CZECH UNIVERSITY OF LIFE SCIENCES PRAGUE

Faculty of Engineering

Department of Agriculture Machines

MASTER'S THESIS

Determination the Erosion Parameters in Different Soil Tillage Technology

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CZECH UNIVERSITY OF LIFE SCIENCES PRAGUE

Faculty of Engineering

DIPLOMA THESIS ASSIGNMENT

Intan Puspita Sari, BSc

Technology and Environmental Engineering

Thesis title

Determination the erosion parameters in different soil tillage technology

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Objectives of thesis

The aim of the work will be to evaluate the effects of different soil tillage technologies on water erosion parameters.

Methodology

The first part will be an introduction. It will be created from current scientific literature on "water erosion and soil tillage technologies and modeling of these processes".The second part will be devoted to the evaluation of field experiments on a specific soil location. Two methods of measuring soil erosion parameters will be used. The data will be statistically evaluated and discussed with other researches.

The proposed extent of the thesis

50 pages

Keywords

erosive wash, surface runoff, soil damage

Recommended information sources

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DECLARATION

I hereby declare that this master’s Thesis ‘Determination The Erosion Parameters In Different Soil Tillage Technology’ is the result of my own work and that it has not been submitted to this University or any institution for a degree. All references, however, used in the development of the work have been dully acknowledged in the text and provided in the list of references.

In Prague, 31st March 2024

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Intan Puspita Sari

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ABSTRACT

Soil, a fundamental natural resource for agriculture, faces numerous threats that threaten its quality and productivity. Soil erosion caused by human activities is a major threat to agriculture. Choosing the correct soil tillage practices is pivotal in controlling water erosion. This study compares conventional and conservation tillage practices' impact on water erosion parameters in wheat and oats. Field experiments were conducted at the Nesperská Lhota experimental location, comprising four variants representing conventional and conservation tillage practices alongside a black fallow control variant. Three primary methods were used to measure soil water absorption: circular and Mini Disk infiltrometer, and the Brilliant Blue indirect method. Results revealed that the oat variant with no-till shows the lowest surface runoff and erosive wash-off levels, indicating adequate soil protection against erosion. No-till farming and more plant residue covering the soil effectively protected the soil against erosion. This study highlights the effectiveness of conservation tillage practices, especially no-till, in reducing water erosion and maintaining soil health in wheat and oat cropping systems. The study emphasizes the significance of adopting sustainable soil management practices to protect agricultural sustainability and environmental well-being.

KEYWORDS: soil tillage, erosion, erosive wash, surface runoff

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1 INTRODUCTION

Soil is vital for agriculture and sustaining life on Earth. It helps plants grow by providing essential nutrients, water retention capabilities, and structural support for their roots. Fertile soil is crucial for agriculture as it is the foundation for growing crops, and without it, global food security and human livelihoods would be at risk. Soil plays a vital role in our ecosystem but is also at risk because of several factors that can impact its health and productivity. Soil erosion is one of the most significant risks, primarily caused by human activities, particularly those related to agriculture. Practices such as deforestation, intensive land use, improper irrigation, and unsustainable soil management have accelerated erosion rates. This leads to the loss of fertile topsoil, compromised ecosystem resilience, and diminished water quality.

Water erosion is a significant concern among various types of soil erosion. The constant force of rainfall and surface runoff causes it. Water droplets dislodge soil particles, leading to soil loss and sedimentation in water bodies. This process creates a challenge for agricultural sustainability and ecosystem health. Soil tillage is a practice that has been used in agriculture for centuries to prepare soil for crop cultivation. However, the mechanical manipulation of soil through tillage can also affect erosion dynamics. Different tillage methods, such as conventional and conservation tillage, impact erosion parameters, including surface runoff, sediment yield, and soil wash-off. While conventional tillage methods usually involve intensive soil disturbance and surface exposure, conservation tillage techniques, like reduced and no-tillage, aim to minimize soil disturbance and maintain soil cover, which helps to mitigate erosion risks.

In the Czech Republic, tillage practices significantly impact the growth, yield, and health of staple crops such as wheat and oats. These crops play a crucial role in Czech agriculture, and understanding how different tillage methods affect their productivity while minimizing soil erosion risks is essential to optimize agricultural output. It is crucial to comprehend how various soil tillage practices affect erosion parameters to develop sustainable land management practices and reduce soil erosion's negative impact.

2 THE AIM OF THE THESIS

The master's thesis will focus on comparing the effects of conventional tillage and conservation tillage practices on water erosion parameters, specifically with wheat and oat crops.

2.1 Hypothesis

Hypothesis 1: Conventional tillage practices will result in higher water erosion rates compared to conservation tillage practices (reduced and no-till) across both wheat and oat crops.

Hypothesis 2: Black fallow areas will serve as a control variant, exhibiting higher erosion rates compared to all tillage treatments due to the absence of vegetative cover and soil disturbance.

3 LITERATURE REVIEW

3.1 Soil Erosion

Anthropogenic and natural causes work together to generate the complicated problem of soil erosion. Natural factors that contribute significantly include erosion caused by wind and water. Human activities significantly contribute to heightened soil erosion rates when compared to natural processes. Soil erosion is mostly caused by activities like farming, deforestation, overgrazing, and the use of agrochemicals. The fertility and quality of the soil can be impacted by soil erosion and degradation resulting from the conversion of natural vegetation into farming. Poor farming practices, such as cutting away vegetation cover, utilizing wide fields, and using improper plowing techniques, are often responsible for this issue (Alam, 2014). Grassland cultivation can cause substantial soil degradation, which includes a loss of nutrients and organic carbon as well as a coarsening of the soil's texture. Livestock overgrazing may severely impact the soil and plants. According to (Warren et al., 1986), it may result in soil compaction, decreased infiltration, and increased runoff, all of which can contribute to soil erosion and fertility loss. An example of an activity that quickens soil erosion is deforestation. The removal of vegetation caused by logging or burning forests exposes the soil to erosion from wind and water. Long-term effects on the land's capacity to regenerate result from loss of topsoil. The application of agrochemicals, especially pesticides, can cause erosion by negatively affecting the beneficial bacteria and composition of the soil. These substances have the potential to affect soil health and agricultural sustainability by changing the soil microbiota, decreasing enzyme activity, and interfering with nutrient cycling mechanisms. (Mandal et al., 2020)

Soil erosion is a vital problem in the agriculture sector. Although rates of soil erosion differ throughout the world, it is thought that the United States is losing soil ten times more quickly than nature can replace it (Pimentel & Burgess, 2013). It was discovered that the average rate of soil loss in the erosion-prone regions (forest, agricultural, and semi-natural areas) in the European Union was 2.46 tons/ha/year (Panagos et al., 2015). Soil loss due to crop harvesting in the EU is also a concern, with sugar beets and potatoes causing soil loss during harvesting. Soil erosion by water is one of Europe's most widespread forms of soil degradation. By 2050, mean soil loss rates due to water erosion may increase by 13-22.5% in the EU and UK agricultural areas compared to the 2016 baseline (Panagos et al., 2021). In agricultural soils across the European Union, the average annual soil loss rate was 3.07

tons per hectare. This rate is predicted to rise to 3.76 tons per hectare annually by 2050 under the business-as-usual or least mitigation route scenario (RCP8.5) (Evans & Boardman, 2016)

Soil erosion has significant off-site impacts, including salinisation and sedimentation of reservoirs, burial of agricultural land and buildings, deterioration of water quality, and loss of aquatic ecosystems. The connectivity of the runoff and sediment system is a key factor in these off-site impacts, with anthropogenic features playing a crucial role.

3.2 Type of soil erosion

An important problem brought on by both natural and human forces is soil erosion, which results in the loss of fertility, nutrients, and soil. It can be classified based on its dynamics and impact on land productivity, with water, wind, and gravitational erosion being the main types (Chu, 1956). There are three types of soil erosion: water erosion, wind erosion, and snow erosion.

3.2.1 Water erosion

Water erosion processes are complex and dynamic, influenced by various factors, including rainfall, overland flow, and wave action (Rose & Hairsine, 1988). These processes can lead to significant changes in sediment size distribution, with fine particles associated with initial stages and coarse particles with rill development. The impact of natural rainfall changes on these processes is a growing concern, with potential implications for soil erosion and hydrological processes. The sediment resulting from soil erosion and the contaminants carried along with the sediment can cause significant losses and life costs.

The four main forms of erosion caused by water are gully erosion, sheet erosion, rill erosion, and inter-rill erosion. Gully erosion is a type of landform that occurs on hillsides, in river floodplains, or terraces and is caused by flowing water, mass movement, or a combination of the two. The material is quickly eroded into the soil or other relatively erodible material. Human activity, soil characteristics, and weather conditions are some of the variables that contribute to gully erosion. Gully erosion can also result from animal overgrazing and trampling, which can degrade the soil and produce overland flow (Strunk, 2003). Traditional plowing methods sometimes cause gully growth and an absence of appropriate waterways to convey excess water.

Sheet erosion happens when the amount of rainfall exceeds the capacity of the soil to absorb water; it typically happens after the soil has been damaged by water and formed a crust. Several factors affect sheet erosion, which is the process of soil particles being carried by flowing water. Smith & Wischmeier (1957) distinguished six important variables, including rainfall, cropping, soil type, management techniques, and land length and slope. The development of tiny, narrow channels on the soil surface known as rills is a type of soil erosion known as rill erosion. The movement of soil particles caused by water flowing through these channels is what characterizes this type of erosion. The channels, or rills, are generated by a variety of factors such as variations in slope, soil type, and vegetation cover. Generally, the rills are smaller than the surrounding soil surface. When there is a high risk of rainfall or when the soil is especially prone to erosion, rill erosion becomes a serious issue. It may result in topsoil loss, which could have a negative impact on slope stability, water quality, and agricultural output. Furthermore, the process could assist in the formation of gullies, which are longer, deeper channels that present extra threats to infrastructure and property. A variety of conservation techniques can be used to prevent rill erosion. These include building fences or other structures to channel water away from sensitive regions, planting trees and bushes to stabilize the soil surface and limit runoff, and using cover crops to lessen the erodibility of the soil (Lou et al., 2022)

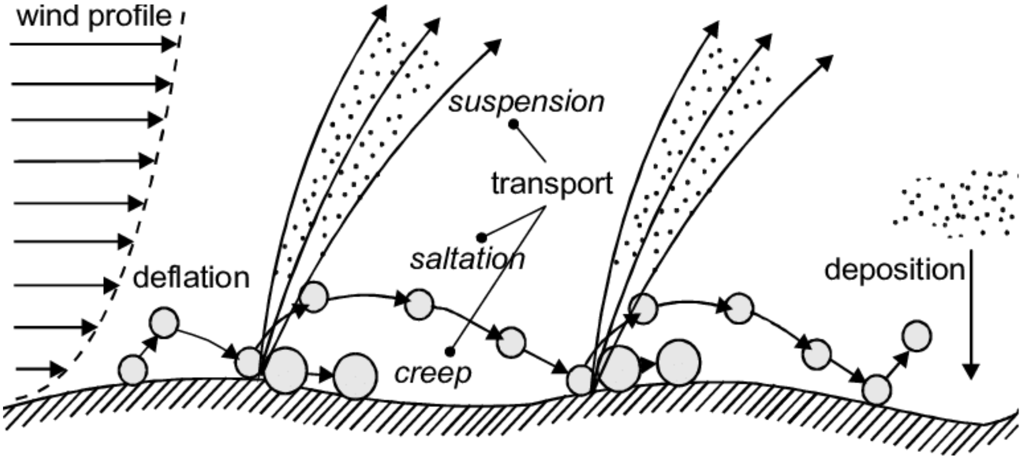
The movement of soil caused by rain splash and its transportation by thin surface flow, whose erosive ability is enhanced by turbulence created by raindrop impact, is known as inter-rill erosion. Hillslopes frequently experience interrill erosion, which is impacted by elements such microtopography relief, ridge shape, and the amount of rainfall (Q. J. Liu et al., 2014). When rainfall hits exposed soil, it separates soil particles and releases them into the surrounding air, causing inter-rill erosion. After that, the separated material is carried by shallow overland flows, which are sometimes made more turbulent by the impact of raindrops. Sediment deposition may occur in the field's downslope regions or in concentrated flows that continue to form gullies and leave the field's edge, depositing the silt in ditches, streams, and rivers.

Inter-rill erosion can have a detrimental effect on the health of the soil, resulting in the loss of organic matter-rich topsoil and the formation of more compact subsoil, which can lower agricultural production. This is particularly concerning in steep slopes, where inter-rill erosion can lead to accelerated soil erosion and sedimentation, threatening soil fertility and water quality. Preventing inter-rill erosion in agriculture can be achieved through conservation tillage, which involves leaving plant waste on the ground.

3.2.2 Wind Erosion

Wind erosion is a natural process that erodes the soil surface due to wind. As a result of the mechanical force of the wind, free soil particles are carried away in different places at different distances. In dryland areas with fine-textured soils, wind erosion is a major problem, especially in locations with high temperatures, strong winds, and little or no precipitation. The movement of soil particles due to wind can be categorized as suspension, saltation, or surface creep. When the wind picks up and lifts loose particles off the surface, deflation occurs. It can result in the removal of fine-grained substances like clay and silt, leaving coarser particles like sand and gravel in their place. When surfaces are worn down by flying debris carried by the wind, it's referred to as abrasion. Rocks and other exposed surfaces may become smoother and more polished as a result of this technique. Particles that have been saltated move around the ground in a bouncing or hopping motion. The movement of sand-sized particles, which are propelled into the air and subsequently deposited elsewhere, is especially connected to this kind of erosion (Shao, 2008)

Figure 1 Main phases involved in the wind-erosion process



Sources: Cornelis (2006)

Soil moisture content and wind speed are two factors that cause wind erosion. Drier soils are more prone to erosion; soil moisture is a key factor in how susceptible soil is to wind erosion. The movement of soil particles on the surface is influenced by wind speed, with greater winds aggravating erosion. An area's vulnerability to wind erosion depends on several factors, including the size of the soil particles, the ground cover, field preparation techniques, agricultural mechanization practices, and the existence of physical obstacles (Ravi et al., 2004).

3.2.3 Snow Erosion

The process of snow erosion occurs when snow is carried by the wind and erodes, changing the environment and landscape. Snow erosion can cause the distribution of snow over different locations and is a major aspect of avalanche dynamics. Snow avalanches and other gravity-driven mass flows can have a substantial impact on the dynamics of their deposition and erosion. Erosion of the snow cover can alter the distribution and accumulation patterns of the snow. Snow and water erosion are two independent processes with unique properties. Soil characteristics and infiltration characteristics are two aspects that affect water erosion, which occurs when water moves over the ground. However, snow erosion caused by melting snow is linked to increased rates of surface runoff and soil erosion, especially in the early spring. Also, snow gliding has an impact on it; in subalpine regions, this activity can have a major impact on the patterns and amount of soil erosion (Meusburger et al., 2014).

