be adjusted to local conditions and simulation studies can help to identify the most favourable combination of measures. Based on the real data from 123 rainfall simulations conducted during years 2013 – 2015 in Krasna Hora, Czech Republic where identified main soil type is haplic cambisols we conclude that best erosion reduction can be obtained through NT farming and conservation farming method as intercropping maize with lacy phacelia or reduced tillage direct sowing with no seedbed preparation. Additionally, we observed benefits to improve soil water retention under disc harrowing practice after incorporating grass residuals into soil before maize cultivation. Finally, interesting findings noted that conventional practice ST 75 has shown high surface runoff rates but low soil loss rates in comparison to ST 37.5 where the rill of rows is narrower, thus the soil disturbance enhances soil particles detachment and total soil loss increment. We suggest tillage reduction to prevent high surface runoff and green manure residuals incorporation into the soil to increase organic matter content and consequential improvement of infiltration rates which can mitigate total soil losses.

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APPENDICES

5.1.1.1.1.1.1 Methodology

5.1.1.1.1.1.1.1 Rainfall simulations

5.1.1.1.1.1.1.1.1 Technical and material equipment for the experiment

- Set for taking the soil samples (undisturbed) – Kopecky's Ring and device for measuring the soil moisture content
- Paper satchels for taking the disturbed soil samples
- Plastic boxes for taking soil samples for soil structure
- Containers for water samples – volume of 1l
- Tools – spade, mattock, hammer etc.
- Office supplies for work in terrain (forms, pens, etc.)
- Soil probes
- Camera
- Inclinometer
- Rainfall simulator (developed and built in Research Institute for Water and Soil Conservation) including all the necessary equipment and accessories

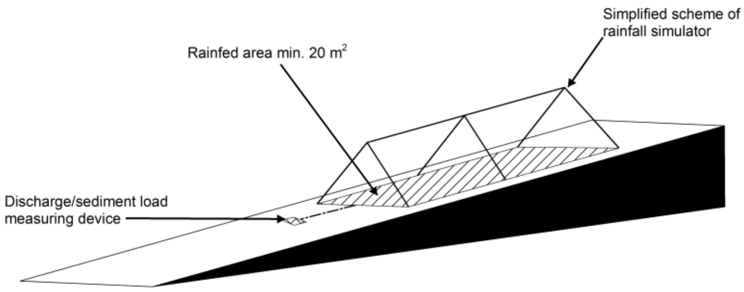
Apx Figure 1: Setting up the simulator on site (VUMOP, 2015).

Apx Figure 2: Rainfall simulator opened up on site (VUMOP, 2015).

Apx Figure 3: "Flip" device - RS is equipped by the flipping device which measure the SR by numbers of flips (VUMOP, 2015).

Apx Figure 4: Rainfall simulation on the plot with vertical tillage practice (VUMOP, 2015).

Apx Figure 5: Rainfall simulation at the no tillage experimental field (VUMOP, 2015).



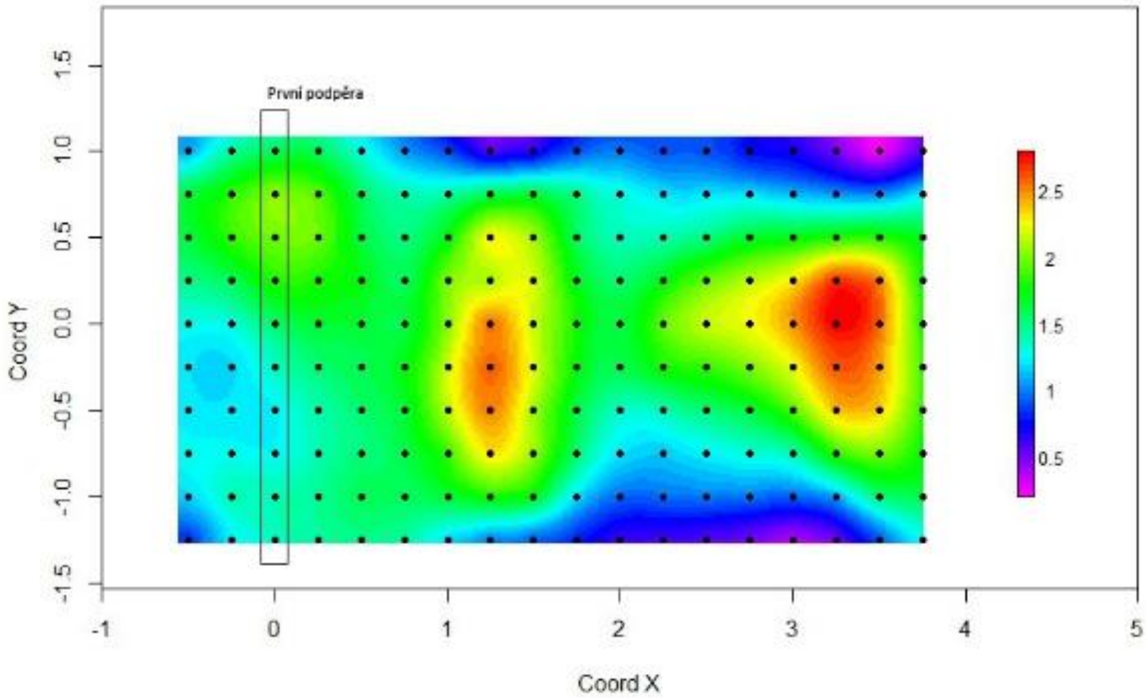
Apx Figure 3: RS scheme.

