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Diploma Thesis

The Effect of Organic Fertilizers on Water Erosion Parameters

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Faculty of Engineering

DIPLOMA THESIS ASSIGNMENT

Amalia Firdausi Putri

Technology and Environmental Engineering

Thesis title

The effect of organic fertilizers on water erosion parameters

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Objectives of thesis

The aim of the work will be to evaluate the effect of organic fertilization in different doses on soil erosion parameters.

Methodology

A literature review of contemporary literature on the issue of water erosion will be compiled. The practical part of the work will be focused on the evaluation of a field experiment with different organic fertilizers. The data will be statistically evaluated and conclusions will be drawn from the measurements.

The proposed extent of the thesis

50pages

Keywords

surface runoff, erosive wash, organic matter

Recommended information sources

Ebabu, K., Tsunekawa, A., Haregeweyn, N., Tsubo, M., Adgo, E., Fenta, A. A., ... & Poesen, J. (2022). Global analysis of cover management and support practice factors that control soil erosion and conservation. International Soil and Water Conservation Research, 10(2), 161-176.

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Declaration

I hereby declare that this Master's Thesis entitled as **'The Effect Of Organic Fertilizers On Water Erosion Parameters'** 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

Amalia Firdausi Putri

Acknowlegement

I sincerely thank the late Governor of West Nusa Tenggara, Dr. H. Zulkiflimansyah, S.E., M. Sc., LPP-NTB and BRIDA NTB for trusting me to pursue my master's degree in Europe, especially at The Czech University of Life Sciences.

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Lastly, I want to thank me for not giving up on many obstacles that were coming through.

"Indeed with hardships comes ease".

Abstract

Finding ways to improve soil health while minimizing environmental damage caused by water erosion is crucial. This research evaluates the effect of the dosage in organic fertilizers impacting the surface runoff rate and erosive wash. This study focuses on the analysis of organic fertilisers, specifically manure, digestate, and compost. The study was carried out in the vicinity of Nesperská Lhota Village, located in the Czech Republic. The correlation between soil carbon content and fertilisation with organic fertilisers, as well as other metrics and technologies, is indeed influenced. The aforementioned concepts can be directly associated with the measurements conducted at the Nesperská Lhota site. Based on the assessment of the measurements, it is evident that the manure yielded the most favourable results. The digestate and compost versions exhibited a little unexpected outcome when administered at a dosage of 200 t.ha-1. It is thought that the digestate has partially clogged the soil pores, hence decreasing the soil's capacity to absorb water. Compost had a lower water infiltration rate compared to different types of manure. This phenomenon can likely be attributed to the lack of bigger macroparticles. The significance of this effort will progressively escalate as time progresses. The continuously growing population necessitates a greater quantity of food, while simultaneously acknowledging that land is one of the few resources. Undoubtedly, the proper utilisation of organic fertilisers is a prominent future trend in agriculture.

Keywords: runoff, erosion, erosive wash, compost

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1 Introduction

Water erosion is considered a major concern in agricultural research, with substantial implications for soil health and environmental sustainability. The need to mitigate water erosion is becoming more pressing as agricultural intensification increases in response to population growth. Manure, digestate, and compost are examples of organic fertilizers. They are promising as interventions because they can improve soil structure, retain moisture better, and promote ecological resilience. But in order to advance sustainable land management methods, a detailed understanding of how these organic inputs, especially at different doses, affect water erosion parameters is necessary.

This research aims to clarify the impact of different amounts of organic fertilizers—manure, digestate, and compost, in particular—on important water erosion parameters, such as surface runoff and erosive wash rate. This study aims to provide empirical knowledge to the conversation on sustainable agriculture and soil conservation by investigating the differences in the impacts of various organic fertilizers and the rates at which they are applied on erosion dynamics.

Developing our study idea requires formulating two hypotheses. First, we hypothesise that water erosion parameters benefit from the application of organic fertilizers. This claim is supported by research demonstrating the benefits of organic amendments to soil, including increased soil stability and decreased erosion susceptibility. Second, we expect variation in the effectiveness of different fertilizers and dosages. It makes sense that different organic inputs would have different capacities to reduce erosion given their varied compositions and nutritional profiles.