3.3 Erosion Parameter

The Universal Soil Loss Equation (USLE), developed by Smith and Wischmeier in 1978, is a widely used model for predicting soil erosion. It considers rainfall erosivity, soil erodibility, slope, land management practices, and soil conservation measures (Toy et al., 2002). The equation has been revised to improve accuracy, incorporating new data and technology (Renard et al., 2003). Integrating USLE with the Geographical Information System (GIS) effectively assesses soil loss risk. The main parameters of soil erosion are soil properties, climate, topography or slope, land use, and land management.

3.3.1 Soil Properties

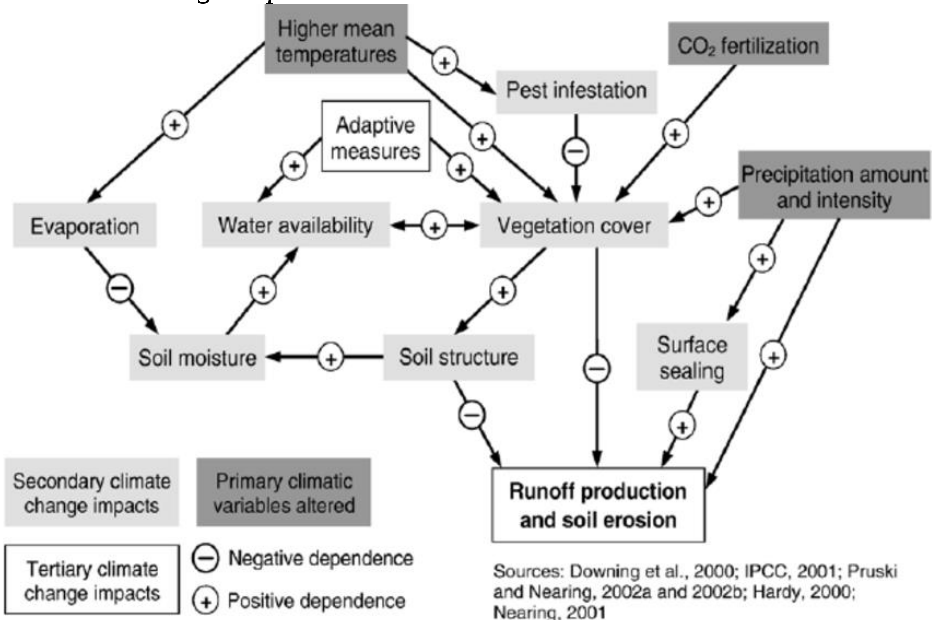
Soil properties are crucial as erosion parameters in different soil tillage technologies. The qualities and characteristics of soil that affect its behaviour and performance are referred to as the properties of the soil. Understanding the qualities of soil is essential to determining its value for different purposes. These properties can be broadly categorized into three main groups: physical, chemical, and biological properties. Physical properties, such as soil texture, structure, porosity, and density, dictate the soil's ability to withstand erosive forces from wind and water. One of the main factors influencing a soil's vulnerability to erosion is its credibility, which is determined by organic matter, moisture content, texture, and structure (WlSCHMEIER, 2002). Sand, silt, and clay comprise a soil's texture; sandy soils are more prone to erosion because of their loose structure. On the other hand, soils that contain more clay generally have more cohesiveness and are less prone to erosion.

Soil is a complex chemical comprising various substances, including ions, compounds, and colloids. These substances, along with the soil's pH and redox potential, influence its chemical environment and the availability of nutrients. The chemical properties of soil can vary significantly under different land use systems, with agroforestry-based systems showing superior properties. Soil with optimal nutrient levels and organic matter tends to have better structural stability, reducing erosion risk. The biological characteristics of soil, such as population density, enzymatic activity, and microbial biomass, are essential for soil fertility and productivity. Soil organisms, such as plants, animals, and microbes, are particularly active in the surface soil zone, influencing soil structure and function (Osman, 2013). A diverse and abundant soil biota can increase nutrient cycling, encourage the decomposition of organic matter, and strengthen soil structure, all of which can help make soil more resistant to erosion.

3.3.2 Climate

Rainfall has a significant role in soil erosion, which is heavily impacted by climate. Based on Dash & Maity (2023), Variations in precipitation patterns caused by climate change can impact soil erosion. Rainfall impacts erosion rates more than land cover or usage changes. Variations can affect rainfall patterns, water levels, and soil erosion. Increased runoff from intense rainfall can exacerbate erosion. Extreme variations in temperature can also increase the susceptibility of topsoil to erosion. Long drought conditions can inhibit plant development, exposing the soil and increasing its susceptibility to erosion.

Figure 2 Cliamte change impacts on soil erosion



Sources: Downing et al., 2000; IPCC, 2001; Pruski and Nearing, 2002a and 2002b; Hardy, 2000; Nearing, 2001

Sources: Scholz et al. (2008)

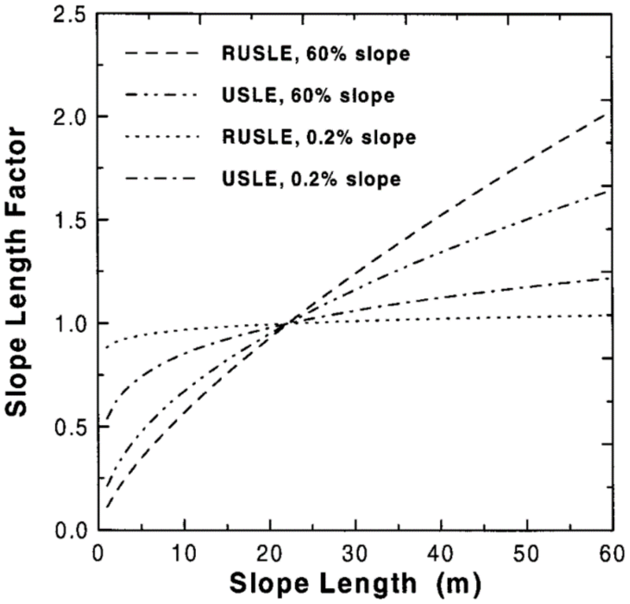
Climate change is predicted to have a major impact on soil erosion due to changes in temperature, precipitation, and evaporation. These changes are expected to result in higher soil erosion rates and more frequent and intense rainstorm episodes. In semi-arid locations, where soil degradation is mostly caused by water erosion, there is a significant expected increase in soil erosion. Climate change is expected to exacerbate the consequences of soil erosion because of changes in precipitation patterns, which can result in increased runoff and soil loss. Soil conservation measures, such as using cover crops, reduced tillage, and installing soil erosion management strategies, are frequently encouraged to counteract climate change's effects on soil erosion.

3.3.3 Slope

One crucial element in the process of soil erosion is the slope factor. The length and steepness of a slope can have a big impact on how quickly and severely erosion occurs. Steep slopes exacerbate soil erosion by increasing water discharge. The length and shape of slopes also influence erosive forces acting on the soil. In assessments of erosion risk, one important indication of soil loss is the slope length and steepness factor (LS-factor). Slope length (flow length) and slope gradient (steepness) together have combined effects described by the LS factor, which is the soil loss ratio per unit area on a site to the related loss from an average experimental plot with particular slope parameters.

Models for predicting erosion, such as the Universal Soil Loss Equation (USLE) and its revised version (RUSLE), depend significantly on the LS factor. It considers the interaction between slope length and steepness and how it affects soil erosion. Longer slopes that are higher typically have higher rates of erosion because of increased runoff velocity and soil separation. The LS factor considers the steepness of the slope and the length of time that water travels across the ground surface, both of which affect soil loss (S. Schmidt et al., 2019).

Figure 3 Slope length



Sources: B. Liu et al. (2000)

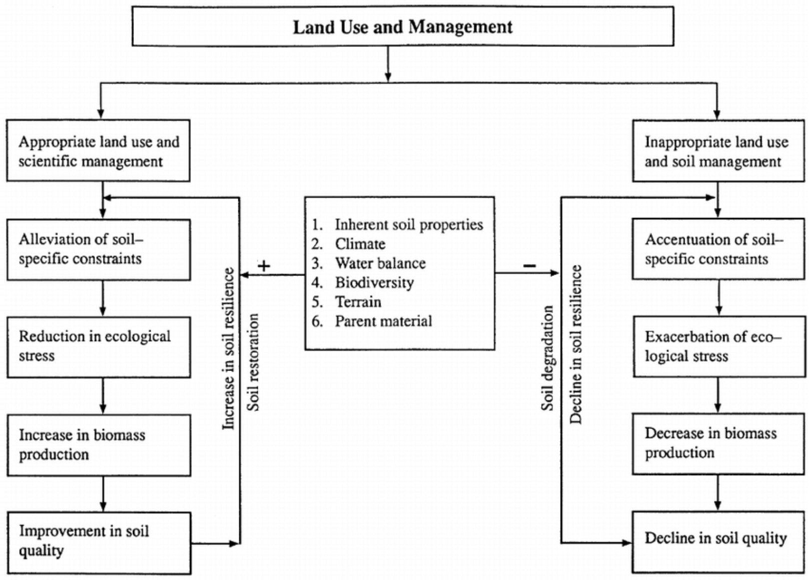
The critical slope gradient for soil erosion is estimated by Wang et al. (2023) to be between 41.5° and 50°. Several factors, including grain size, soil bulk density, surface roughness, runoff length, net rain excess, and soil friction coefficient, influence this essential slope gradient.

An important aspect in determining the risk of soil erosion is the LS factor, which incorporates the impacts of slope length and steepness. Steeper slopes speed up water runoff, which moves across the surface faster. Because of its faster velocity, it can pick up and transfer soil particles more easily, leading to higher erosion rates. Some land management techniques may make this issue worse.

3.3.4 Land use and land management

Soil erosion is a major environmental and agricultural hazard that can be effectively controlled through land use management. Good land use management can lessen the detrimental effects of soil erosion, such as topsoil loss, soil structure deterioration, and decreased water quality. Terracing, drainage, and vegetation cover are some effective ways to reduce erosion during heavy rainstorms. Changes in land use, especially the conversion of wasteland and forests, can exacerbate soil erosion, but they can also be lessened by switching to forests and orchards.

Figure 4 Land use management effect



Sources: Han et al. (2020)

Heavy machinery is essential in many ways when it comes to managing land usage to prevent soil erosion. When heavy machinery compacts the soil, as happens in agriculture or construction, the soil's ability to absorb water is reduced, which increases surface runoff. Compaction also modifies the structure of the soil, increasing its susceptibility to erosion. Erosion risk is further increased by using inappropriate methods such as over-tilling or leaving fields untended, which expose the soil to the full force of rainfall. Terracing, covering crops, and other environmentally friendly land management techniques are examples of soil conservation measures that must be put into effect in order to reduce soil erosion and maintain sustainable land management techniques. These strategies help to prevent land deterioration, erosion, and depletion. Soil conservation is crucial to maintaining the fertility of agricultural areas because it prevents soil erosion, salinization, and chemical pollution. Using effective soil conservation techniques, can enhance the productivity and quality of their property, lessen erosion, promote water penetration and storage, aid in the purification of the air and water, provide food and refuge for wildlife, and offer a host of other benefits to sustainability.

3.4 Tillage Technology

Soil tillage plays a significant role in controlling water erosion, and the choice of tillage practice can greatly influence soil erosion and water conservation. The choice of tillage practice is influences by various factor, such as soil type, crop rotation, climate, and land management. Soil tillage practices can be categorized into various types, each impacting soil erosion and water conservation differently. There are two main types of tillage: conventional and conservation. Conventional tillage, like plowing, can cause erosion and nutrient loss. Reduced or no-till farming methods are examples of conservation practices that are proven to reduce soil disturbance, increase soil porosity, improve aggregate stability, and support soil health in the long term. These methods support the preservation of soil nutrients, erosion control, and soil structure—all of which are important to sustainable agriculture.

3.4.1 Conventional Tillage

Karlen (1990) defines conventional tillage as using tillage and planting systems that maintain a certain level of surface residue cover to reduce soil erosion. Conventional tillage, such as moldboard plowing, involves leaving the soil surface bare and loosening soil particles, making them susceptible to wind and water erosive forces. This tillage technique is known to contribute to soil erosion and degradation. However, this practice has been criticized for its negative impact on soil structure and carbon loss. On the other hand, conservation tillage techniques minimize erosion by covering the soil's surface and letting water absorb it instead of runoff.

Frequent tillage has a major effect on water erosion and soil quality. Frequent tillage can lead to increased soil erosion and a general decline in surface water quality. It can also be expensive regarding soil production, quality, and increased wear on labor and equipment requirements. It is known that conservation tillage and no-till methods can reduce soil erosion rates compared to conventional tillage. Previous research has identified several key erosion parameters associated with conventional tillage. Dickey (1984) found that different tillage systems can lead to varying levels of erosion during furrow irrigation, with slot-planting resulting in the least erosion and the chisel system the most. J. H. Zhang et al. (2009) found that conservation tillage significantly reduced soil movement and erosion compared to conventional tillage. S. M. Dabney et al. (1993) also found that conventional tillage, narrow row spacing, and row cultivation can all increase erosion rates, with the latter having the most significant impact.

3.4.2 Conservational Tillage

One important technique for minimizing soil erosion is conservation tillage, defined as keeping at least 30% of the area covered with residue after planting. This practice has seen increased adoption in the US, with 38.3% of cropland using conservation tillage in 1988 (Karlen, 1990). Conservation tillage can minimize energy consumption and carbon dioxide emissions while increasing soil structure, decreasing erosion, and improving water-holding capacity (Blanco-Canqui & Lal, 2010). By shielding the soil's surface and allowing water to penetrate in rather than run off, conservation tillage plays an important part in lowering soil erosion. However, efficient weed and disease control, nitrogen availability, and local soil conditions are necessary for conservation tillage to be effective in organic farming (Peigné et al., 2007).

There are various conservation tillage practices, including no-till, mulch-till, ridge-till, and strip-till, each with specific benefits and considerations (Kladivko, 2001). These methods preserve water and soil, lessen energy consumption, and manage erosion. Location, soil type, crop being cultivated, and other site-specific considerations all play a role in the selection of tillage technique. High levels of management are needed for conservation tillage, which can assist farmers in adhering to conservation laws but also comes with problems such as soil amendment, drainage, labor and expense, chemical use, short-term benefits, and greenhouse gas emissions. A comparative analysis of erosion parameters under different conservation tillage methods reveals significant differences in soil erosion control and water infiltration. Compared with conventional tillage techniques, which leave less than 30% of ground cover undisturbed from harvest to planting, no-till systems, which leave 50% or more of the ground cover undisturbed, are particularly effective in decreasing runoff and erosion (Beneš, 2007). No-till farming was more effective on hill slopes and watersheds in reducing runoff and erosion, with significantly lower runoff and eroded material produced under the no-till system.