Apx Figure 6: Simulator - capturing the runoff of rainfed surface.

5.1.1.1.1.1.1.1.2 Calibration of RS

Height of nozzles	210 cm	220 cm	230 cm	210cm
Time of rainfall (min)	5	10	10	10
Pressure	0.6 bar	0.5 bar	0.7 bar	0.7 bar
Nozzles	30SWQ	30SWQ	30SWQ	30SWQ
Cu (cup number. 1 - 198)	0.593	0.683	0.710	0.674
Cu (cup number 1 - 66)	0.530	0.866	0.865	0.839
Cu (cup number 12 - 44)	0.817	0.863	0.889	0.870

Apx Table 1: Final coefficient results for various nozzles and pressure set ups



Apx Figure 7: Distribution of rainfall intensity (mm.min-1) for correct parameters of simulator set up – Intensity 2 (10 minutes, pressure 0.5bar, height 220cm).

5.1.1.1.1.1.1.1.3 Tillage practises

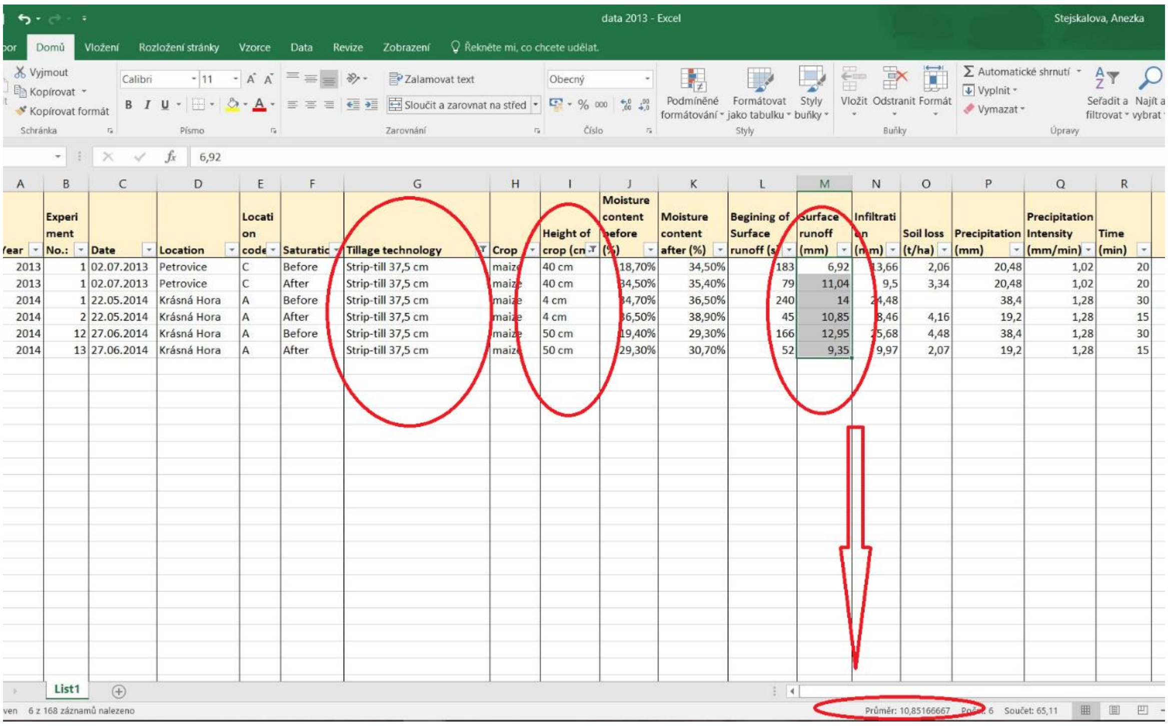
Apx Figure 8: Strip tillage with machine KUHN-STRIGER (VUMOP, 2015)

Apx Figure 9: Vertical tillage.