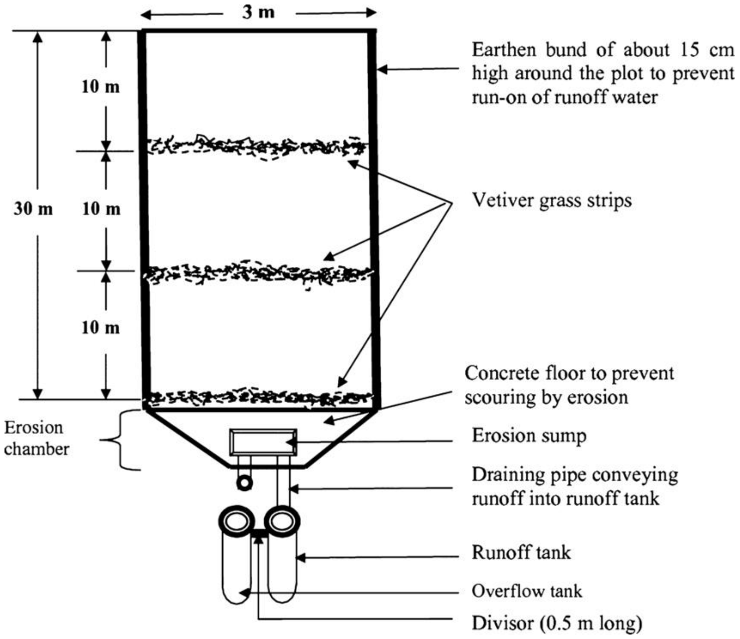
3.5 Methodologies for Assessing Erosion Parameters

A range of methodologies have been proposed for assessing erosion parameters. Alexakis et al. (2019) evaluated significant soil parameters and estimated soil erosion risk using a mix of satellite remote sensing, field spectroscopy, and GIS. Mahapatra et al. (2008) applied the Taguchi method to determine optimal parameter combinations for minimizing erosion wear in polyester composites using material wear data and CFD simulations, Gnanavelu et al. (2011) developed a method for forecasting wear profiles caused by slurry erosion. These studies highlight the potential of various techniques for assessing erosion parameters, each with its strengths and limitations. There are four main methods for assessing erosion parameters. The first is field studies, modelling approaches, and laboratory experiments.

3.5.1 Field Studies

Field research often sets up experimental plots or establishes observation locations in natural areas or farmlands. Researchers choose these sites based on soil, terrain, land usage, and erosion likelihood. Then, they use different methods and tools to track erosion over time. The common methodologies used for field studies are erosion plots**,** sediment traps, and instrumentation. An erosion plot is a specified area in a field or landscape where soil erosion processes are tracked and measured over time. These plots were chosen carefully to show homogenous areas of the landscape, enabling researchers to examine erosion processes in particular situations. Erosion plots are important for research on soil erosion processes. These plots, which come in various forms and sizes, are frequently used to study soil erosion-related geomorphological processes. Field plots are necessary for comparative research and experiments to evaluate runoff prediction models and determine vegetation cover's and other factors' effects on erosion.

Figure 5 Schematic diagram of erosion



Sources: Are et al. (2011)

Sediment traps are essential for evaluating soil erosion, and factors like vegetation type and measure integration affect their efficiency. Brooks et al. (2014) highlight the importance of sediment traps in measuring surface sediment movement and erosion rates. When properly designed and installed, Sediment traps can effectively remove eroded soils, with trap efficiencies of 80% or greater (Robichaud et al., 2001). This is supported by research conducted by Haribowo et al. (2019), who found that a layered sediment trap was the best method for reducing erosion on agricultural land. However, the efficiency of sediment traps can vary, as demonstrated by (Dendy and Cooper, 1984), who found that trap efficiency was influenced by sediment loads and concentrations.

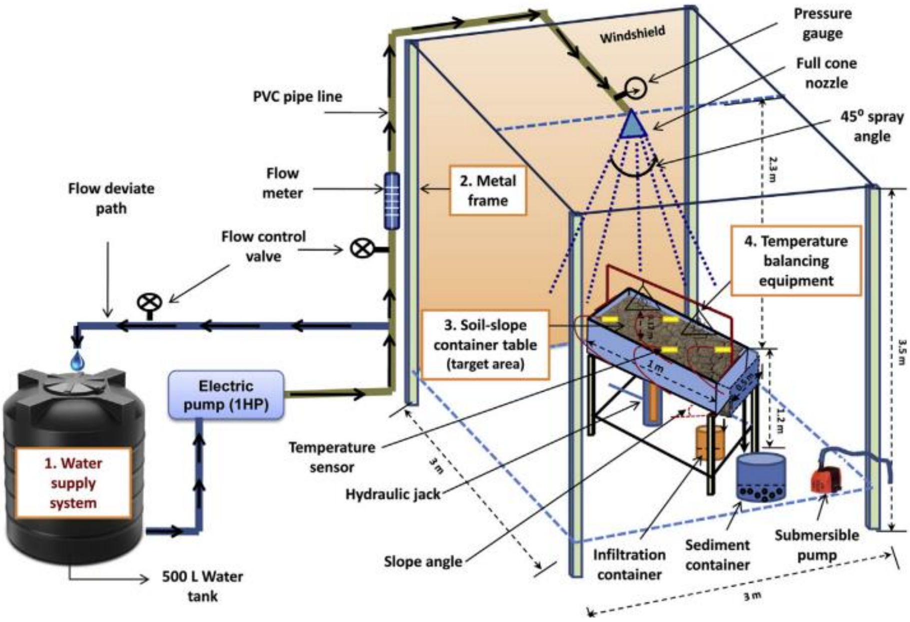
Various devices and instruments are used in soil erosion assessment instrumentation, which monitors different parameters related to erosion processes. These tools are essential for gathering precise experimental, laboratory, or field data. Common instruments widely used are sediment samplers, sediment pins, and rainfall simulators. When assessing soil erosion, erosion pins are a useful instrument. Their usefulness is increased when the pin height change's absolute value is considered. Erosion pins are placed in the ground and the length of the pin is measured over time, with the initial measurement serving as a reference to determine the rate of soil erosion. They accurately measure the rates of soil erosion and loss in various situations. The method for measuring changes in the soil surface over time is driving a pin into the ground and using the top of the pin as a reference point. Erosion pins offer an efficient and cost-effective way of evaluating soil erosion and deposition on slopes by determining the annual variations in pin height (Kearney et al., 2018).

Figure 6 Erosion pins

Sources: (Puno & Marin, 2017)

Simulators of rainfall are crucial instruments for evaluating soil erosion and water penetration. The simulator comes in various classifications and operating characteristics, effectively studying erosion processes. Small plot field experiments, outdoor experiments measuring soil erosion, soil water infiltration, and soil-water contamination (Strauss et al., 2000), and testing the hydrological performances of micro-detention pond permeable pavement (Bateni et al., 2018) are just a few of the applications for rainfall simulators. These simulators are designed to mimic natural rainfall, with the ability to control rainfall intensity and simulate raindrop size and velocity. They are particularly useful for obtaining initial hydrology data and designing application prototypes.

Figure 7 Rainfall simulator scheme



Sources: (Mhaske et al., 2019)

3.5.2 Modeling Approaches

Soil erosion modeling categorized approaches into statistical, process, physically-based, and spatially distributed models (J. Schmidt, 2000; L. Zhang et al., 1996). They highlight the effectiveness of process and physically-based models, such as WEPP, in predicting soil erosion when adequately describing the processes and components that affect erosion. Abdulkareem et al. (2021) further divide these models into three categories: conceptual (SEDNET), empirical (USLE), and physical (WEPP, for example). The USLE is the most often used model because of its simplicity and use. However, the lack of data for validation is a major limitation.

Three primary categories of modelling approaches are available for evaluating soil erosion: physically based models, conceptual models, and empirical models. Depending on the intended use and features of the landscape, each category offers advantages and disadvantages. The study's specific objectives and data needs determine which model should be used.

Empirical models for soil erosion are mathematical constructs founded on statistical correlations between soil erosion and its influencing factors like rainfall intensity, soil composition, land management methods, vegetation cover, and slope attributes. These models are crafted by analyzing data obtained from field experiments and measurements. Examples of empirical models comprise the Revised Universal Soil Loss Equation (RUSLE) and the Modular Soil Erosion System (MOSES) (Ferro & Nicosia, 2023). While empirical models offer simplicity and rapid soil erosion estimates, they might not fully capture the intricate physical processes inherent in soil erosion.

Understanding the physical processes involved, such as soil particle division, transportation, and deposition, is the foundation of conceptual soil erosion models. Compared to physically based models, these models usually demand less comprehensive data and simplify these processes to make them easier to handle. Examples of conceptual models include the Modified Universal Soil Loss Equation (MUSLE) and the Soil Loss Estimation Model for Southern Africa (SLEMSA) (Raza et al., 2021).

These conceptual models are valuable because they offer insights into the factors that control soil erosion, providing a framework for understanding how different variables interact. However, their accuracy may be limited by the simplifications inherent in their structure. By simplifying complex processes, conceptual models may overlook certain nuances or interactions that could affect the accuracy of their predictions. Thus, while conceptual models provide a useful starting point for understanding soil erosion, they may need to be supplemented or refined with more detailed data or physically based models for more accurate predictions.

Physically Based soil erosion models are rooted in the underlying physical principles that govern erosion processes, such as fluid mechanics and sediment transport. Unlike empirical or conceptual models, which simplify these processes, physically based models aim to simulate them directly using mathematical equations derived from physics. Such models include the Water Erosion Prediction Project (WEPP) and the Productivity, Erosion, Runoff, and Functions to Evaluate Conservation Techniques (PERFECT). While physically based models can predict soil erosion more accurately, their complexity may limit their utility in some circumstances.

A serious problem that can greatly influence ecological sustainability and agricultural growth is soil erosion. Remote sensing (RS) technology offers particular advantages for analyzing processes related to soil degradation at regional to global scales, such as soil erosion. Given the difficulty of doing so on a wide scale, it offers a way to measure and monitor soil parameters relevant to soil degradation. Using geo-informatics technology for agricultural system management, soil erosion threats have been identified and assessed using remote sensing technology. Soil erosion and changing plant cover are monitored using GIS techniques, computer simulation, mathematical modelling, and remote sensing (Senanayake et al., 2020). Large-scale soil erosion can be assessed via remote sensing, providing researchers with a comprehensive picture of the trends and patterns in erosion.

Although remote sensing technology offers special advantages for researching soil erosion, there are limitations to its application. More thorough work is required to evaluate the geographic variability and extent of soil erosion at regional sizes. Most soil deterioration caused by erosion assessments is now conducted locally. Nevertheless, there is much possibility of overcoming these obstacles and completely transforming the tracking of soil erosion and land degradation thanks to developments in remote sensing technologies.

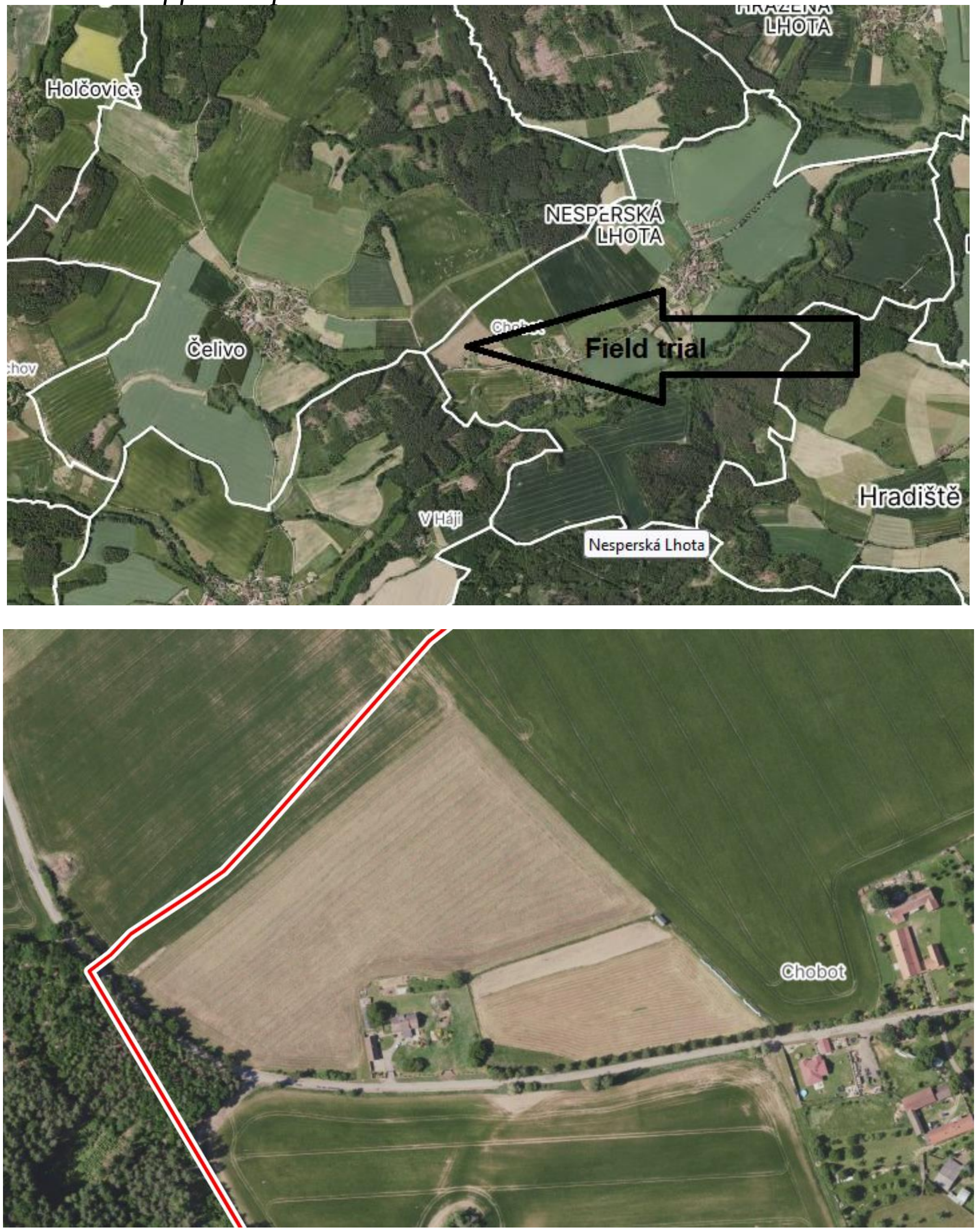
3.5.3 Laboratory Experiments

Soil erosion can have significant environmental and agricultural impacts. It can be assessed through various laboratory experiments that simulate natural processes and human activities contributing to erosion. One common method used in laboratory experiments is tray observation. This method involves placing a tray with soil in a secure location outside for three days, preferably when no rain is expected, and observing and recording daily soil erosion due to wind. Simulation for water erosion using shallow water simulation to simulate erosion processes in real-time. This technique simulates processes, including the development of rivers and lakes, the erosion of mountains, and the erosion of surfaces impacted by high water levels, by modelling water velocity and material transportation on the ground using a shallow water equation. This simulation's economy and speed make it appropriate for real-time surface modelling and modification, offering insightful information about erosion dynamics.

4 METHODOLOGY AND FIELD EXPERIMENT

The thesis focuses on determining erosion parameters in different soil tillage technologies. To conduct the measurement, a field experiment was initiated at the Nesperská Lhota experimental location.

Figure 8 Location of field experiment



Source: https://www.mapy.cz

The experiment began in the autumn of the preceding year for winter variants, specifically winter wheat, and for spring variants, such as oats, it commenced at the end of March. Throughout the season, the experiment concentrated on assessing the depth and intensity of soil cultivation and its impact on erosion parameters. Typical crops for the locality were utilized in the experiment, which was conducted on light, loamy-sandy soil situated at an altitude of 450 meters. This soil type contains 32.3% particles smaller than 0.01 mm and has a combustible C (Ct) content of 3.8%. Besides examining the basic soil properties, other physical characteristics were determined by employing intact soil samples and analyzing them using Kopecky cylinders with a volume of 100 cm^3 within CZU laboratories.

The field experiment comprised four basic variants and one control variant, each with a fenced area of 40 m2 with dimension 2 x 20 m, and the longer side oriented towards the fall. Each variant represented the cultivation of a crop typical of local conditions, specifically winter wheat (Triticum aestivum) and oats (Avena sativa). Variants also varied in the technology used to establish the stand. The fifth variant served as a control and was black fallow, devoid of vegetation, maintained using non-selective herbicides (glyphosate).

Characteristics of individual experiment variants:

a. Conventional Soil Tillage Technology for Winter Wheat (Bagou variety):

The initial variant involved conventional soil tillage methods for winter wheat cultivation, specifically the Bagou variety. Prior to sowing, ploughing to a depth of 0.2 meters was conducted, followed by pre-sowing preparation using a combine harvester. Sowing took place on September 28th at a seeding rate of 190 kg/ha. No further treatment was applied to the growth, with weed control deferred until spring. An herbicide based on MPCA (Dicopur M 750) was utilized for weed management. Additionally, nitrogen fertilization with LAV 27 at a dose of 200 kg/ha and fungicidal treatment against stem heel diseases (Sportak HF) were carried out.

b. Reduced Soil Tillage Technology for Winter Wheat (Bagou variety):

In the second variant, reduced soil tillage methods were employed for winter wheat cultivation using the Bagou variety. Loosening to a depth of 0.1 meters was conducted with a tine cultivator before sowing. Sowing occurred on September 28th at the same seeding rate as in variant 1 with 190 kg/ha. Similar to the conventional method, no further growth treatment was applied, and weed control was scheduled for spring. The same herbicide, nitrogen fertilization, and fungicidal treatment were utilized.

c. Conventional Technology of Tillage for Oats (Zlaťák variety):

The third variant focused on oats cultivation, specifically the Zlaťák variety, using conventional tillage techniques. Plowing was performed in autumn, leaving a rough furrow over winter. Pre-sowing preparation was conducted in spring using a combine harvester. Sowing of oats took place on March 27th at a seeding rate of 200 kg/ha.

d. Minimizing Soil Tillage Technology for Oats (No-Till System) (Zlaťák variety):

Variant four implemented minimized soil tillage methods for oats cultivation, employing a no-till system for the Zlaťák variety. No loosening was conducted in the fall, and oats were directly sown on March 27th at the same seeding rate as in variant 3 with 200kg/ha.

e. Black Fallow:

The fifth variant involved a black fallow scenario. The black fallow variant involves maintaining the soil in a fallow state, devoid of vegetation. Similar to previous variants, conventional tillage methods are employed. However, residual vegetation appears on the plot, prompting the use of a non-systemic herbicide (glyphosate) in mid-November for eradication. This herbicidal treatment is repeated multiple times during the measuring season. Spring loosening, akin to the oats variant, is performed to prepare the soil for subsequent experiments.

The individual experiment variants were enclosed within boundaries made of wooden boards, each measuring 0.15 meters in width and 4 meters in length. These boards were securely positioned by sinking them into the ground to a depth of 0.1 meters and then fastened using steel hooks. To enhance protection against water ingress from above, the upper wall was bordered twice. The layout of the experiment was meticulously planned, with the three autumn variants positioned adjacently, as were the remaining spring variants.

To monitor precipitation and its intensity accurately, a Vantage Vue weather station was strategically installed near the experimental plot. This weather station facilitated the measurement of rainfall, providing crucial data for the study. Following any potential rainfall event that could lead to surface runoff of stormwater, immediate checks were conducted on the water and sediment content of plastic containers placed within the experimental area. The volume of surface runoff was promptly measured post-precipitation.

To further analyze the collected data, the weight of captured soil was determined after filtering the sediments and subsequently drying them at 105°C in a laboratory oven located at the Czech University of of Life Sciences. This meticulous process ensured accurate measurement and recording of soil weight, a critical parameter for assessing erosion. The data obtained from these comprehensive measurements were meticulously evaluated using statistical analysis software such as STATISTICA 12 and MS Excel. These powerful tools enabled researchers to process and interpret the gathered data effectively, providing valuable insights into the erosion parameters under different soil tillage technologies.

As part of the comprehensive testing regimen, an evaluation was conducted to assess the soil's infiltration capacities using alternative measurement methods. Three primary measurement techniques were employed to gauge the soil's ability to absorb water effectively. The first method utilized a circular infiltrometer with a diameter of 0.15 meters, employing the "simplified falling-head" (SFH) approach. In this method, infiltration is quantified by converting it to saturated hydraulic conductivity. A predetermined volume of water, specifically 0.5 dm^3, was carefully poured into the infiltrometer. After allowing sufficient time for soaking, the duration, along with the moisture content of the surface layer of the soil, was meticulously measured. To ensure accuracy and reliability, this process was repeated 10 times for each variation under study.

The second method entailed measurement using a Mini Disk infiltrometer, which offers distinct advantages such as its compact dimensions, ease of use, and minimal maintenance requirements. This infiltrometer comprises a polycarbonate tube with a diameter of 3.1 cm and a height of 32.7 cm, divided into two parts. Both sections of the tube were filled with water. The lower segment of the tube featured a stainless steel semi-permeable membrane with an area of 15.20 square cm on the underside, facilitating water penetration into the soil. A scale marked at the bottom of the tube enabled the determination of the volume of water in mm. Each infiltrometer was filled with water and subsequently positioned within the designated area of the experimental variant. Readings from the circular infiltrometer scale were recorded and entered into pre-prepared charts. Using a stopwatch, the timer was initiated, and scale readings were noted and recorded at two-minute intervals over a period of 30 minutes in each experimental area. Similar to the SFH method, this technique involved conducting ten repetitions to ensure robustness and reliability of the results.

These meticulous measurement methods provided valuable insights into the soil's infiltration capabilities under various experimental conditions, contributing to a comprehensive understanding of soil behaviour and its response to different tillage technologies.

Figure 9 Measurement with Mini Disc and SFH methods

The third method is the indirect method using Brilliant Blue. This method describes the movement of water in the soil and is therefore more informative. The dye, made with water and brilliant blue, was applied over an hour using a rain simulator. After the application period, there was a 5-hour break for the distribution of the blue colour in the soil profile. After this time, the soil profile was uncovered to about 35 cm. The profile was exposed a total of 3 times for each variant. The discovery was followed by surveying and subsequent photography of the soil profile. Photography was done with a digital camera that saves images in JPEG format. The images are transferred to the computer for further editing in the same quality at which they were created. Photos stored on the computer were edited in Gwyddion 2.30. First, a cutout is made from the frame, in our case from the stakes marked out after alignment.

Using the function of the grain marking program according to the threshold, the program marks the boundaries for the colour zones. Next, the grain removal function according to the threshold is used, where the value of the smallest grains is set, which will not be counted in order to eliminate the error arising from the reflection of small parts of the soil. The mask function is applied to the image modified in this way, which is transformed in the program into black and white, where the black colour represents the surface of the soil, and the infiltrated places are marked with white colour. The photo edited in this way is saved so that it can be used for further editing. The image edited in this way is inserted into the ImageJ program, and a function is used that determines the total area of the image. Subsequently, in this program, the image is converted into a binary system, in which parts of the soil are represented by black colour, and the infiltrated blue colour is represented by white colour. Finally, a function is applied to the image modified in this way, which determines the area and at the same time the percentage of infiltration in the image.

Figure 10 Surface after application of Brilliant Blue solution

5 RESULT OF FIELD EXPERIMENT

This chapter presents the main results from the measurements as part of the diploma thesis. The table below shows the basic physical properties of all experiment variants. Five intact soil samples were taken for each depth and variant as part of the experiment. Within the evaluation, small differences between the individual variants are visible. The values are generally typical for this type of soil and soil use, and no significant structural problem can be found in them at any evaluated depth. Porosity decreases with increasing depth, but this is an entirely natural property. Significant differences are not even reduced in the values of volumetric weight. Variants with a reduced management system show slightly lower values, but these differences are below the statistical significance threshold.

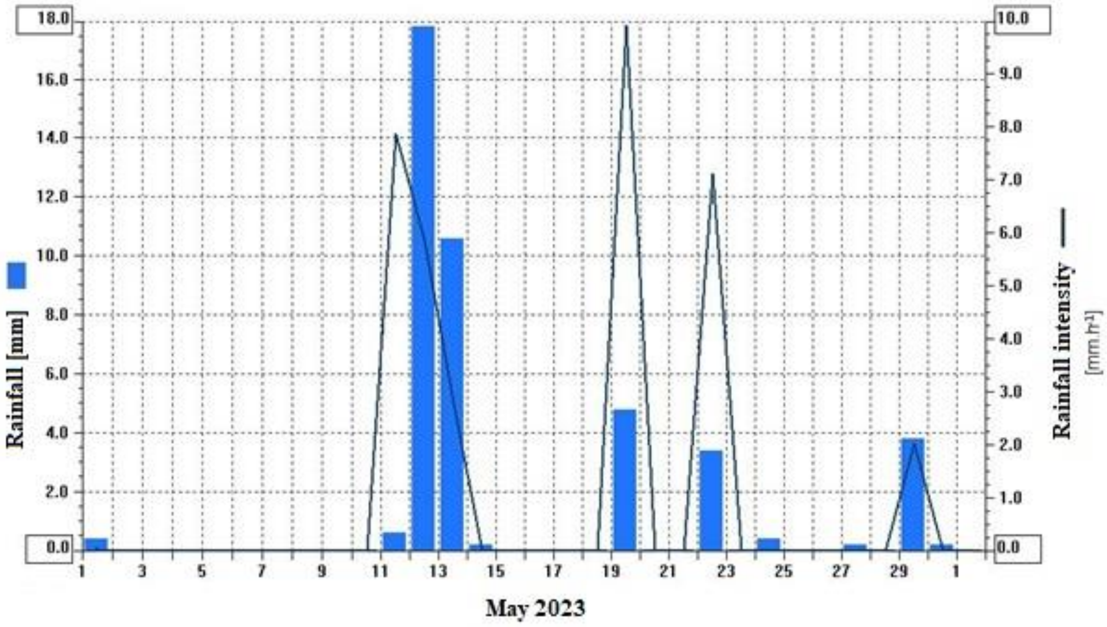
Table 1 Basic physical properties of soil

Variant	Depth (m)	Bulk density (g.cm^{-3})	Porosity (%)
Wheat conventional technology	0.05-0.10	1.49	43.8
	0.10-0.15	1.52	37.6
	0.15-0.20	1.51	37.2
Wheat reduced technology	0.05-0.10	1.41	44,2
	0.10-0.15	1.48	41.0
	0.15-0.20	1.50	39.2
Oat conventional technology	0.05-0.10	1.44	44.6
	0.10-0.15	1.47	40.3
	0.15-0.20	1.52	35.9
Oat no-till technology	0.05-0.10	1.40	45.4
	0.10-0.15	1.41	42.6
	0.15-0.20	1.46	40.2
Black fallow	0.05-0.10	1.46	44.1
	0.10-0.15	1.46	43.3
	0.15-0.20	1.47	42.1

Meteorological data, including rainfall amount in millimetres (mm) and precipitation intensity in millimetres per hour (mm/h), were collected by the Vantage Vue weather station positioned near the field experiment area. These records correspond to each month when erosion events took place. Each significant erosive precipitation event is assessed individually. The findings are presented through a basic bar graph illustrating the measurements of surface runoff and erosive wash.

The initial erosion event was triggered by two storms that occurred from May 11th to May 14th. The combined precipitation during this timeframe amounted to 29 mm. The intensity of precipitation during these storms was relatively low. The total and intensity of precipitation is shown in the image below.

Figure 11 Total and intensity of precipitation on May



Based on the graph in Figure 14 and Figure 15, it is evident that the oat variant, cultivated using direct sowing technology (no-till) and with higher soil coverage due to plant residues, exhibited the lowest levels of surface runoff and surface erosive wash. This condition indicates effective soil protection against surface erosion. Conversely, the control variant, devoid of vegetation, demonstrated the highest expected surface runoff and erosive wash levels. In this scenario, the absence of vegetation leaves the soil vulnerable to erosion. However, a similar problem also occurs in stands of very early vegetation stages. The differences, especially in soil loss, would be even more apparent with a more intense effect of precipitation.