Apx Figure 10: Disc harrow tillage.

5.1.1.1.1.1.1.2 Data analysis

Gaining the mean values from the data set – I have selected the particular TP (Figure x) in this case ST 37.5 and filtered the stage of growth needed – afterwards I have obtained the data of SR, IF and SL – out of all values I have taken the MEAN value – which Excel calculated.



Apx Figure 11: Gaining the mean value of SR, IF and SL for different TP (Stejskalova, 2016).

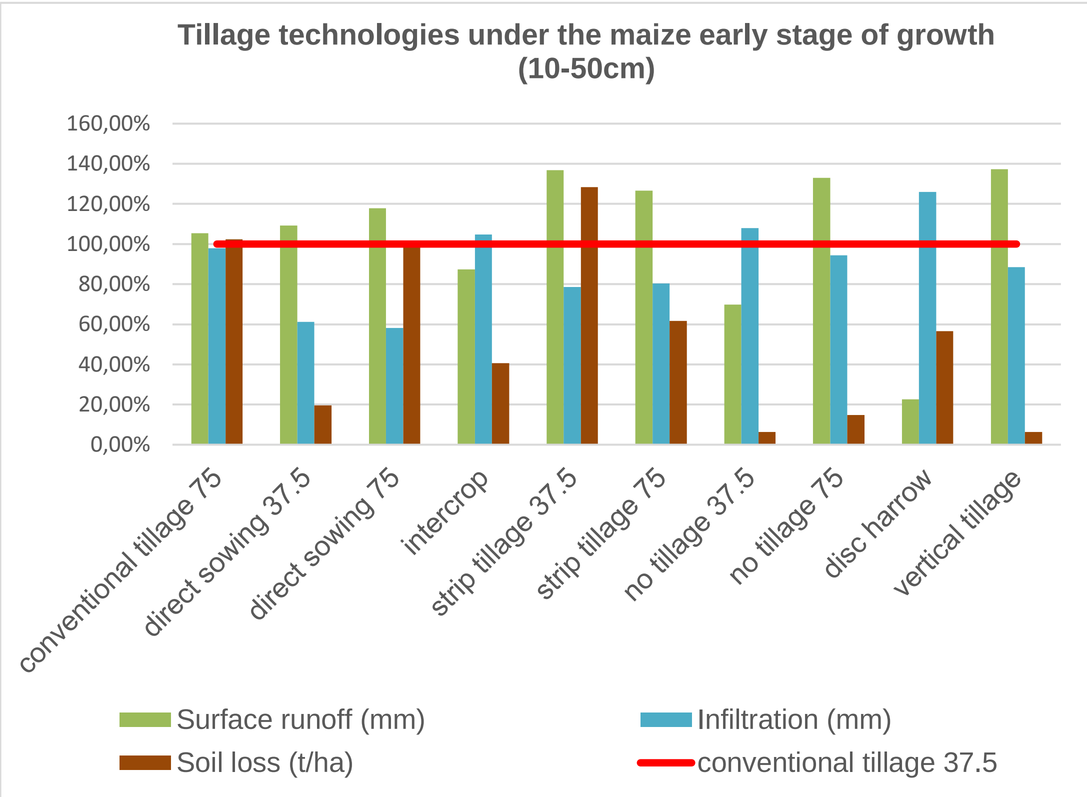
5.1.1.1.1.1.2 Results

Treatment	Stage of growth	Surface runoff (mm)	Infiltration (mm)	Soil loss (t/ha)	Surface runoff (%)	Infiltration (%)	Soil erosion reduction (%)
CT	Early (5-50 cm)	7.93	19.45	2.51	100.00%		100.00%
CT 75	Early (5-50 cm)	8.36	19.05	2.57	105.42%	19.45	102.39%
DS 37.5	Early (5-50 cm)	8.66	11.92	0.49	109.21%	19.05	19.52%
DS 75	Early (5-50 cm)	9.34	11.31	2.51	117.78%	11.92	100.00%
IC	Early (5-50 cm)	6.93	20.39	1.02	87.39%	11.31	40.64%
ST 37.5	Early (5-50 cm)	10.85	15.29	3.22	136.82%	20.39	128.29%
ST 75	Early (5-50 cm)	10.04	15.64	1.55	126.61%	15.29	61.75%
NT 37.5	Early (5-50 cm)	5.54	20.99	0.16	69.86%	15.64	6.37%
NT 75	Early (5-50 cm)	10.55	18.35	0.37	133.04%	20.99	14.74%
DH	Early (5-50 cm)	4.4	24.49	1.42	22.62%	18.35	56.57%
USB 37.5	Early (5-50 cm)	12.08	15.35	13.9	152.33%	24.49	553.78%
USB 75	Early (5-50 cm)	8.86	18.63	9.29	111.73%	15.35	370.12%
VT	Early (5-50 cm)	10.89	17.22	0.16	137.33%	18.63	6.37%