Figure 12 Surface runoff after rains in mid-May

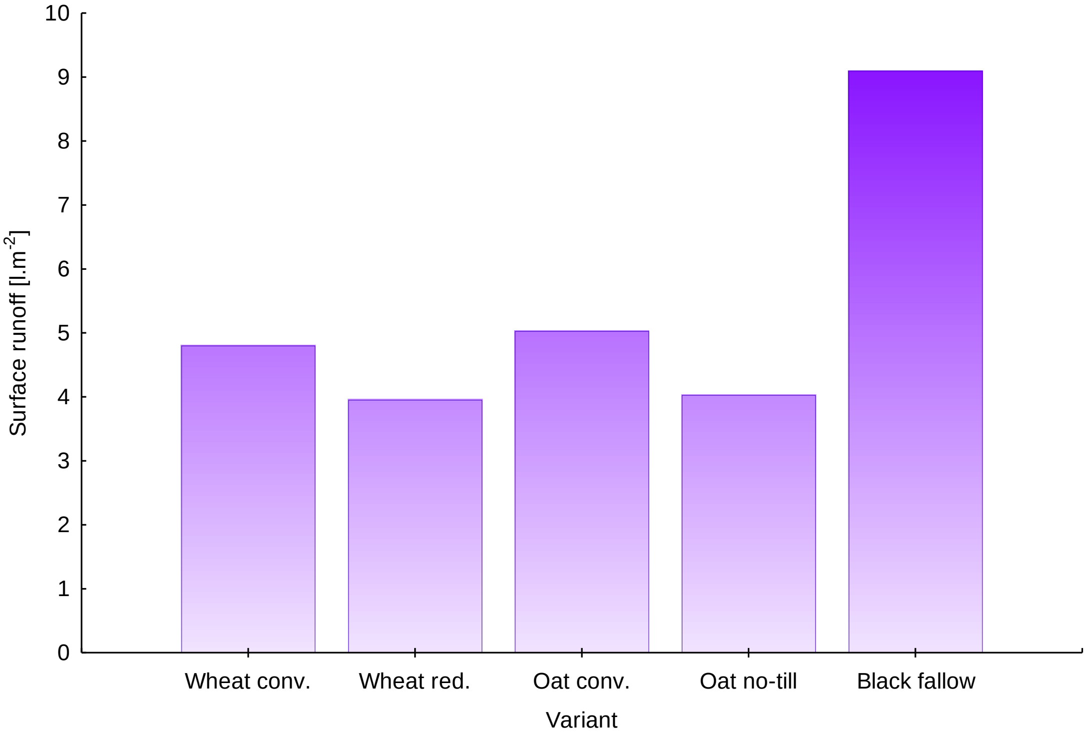
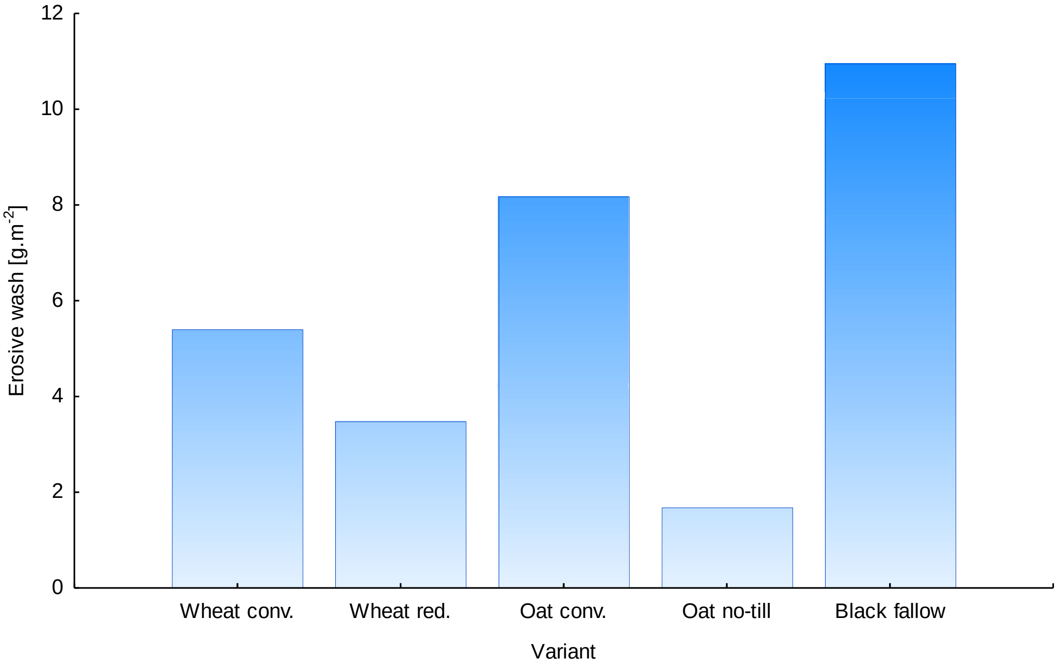


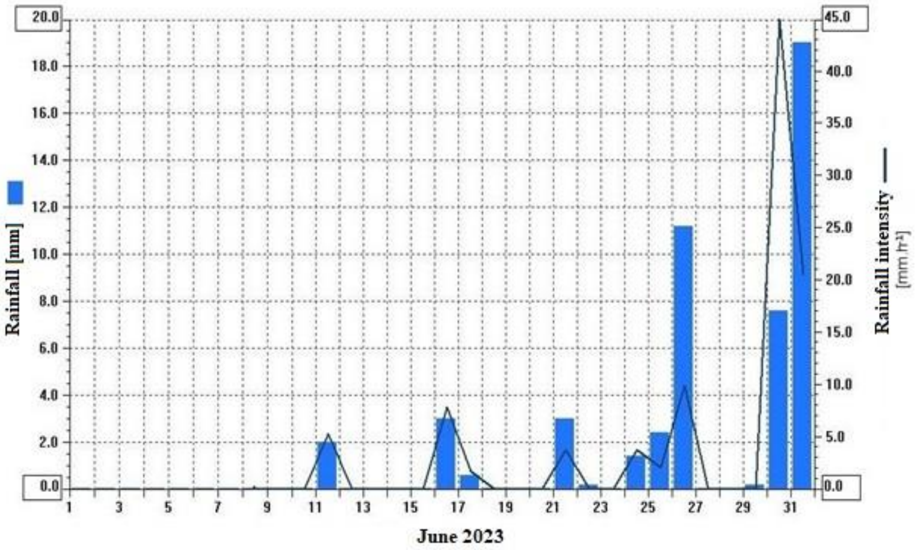
Figure 13 Erosive wash after rains in mid-May



During June, two notable erosional events occurred. The first event took place from June 25th to June 27th, accompanied by rain and a brief thunderstorm, accumulating 15 mm of precipitation. The intensity of rainfall remained relatively low during this period. The second event occurred towards the end of June, where two rainfall episodes contributed to

26 mm of precipitation. The intensity of these rainfall events peaked at 45 mm/h. The total precipitation and intensity of individual rainfall are shown in the figure below.

Figure 14 Total and intensity of precipitation in the month of June



Based on the data in the graphs below, it is evident that the oat variant with no-till technology exhibited the lowest levels of surface runoff and surface erosion wash. In contrast, variant 5 without vegetation (the control variant), demonstrated the highest measurements of surface runoff and erosion wash. Similar high values were observed in other variants utilising conventional technology, even with minor differences between the parameters. Higher differences are found for the parameter of soil erosion. This parameter is more critical as it represents direct soil loss.

Figure 15 Surface runoff after rain and brief thunderstorms on June 26-27

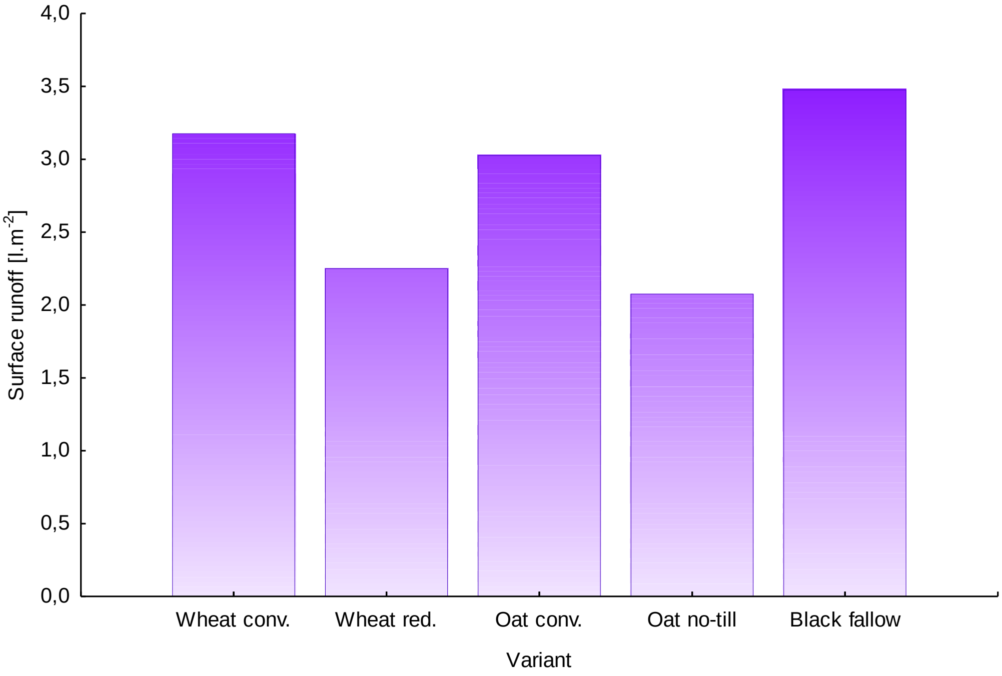
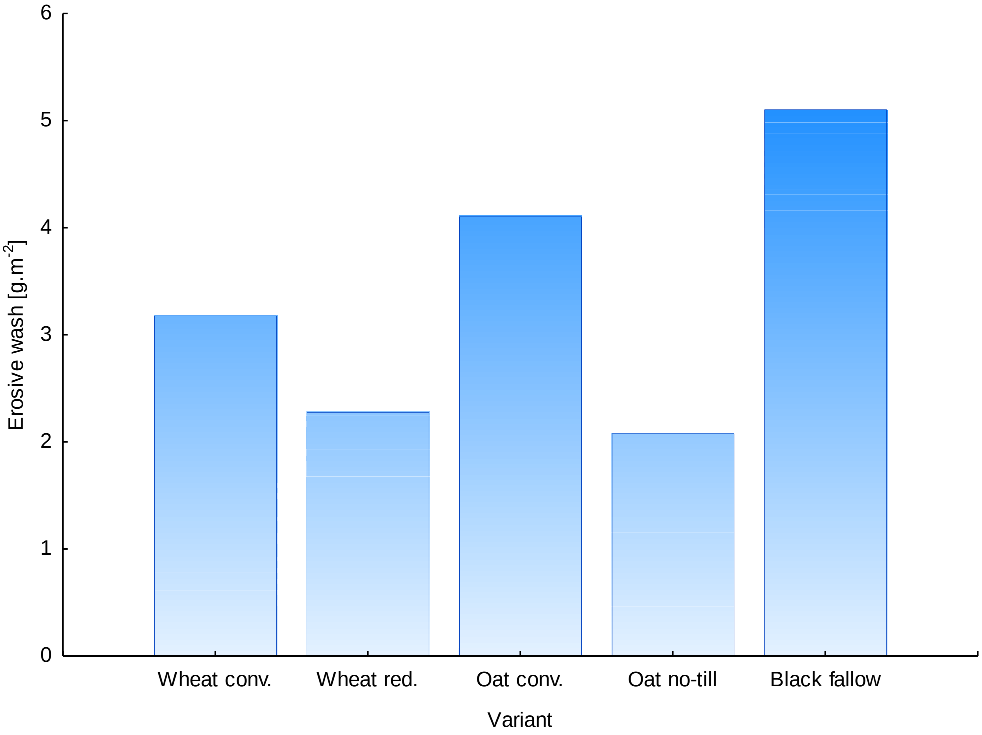


Figure 16 Erosive wash after rain and brief thunderstorms on June 26-27



The second significant erosional occurred around the transition from June to July. Upon examination of the graphs provided below, it becomes evident that the wheat variant with reduced tillage exhibited the lowest levels of both surface runoff and surface erosive wash during this period. This variant is characterised by full vegetation development, offering significant soil protection. On the other hand, the control variant show the highest levels of surface runoff and erosive wash. The differences between these measurements were particularly stated due to a storm with to high rainfall. Soil ineffectively protected by plant residues or underdeveloped vegetation experiences increased erosion, resulting in elevated soil runoff and surface runoff values.

Figure 17 Surface runoff after two storms in late June

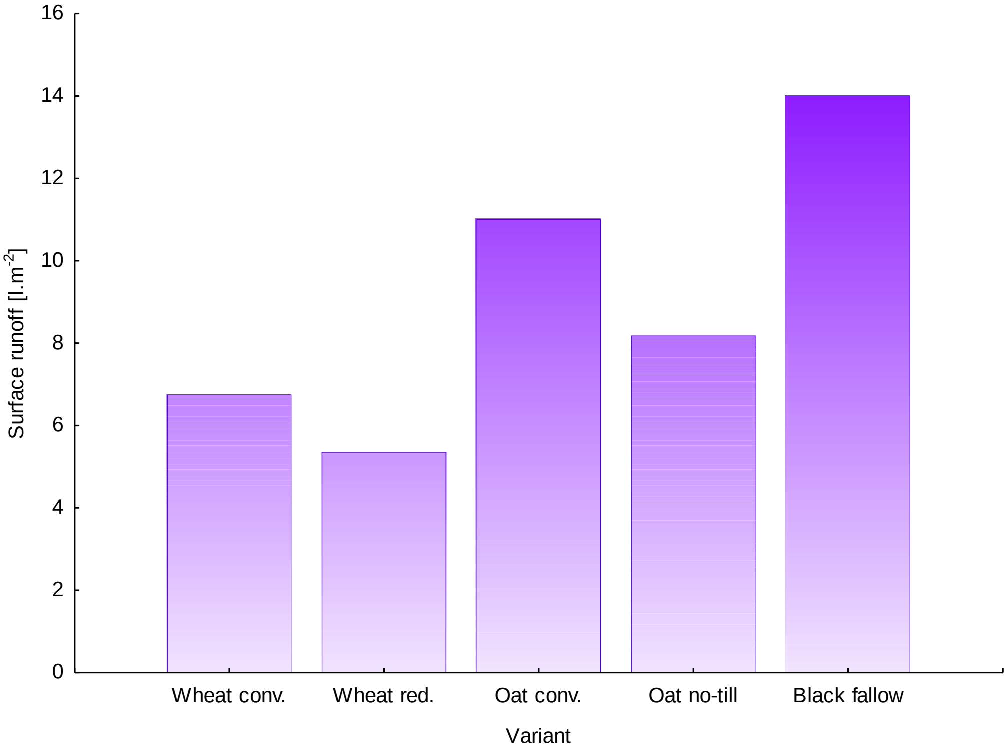
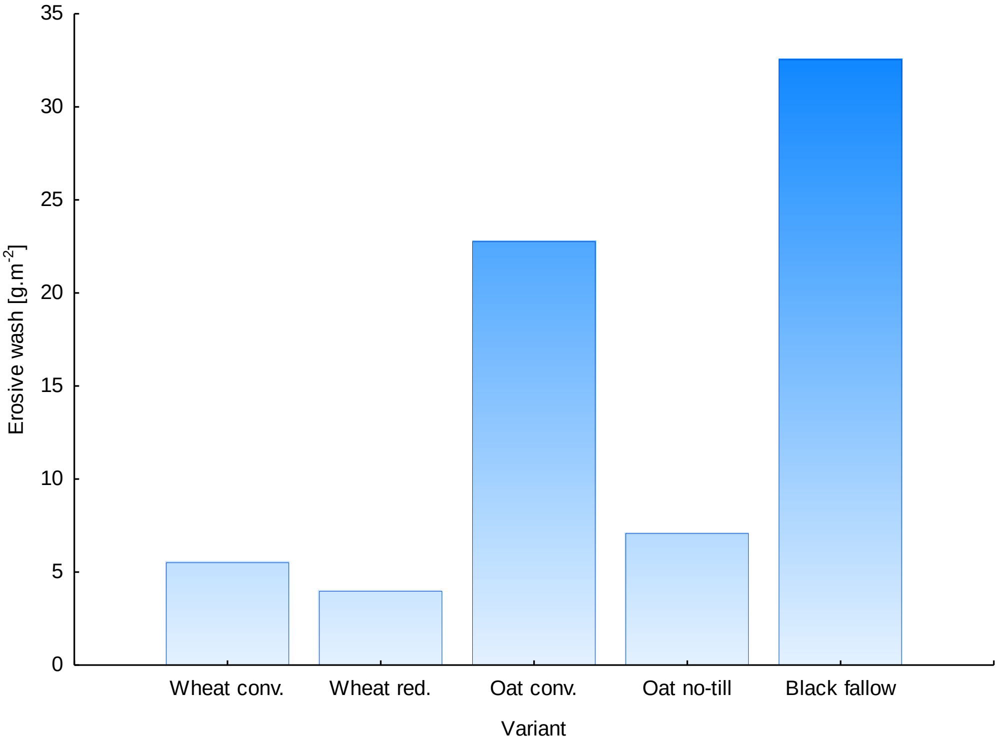
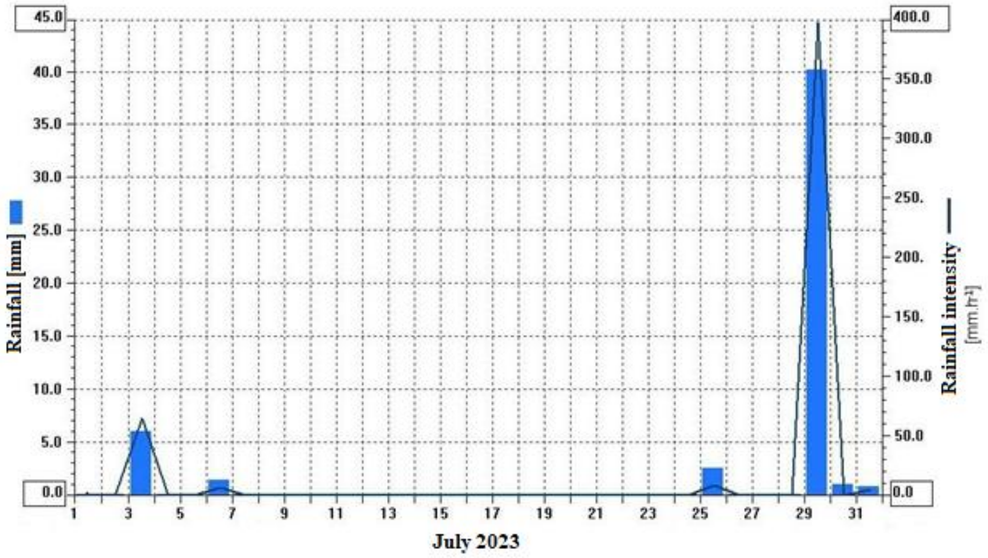


Figure 18 Erosive wash after two storms in late June



The fourth erosion event occurred at the end of July during a violent storm, when the total rainfall was 41 mm, and the rain intensity reached very high values (short-term).

Figure 19 Total and intensity of precipitation in July



The third and fifth variants exhibited notably high surface runoff values, which could be attributed to the prolonged period between erosion events, contributing to consistently elevated surface runoff levels. On the soil surface, a layer of dried-up soil was observed, likely formed due to the preceding storm and subsequent formation of a soil crust. It's essential to highlight that soil erosion values were notably higher in the control variant, which lacked vegetation. Furthermore, the unexpectedly high value observed in the conventional technology variant is significant. Despite relatively narrow spacing between the rows (0.15 meters), the flowing surface runoff still resulted in a considerable erosion effect.

Figure 20 Surface runoff during a violent storm in late July

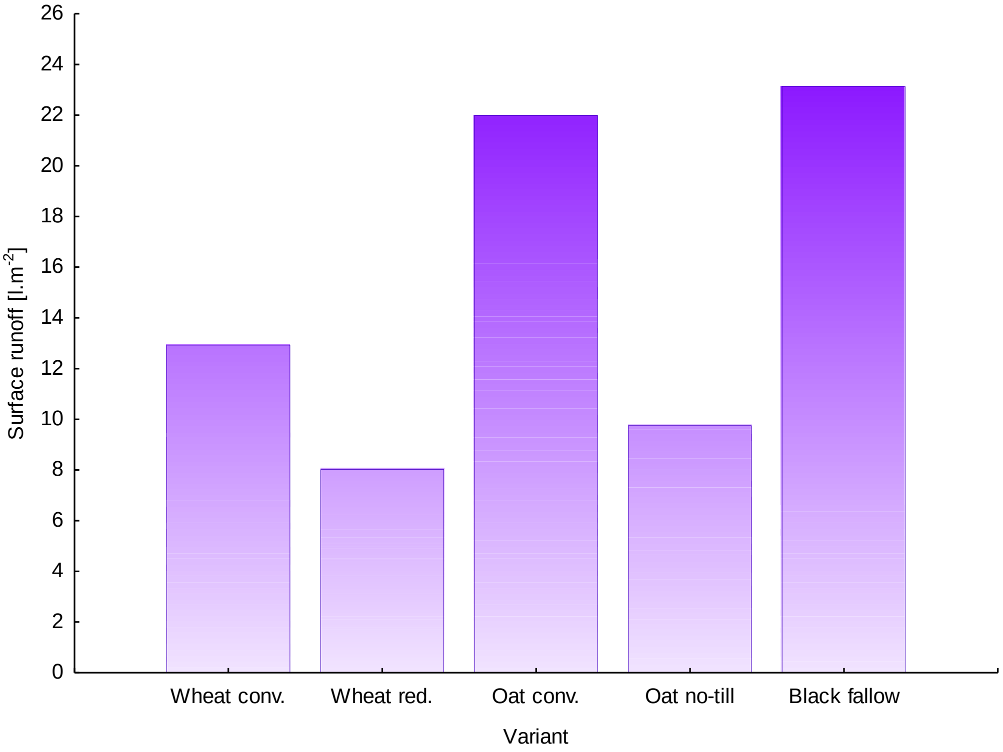
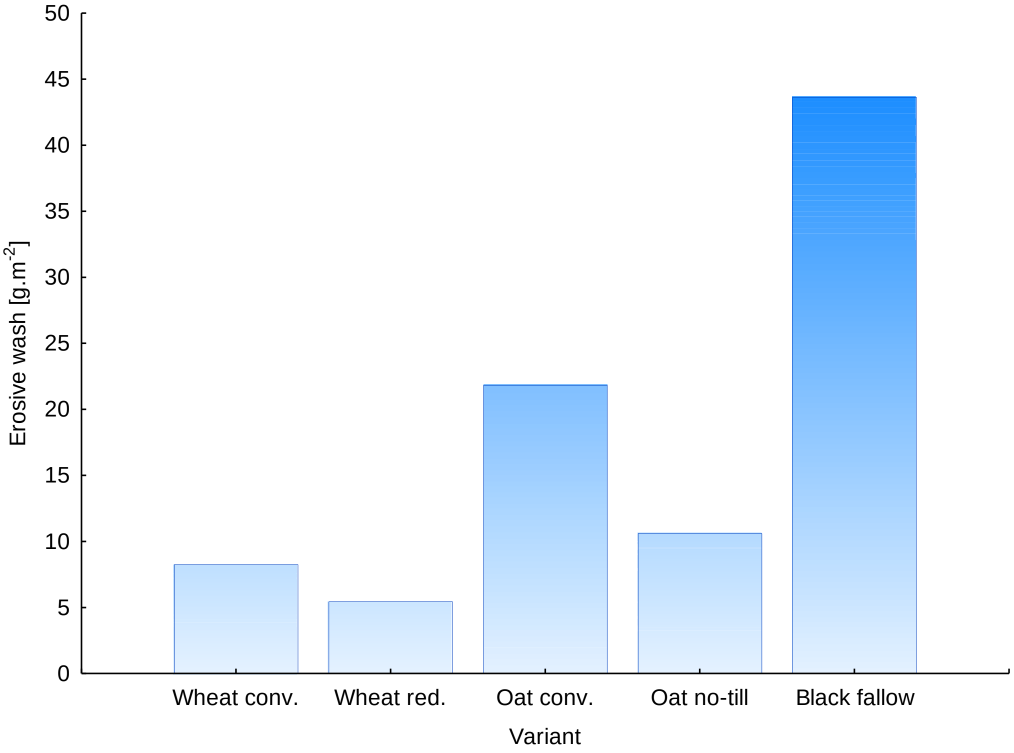


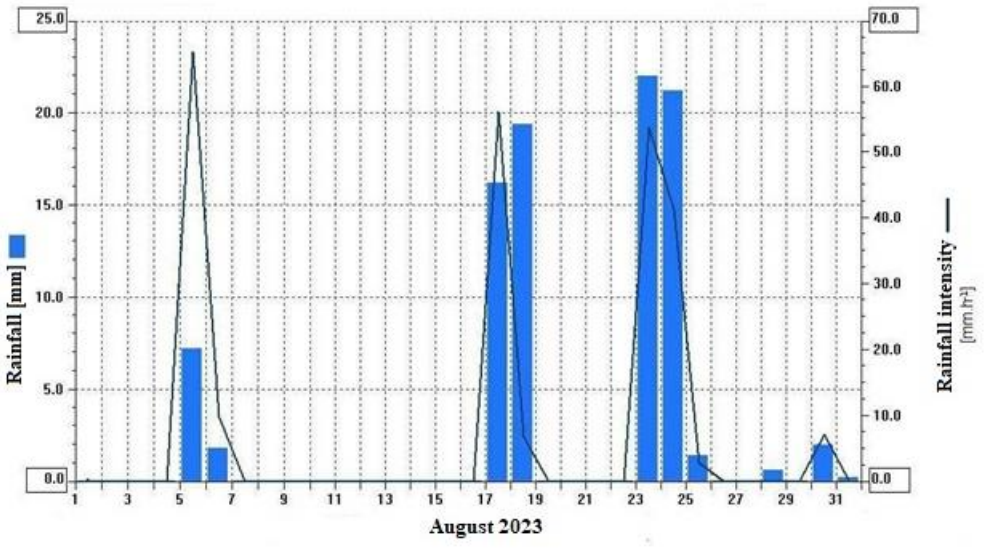
Figure 21 Erosive wash during a violent storm in late July



The final two erosion events that were documented occurred during the latter half of August. These events were associated with two significant storms featuring heavy rainfall.

The first event, transpiring on August 18th and 19th, entailed a substantial downpour amounting to a total of 35 mm of rainfall. The second event, transpiring as torrential rain during the night of August 24th to 25th, resulted in a slightly higher precipitation total, exceeding 44 mm. Both of these events were characterised by a significantly high intensity of rainfall, as indicated by the records from the meteorological station.

Figure 22 Total and intensity of precipitation in August



The graph below shows that the trend of the previous measurements was mainly established. However, especially in the case of surface runoff, there is a gradual reduction of the differences. In this case, it was observed that only the variant without vegetation showed a significant difference. The impact of tillage or the methods used to establish the crop are insignificant during rainfalls. This observation is also supported by the soil loss measurements, where only the variant without vegetation showed a significant deviation. However, it should be noted that the absence of vegetation cover limits this result. For the other variants, the land loss measurements were comparable as there was already only stubble on the land.

Figure 23 Surface runoff during heavy rain in mid-August

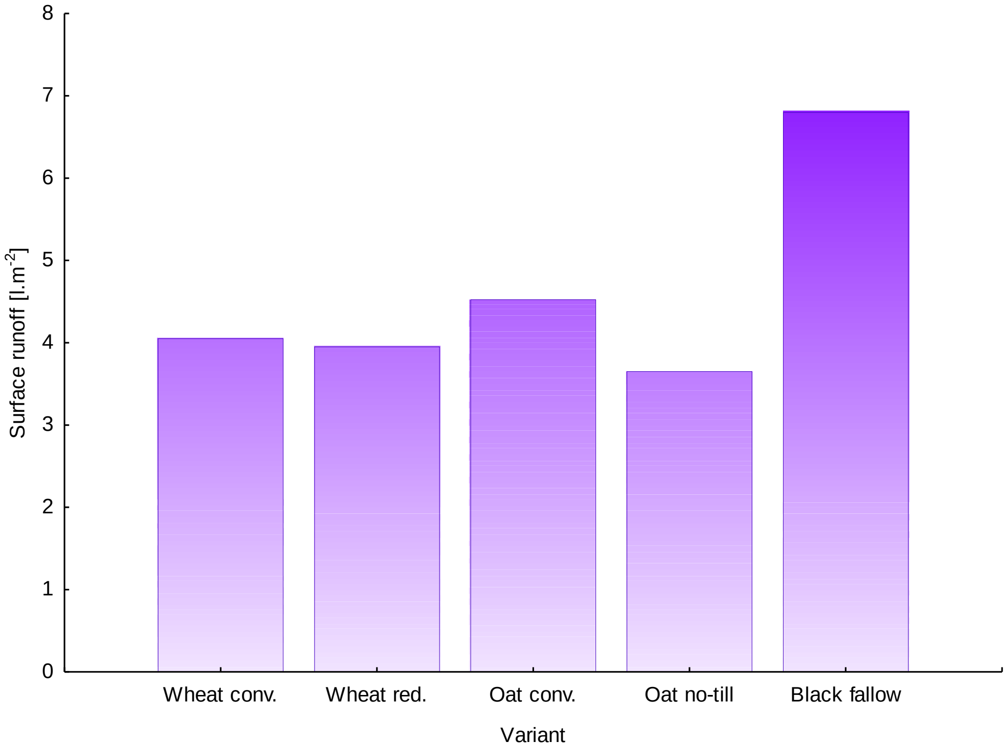
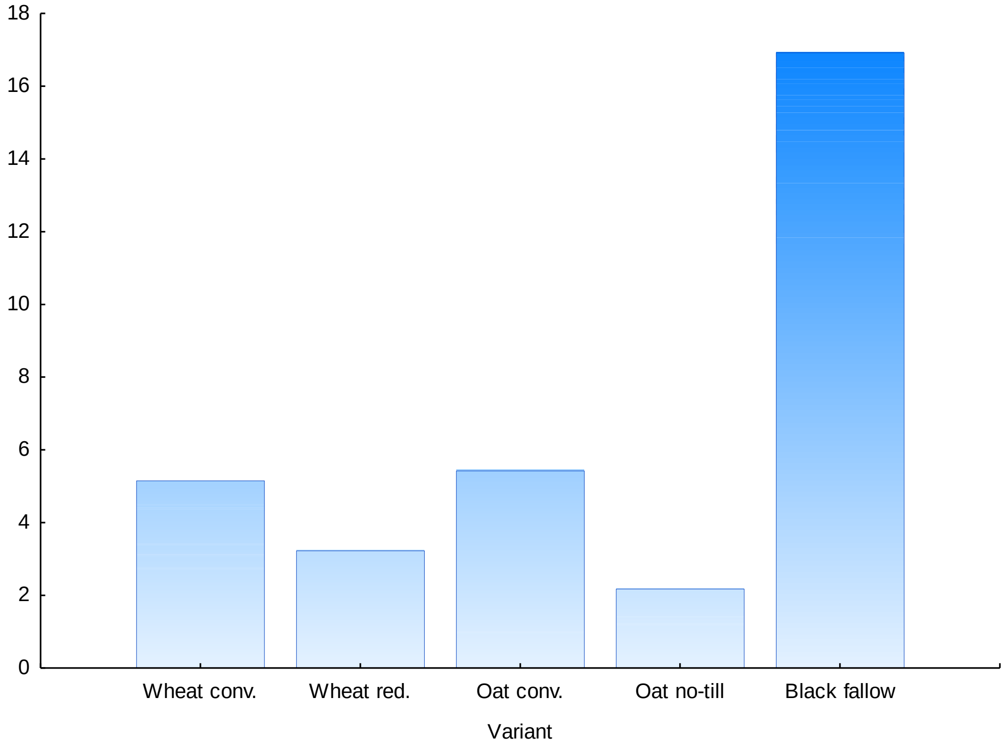