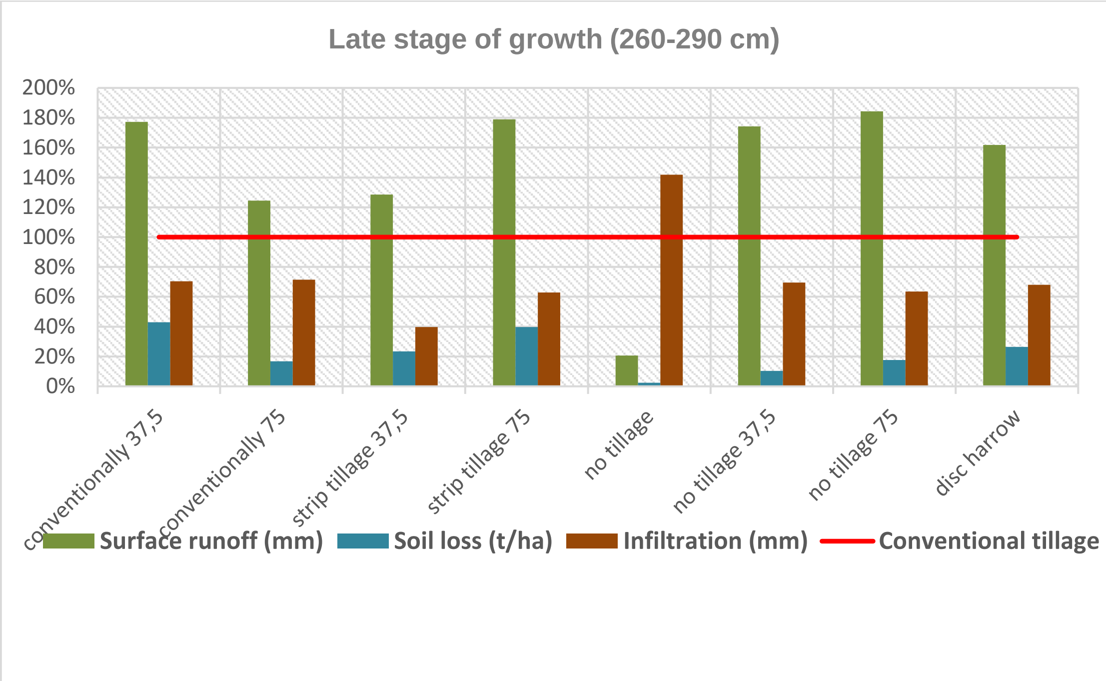
Apx Table 2: Comparison of tillage practices - data analysis results - soil erosion reduction (%) compare to the conventional tillage at the early stage of growth of maize (5-50cm)

Treatment	Stage of growth	Surface runoff (mm)	Infiltration (mm)	Soil loss (t/ha)	Surface runoff (%)	Infiltration (%)	Soil erosion reduction (%)
CT	Late (260-290cm)	9.46	17.95	3.28	100%	100%	100%
CT 75	Late (260-290cm)	11.78	12.84	0.55	124.52%	71.53%	16.77%
ST 37.5	Late (260-290cm)	12.15	7.15	0.77	128.44%	39.83%	23.48%
ST 75	Late (260-290cm)	16.93	11.29	1.3	178.96%	62.90%	39.63%
NT 37.5	Late (260-290cm)	16.48	12.49	0.34	174.21%	69.58%	10.37%
NT 75	Late (260-290cm)	17.43	11.4	0.58	184.25%	63.51%	17.68%
DH	Late (260-290cm)	15.3	12.21	0.87	161.73%	68.02%	26.52%

Apx Table 3: Comparison of tillage practices - data analysis results - soil erosion reduction (%) compare to the conventional tillage at the late stage of growth of maize (260-290cm).



Apx Figure 12: Results of comparison of different TP at the early stage of growth of maize (Stejskalova, 2016).



Apx Figure 13: Results of comparison of different TP at the late stage of growth of maize (Stejskalova, 2016).