Figure 24 Erosive wash during heavy rain in mid-August



The graphs below show the progress of the last erosion event of the 2023 season. Especially for surface runoff, there was a further reduction in the differences between the basic four variants. Even in this case, only the variant without vegetation differed more significantly. The effect of tillage or methods of establishing the stand continued to decrease. The tillage system was also confirmed by soil erosion measurements, where only the variant without vegetation deviates significantly.

Figure 25 *Surface runoff during heavy rain at the end of August*

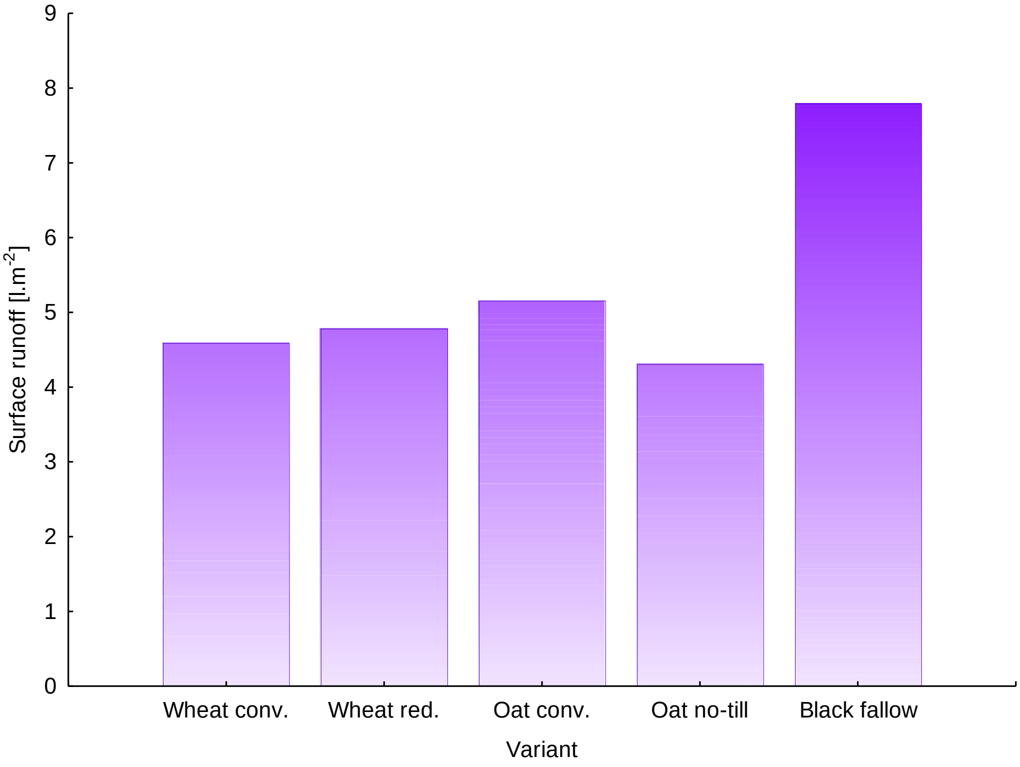
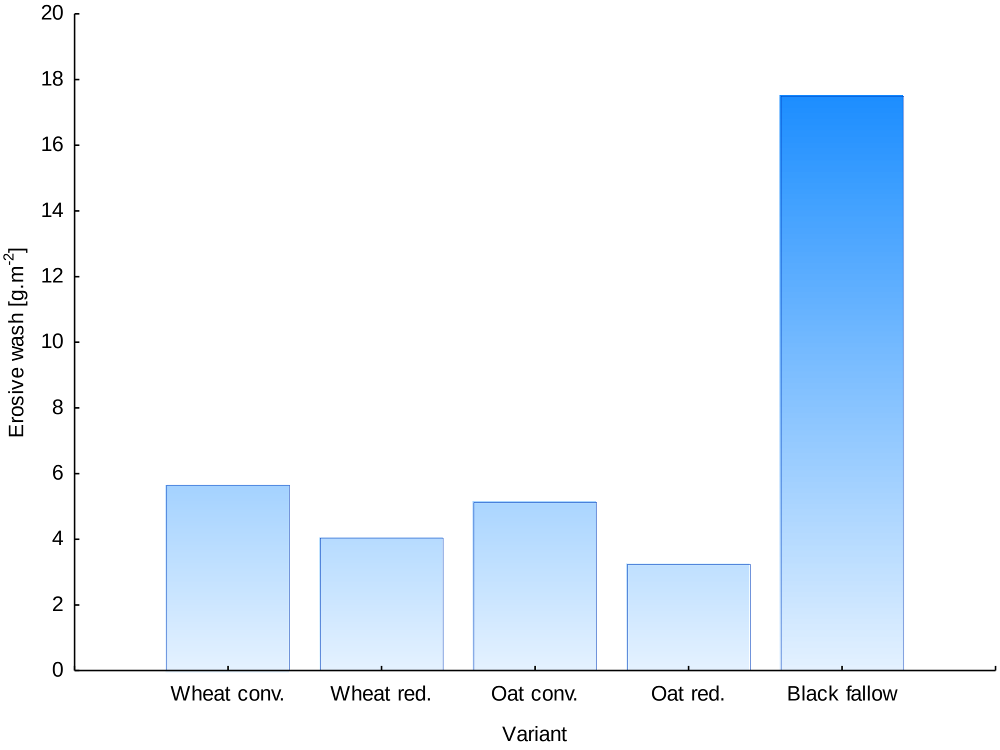


Figure 26 Erosive wash during heavy rain at the end of August



5.1 Brilliant blue measurement results

Figure 30 shows a picture of variant 1 - wheat with conventional tillage. The figure represents the 0.5 m length of the soil profile. It can be seen from the picture that the blue dye penetrated the profile very well, only in the upper layer of the soil. This results from the soil's natural subsidence and the long distance since the last tillage. The dividing plane, indicated by the depth of secondary tillage, is only crossed by a few parts of the soil profile. Generally, the solution quickly penetrates the soil profile, but only to the depth of the layer created by the last technological treatment, the secondary tillage. As a result, the impact of the soil tillage machine, which causes micro-compaction in the layer below the depth of treatment, is likely to be noticeable. The root system of wheat plants does not significantly disrupt this, which is reasonable considering the depth of the roots of cereals.

Figure 27 Image of dye infiltration after conversion - variant 1

In the Figure 31 picture, the blue dye evenly penetrated the entire soil profile of the reduced-technology wheat variant even deeper. Given the conditions of the 2023 season, this is a significant benefit of no-till systems without creating a compacted layer. Infiltration of water into the soil is very fast and uniform. This difference typically stands out in difficult conditions, such as the 2023 season. The amount of infiltration is lower in variant 1. The image displays traces of the cultivator blades, aiding the solution's penetration into deeper layers.

Figure 28 Image of dye infiltration after conversion - variant 2

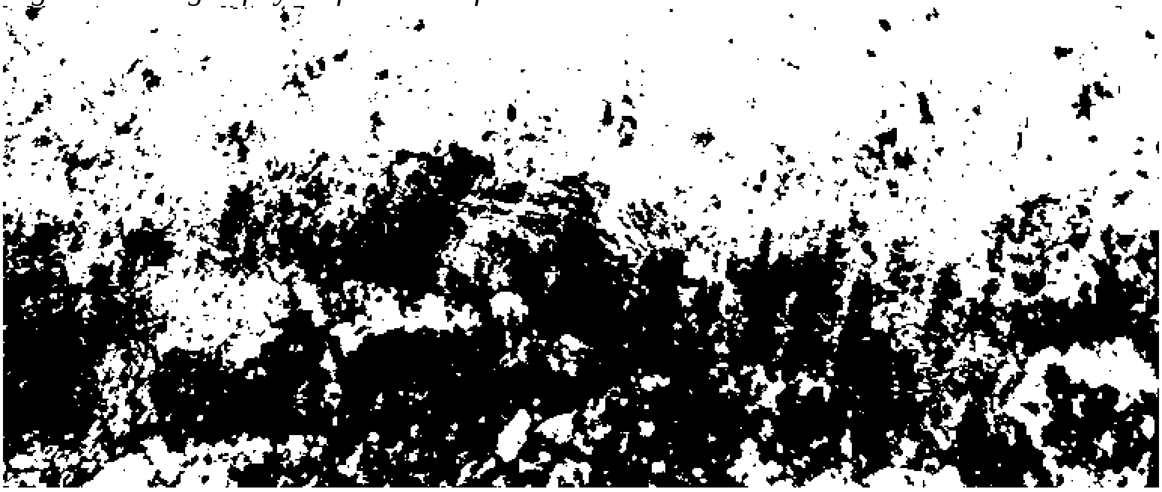
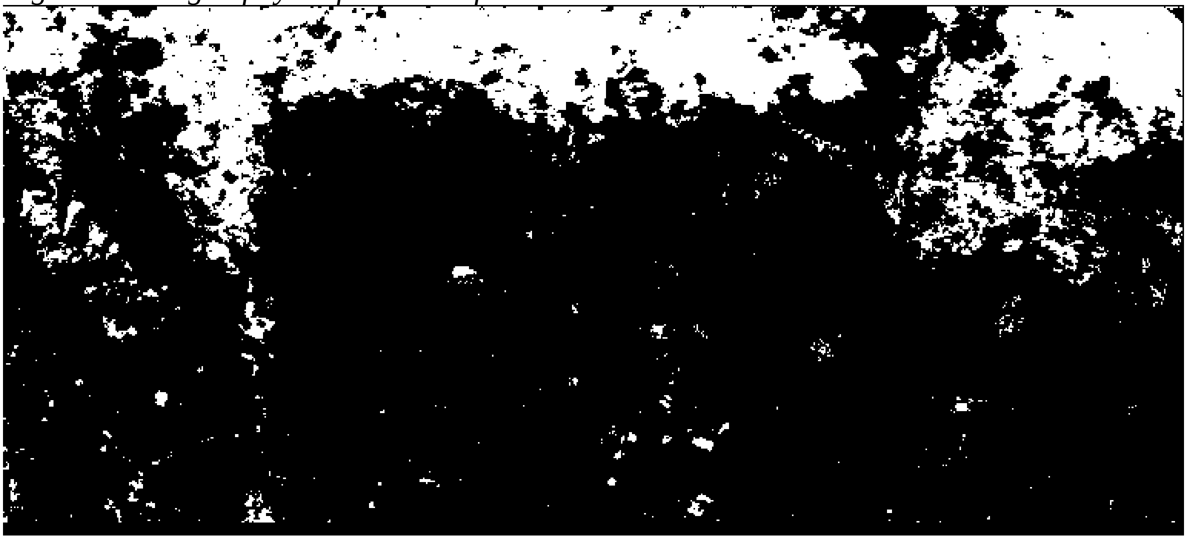


Figure 32 shows the course of infiltration in the third variant with oats with conventional tillage. The infiltration course shows a uniform but slow water infiltration into the soil. When the porosity of the soil decreases and the bulk density increases, the physical properties of the soil are impacted. In this case, water can infiltrate the soil, but at a much slower rate than the previous condition. The course is very similar to variant 1; there is a thin layer of technogenic compaction created during the secondary tillage when the working tools of the machine compacted the layer below. The preparation was carried out under relatively high soil moisture, which typically causes this infiltration character.

Figure 29 Image of dye infiltration after conversion - variant 3



The Figure 33 picture shows that the blue dye penetrated well through the entire soil profile but relatively more slowly than in variant 2. This variant could effectively drain water into deeper layers by directly seeding through a handicap in an area with temporary tillage effects. Moreover, due to the depth of the oat root system, this effect cannot be attributed simply to this influence. Thus, minimization systems can influence the infiltration capabilities of the soil and thus contribute to its anti-erosion protection. The effect would improve with the duration of the experiment, which is also the conclusion of many other studies (Johnson et al. 1988, Titi 2002).

Figure 30 Image of dye infiltration after conversion - variant 4

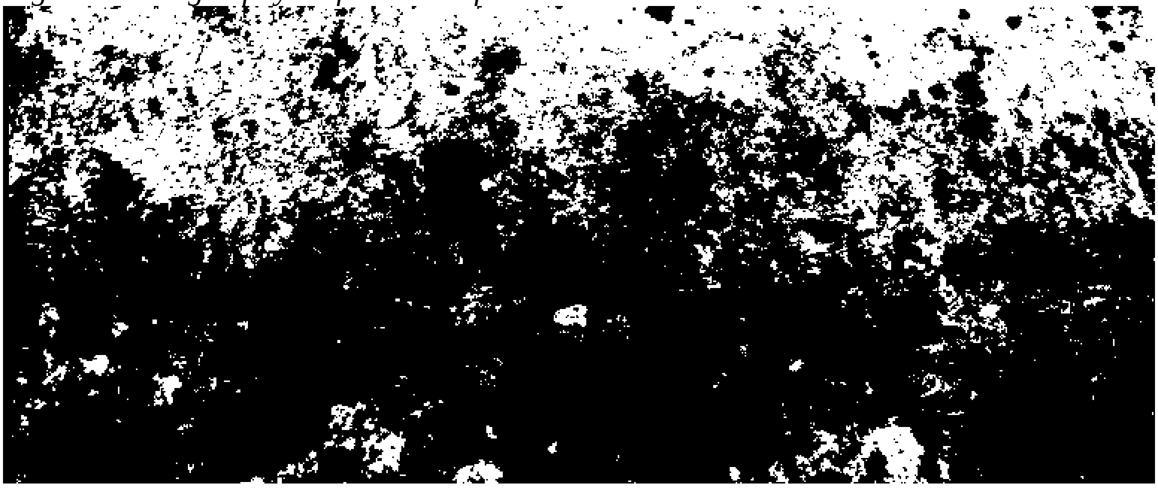


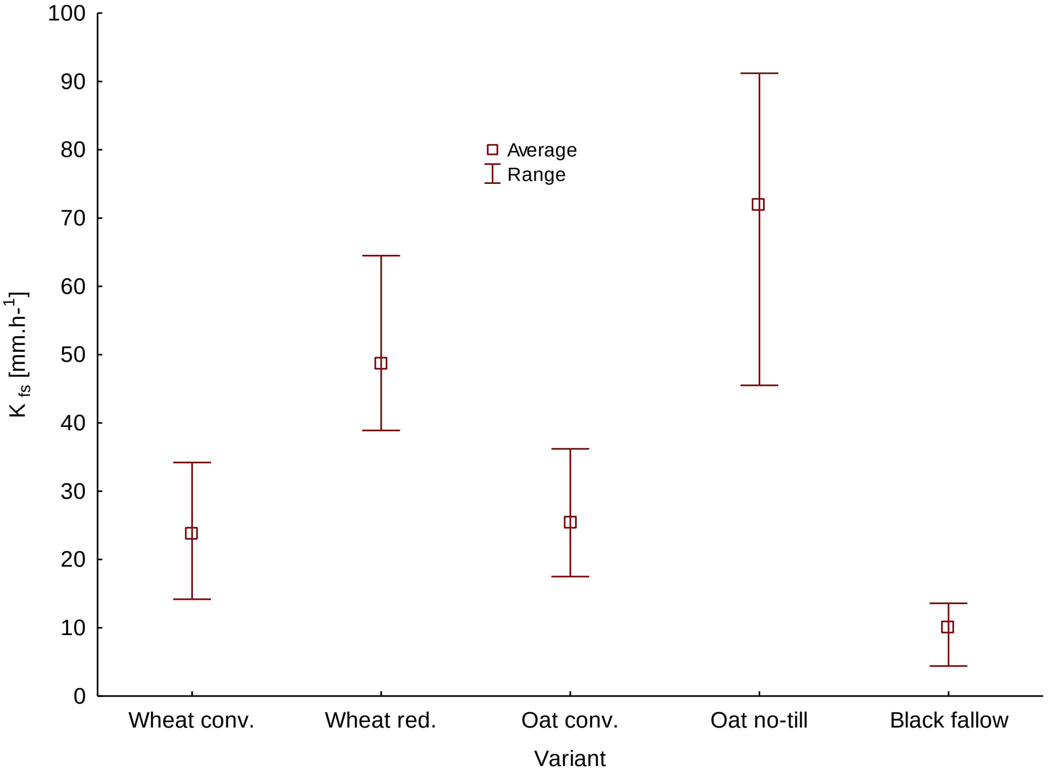
Figure 34 shows the course of infiltration in the control variant. The variant absorbed the solution better than expected. A rapid onset in the upper layer can be seen, but a slight influence of the deeper layers is also noticeable. It will probably be the effect of cracks created in the soil without vegetation due to the drying of the soil, which is different from the variants with plants. However, infiltration does not reach the values of the reduced variant, especially in deeper layers.

Figure 31 Image of dye infiltration after conversion - variant 5

5.2 Results of the SFH and Mini Discs methods

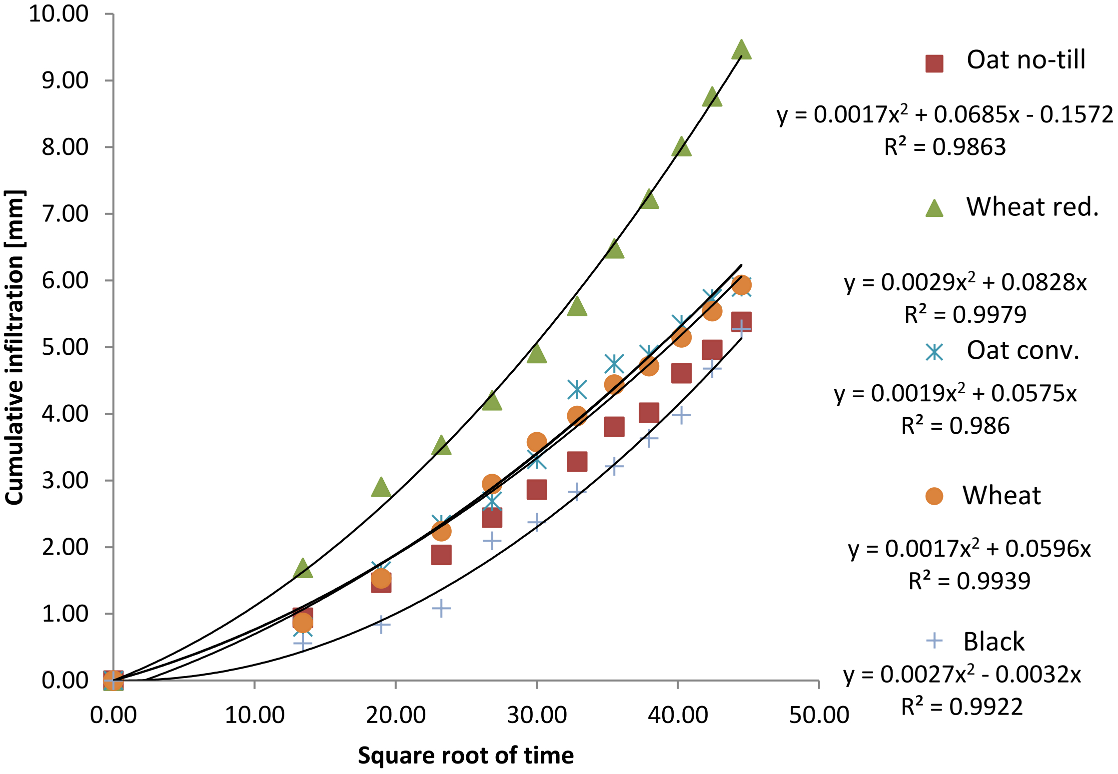
This graph below shows the Saturated Hydraulic Conductivity (Kfs) values in five different tillage systems measured by the SFH method. The Kfs value for the oat with no tillage and wheat with reduce tillage are higher than those of the oat and wheat with conventional tillage, while the black fallow treatment has the lowest Kfs value. This indicate treatment with higher Kfs value is better infiltration capacity and lower runoff, and erosion potential. The black fallow treatment has lowest Kfs value, indicating a reduced infiltration capacity and higher runoff and erosion potential.

Figure 32 Saturated hydraulic conductivity by the SFH method - June 2023



Another method used was evaluation by the measurement with circular infiltrometers (Mini disks). The graph shows the highest cumulative infiltration for the wheat variant based on reduced tillage. Other variants showed very similar values. The R-squared values of the fitted lines differ depending on the tillage system, indicating the proportion of the variance of the soil erosion parameters that can be explained by the tillage system. Wheat with reduced tillage has $R^2 = 0.9979$ indicating a good fit considered better than conventional tillage in term of soil erosion. The worst infiltration traditionally showed the variant without vegetation which is variant 5 or black fallow. Measurement by this method is undoubtedly significantly influenced by the condition of the soil surface.

Figure 33 Cumulative infiltration as measured in June 2023



6 DISUSSION

Based on the initial hypothesis, it was predicted that treatment variants characterized by higher soil coverage with organic matter during intense rainfall would lead to a decrease in surface runoff and erosive soil wash. However, it was expected that treatments involving reduced tillage technologies would result in lower surface runoff and erosive wash-off. The subsequent field experiment validated these hypotheses.

Following the field experiment, it was confirmed that reducing tillage practices indeed led to a reduction in surface runoff and soil wash-off. This reduction was achieved by employing measures to protect the soil during periods of potentially erosive rainfall, such as maintaining organic matter on the soil surface. By implementing such practices, the soil was effectively shielded from the kinetic energy of falling raindrops. Raindrops carry their kinetic energy to the soil particles when they strike the surface, causing the soil to break down and become more movable, causing splashing and the beginning of soil erosion. Raindrops separate soil particles from the topsoil during the early phases of water-induced soil erosion, which contributes to soil loss. This process is known as rainsplash erosion (Van et al., 2022). The field experiment provided empirical evidence indicating that reduced tillage practice resulted in only minimal unwanted soil erosion.

Based on the field experiment, it was evident that both the control variant of black fallow and the conventional tillage method used to establish the stand consistently resulted in high surface runoff and erosive wash levels. The trend was observed throughout all the measurement attempts. Variants without vegetation consistently showed a higher erosion rate. It was concluded that vegetation is crucial in protecting the soil from unwanted erosion caused by the force of raindrops. Leaving the soil uncovered without plant residues also negatively affected control variant 5 (black fallow) and led to increased surface runoff and soil erosion. Land left in a black fallow condition experiences more surface runoff because it's directly exposed to rainfall. This exacerbates soil erosion and deterioration, as surface runoff removes nutrients and soil particles. This process is especially hazardous on steep slopes and poorly drained soils, which can cause runoff to become torrential, eroding the soil's surface and removing essential topsoil (Grogan et al., 2012).

C. Brown et al. (1989) study suggested that newly disturbed soil is more prone to erosion than soil undergoing multiple drying and rewetting cycles. This susceptibility to erosion decreases over time from the initiation of the experiments, regardless of soil conditions, possibly due to changes in cohesive forces among soil particles. Our experiments found similar findings, as we observed reduced differences in surface water runoff and soil washing values over time. This suggests that the impact of heavy rainfall and soil washing diminishes gradually as the detachment of particles decreases with increasing time from soil preparation and seeding.

A significant change in the soil structure is observed when comparing soil conservation tillage with conventional tillage. This change affects the soil's capacity to absorb and transport water. Numerous studies, such as those conducted by Morgan (2009) and El Titi (2002), have described the positive effects of conservation tillage on soil's physical, chemical, and biological properties. According to Renard (1997), the physical properties of the soil play a crucial role in soil cultivation. These properties determine how the soil should be cultivated and what changes in physical properties are necessary to create the most favourable physical conditions for cultivated plants.

In line with the understanding that tillage disrupts soil structure, the experiment revealed significant changes in soil properties following different tillage practices. The disruption caused by tillage led to a breakdown of soil aggregates and disturbance of soil organisms responsible for soil stability. This disruption resulted in decreased soil stability and increased soil porosity in the tilled areas compared to untilled ones such as in variant 3 (oat with conventional tillage) and variant 4 (oat with no-till). Consequently, the tilled soil exhibited a lower density and increased aeration, as observed in the results. These changes in soil structure and properties underscore the significant impact of tillage practices on soil health and highlight the need for careful consideration of tillage methods to minimize soil disturbance and preserve soil integrity. These parameters eventually return to their original state over time. Natural soil subsidence is caused by precipitation, soil drying, biological activity, and agrotechnical practices. The change in soil structure after tillage also affects hydraulic conductivity and permeability to water, heat, and air. The effect of porosity can be seen in the types of pores that either retain water or promote water outflow. The intensity of tillage determines the orientation of the soil structure or pores. According to Leij et al. (2022), there are two soil structural states: a homogeneous layer with a horizontal structure formed by conventional tillage and a vertical structure formed by reduced tillage, created by biological agents and cracks.

Surface runoff, which occurs when water flows over the soil surface without infiltrating, is a natural process that does not inherently cause harm to the soil. However, if left unmanaged, surface runoff can carry sediments, nutrients, pesticides, and other pollutants, leading to soil erosion, loss of soil fertility, and water pollution. The intensity and duration of precipitation also play a crucial role in water erosion. Short rainfall durations can be managed by conventional tillage, which allows the soil to absorb the water gradually. On the other hand, during long-lasting precipitation, no-till or minimum tillage techniques that utilize plant residues on the surface can provide better protection against surface runoff and erosion.

7 CONCLUSIONS

Soil tillage plays a significant role in controlling water erosion, and the choice of tillage practice can significantly influence soil erosion and water conservation. Water erosion results in soil surface disturbance, transport, and sedimentation of soil particles. Agricultural land is most threatened in the conditions of the Czech Republic by water erosion, mainly caused by the intensive management of agricultural land. Existing literature suggests that implementing soil protection or reduction tillage technologies can help mitigate this undesirable phenomenon. The experiment provides evidence that conservation tillage practices lead to less surface runoff and soil wash-off as compared to conventional soil tillage practices. This finding supports the fact that conservation tillage practices effectively prevent soil erosion. Covering the soil surface with plant residues or vegetation during periods of increased erosion risk significantly reduces runoff and soil wash-off. Conservation tillage practices offer several advantages, including improved soil health, reduced soil erosion, enhanced water infiltration, lower need for manpower, and lower energy consumption. When using conservation tillage practices such as reduced tillage and no-tillage practices, the risk can be the spread of perennial weeds, acidification of the soil and more frequent occurrence of pests and fungal diseases. The most effective measure against water erosion is a suitable combination of organizational, technological and agrotechnical measures.

Based on the field experiment, the hypothesis about the favourable influence of reduced tillage technologies was confirmed. The experiment proved that covering the soil surface with vegetation during high rainfall intensity has a beneficial effect. It protects the soil from the significant kinetic energy of the falling drops and increases the infiltration of water into the soil. This, in turn, has a positive impact on minimal surface runoff and soil erosion wash. When comparing the literature search with the measurement results, the beneficial effect of covering the soil surface with vegetation is apparent. The vegetation cover and post-harvest residues should be present on the soil during periods of erosion-dangerous rains to protect the soil from unwanted soil erosion.

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