This study attempts to give empirical support for our theories through systematic experimentation and statistical analysis. Our research aims to contribute to the sustainable management of soil resources and educate evidence-based agricultural practices by clarifying the function of organic fertilizers in reducing water erosion. We pay particular emphasis to the dosage-dependent effects of organic fertilizers.

2 Objective

The objective of this study is to assess the impact of varying dosages of organic fertilizers such as manure, digestate, and compost on soil erosion parameters especially surface runoff and erosive wash rate.

2.1 Hypothesis

1) Organic fertilizers have a beneficial effect on water erosion parameters.
2) A different effect of individual fertilizers and doses will be observed

3 Literature Review

3.1 Introduction to the issue

Sustainable agriculture is critical in this modern world, where lands are used more for buildings. Along with climate change, soil health has worsened. Therefore, finding ways to improve soil health while minimizing environmental damage is essential. Because organic matter improves the physical, chemical, and biological qualities of the soil, it is crucial for nursery management.This advantage indeed improves the soil quality and resistance to water runoff and erosive wash (Davey, 1984). Maintaining the sustainability of cropping systems, and adopting appropriate management practices can enhance its preservation and environmental benefits. It is a key to a balanced global carbon storage, and to mitigate climate change (Fageria, 2012).

One way to enhance the quality of soil is by using fertilizers from organic compound and leftovers. Manure, compost, digestate are included. A range of studies have demonstrated the positive impacts of organic fertilizers, such as manure, compost, and digestate, organic matters and properties of the soil. Studies result in the application of compost can promote improvements in soil chemical properties, including increased organic carbon content, cation exchange capacity, and total bulk of nitrogen (Mensah & Frimpong, 2018; Nada et al., 2012).

This research delves into the complex topic of organic fertilization, exploring its potential to prevent one of agriculture's most significant ecological threats as known as water erosion. Water erosion is a severe problem that affects agriculture and the environment. Its impact on crop productivity has become more significant over time, leading to soil degradation, and negatively affecting soil organisms. Monoculture farming systems such as corn farming are one of the objects most vulnerable to water erosion. Therefore, it is necessary to conduct research on soil properties based on the application of various doses of organic fertilizer to determine the level of soil resistance.

This study carefully examines how different amounts of organic fertilizers (compost, digestate and manure) affect soil erosion parameters in. This investigation challenges traditional perceptions of fertilizer use and opens the way towards sustainable agriculture that balances productivity with environmental wisdom.

3.2 Soil

Soil is the most divergent and crucial environs on the planet. The enormous amount of natural processes continuously active in soils are fundamental for maintaining other ecosystems in the main planet (Roger-Estrade et al., 2010). According to (Weber et al., 2022), soil normally defined as organic soil crusts (biocrusts) formed by a close connection between soil particles and diverse photoautotrophic and heterotrophic microbes that live inside or on top of the uppermost layers of the soil. This statement is emphasized by Gomiero (2016), stating that erath's surface comprises soil, living beings, mineral particles, water, air, and organic materials.

Soil is where plants develop, and nutrients are recycled. It is an important agricultural medium that promotes plant development and provides crucial ecosystem services. The existence of microbes is what makes the soil has different qualities. These organisms (cyanobacteria, algae, lichens, bacteria, fungi, and archaea) perform a crucial part in aggregating the soil particles as well as producing a cohesive layer on the ground surface, focusing on biocrusts' ecological functions and global distribution, as well as emphasizing their importance in ecosystem and Earth system functioning.

Aggregation refers to the process of combining many soil particles to form a cohesive unit called an aggregate (Figure 1). Strongly aggregated soil refers to soil that possesses a stable soil structure and is conducive to plant growth (Gowariker et al., 2008).

Figure 1. The aggregation of soil fragments results in the creation of clods

Source: (Gowariker et al., 2008)

3.2.1 Soil Organic Matter

Soil organic matter, a mixture of plant and animal residues, microbial biomass, and other soil sources, helps maintain soil fertility, nutrient cycling, and health. It contains partially degraded plant debris and microbial residues, allowing nutrients to be released for further processing. Soil organic carbon is a vital storage of carbon in the Earth's carbon cycle, and its quality impacts soil health and productivity.

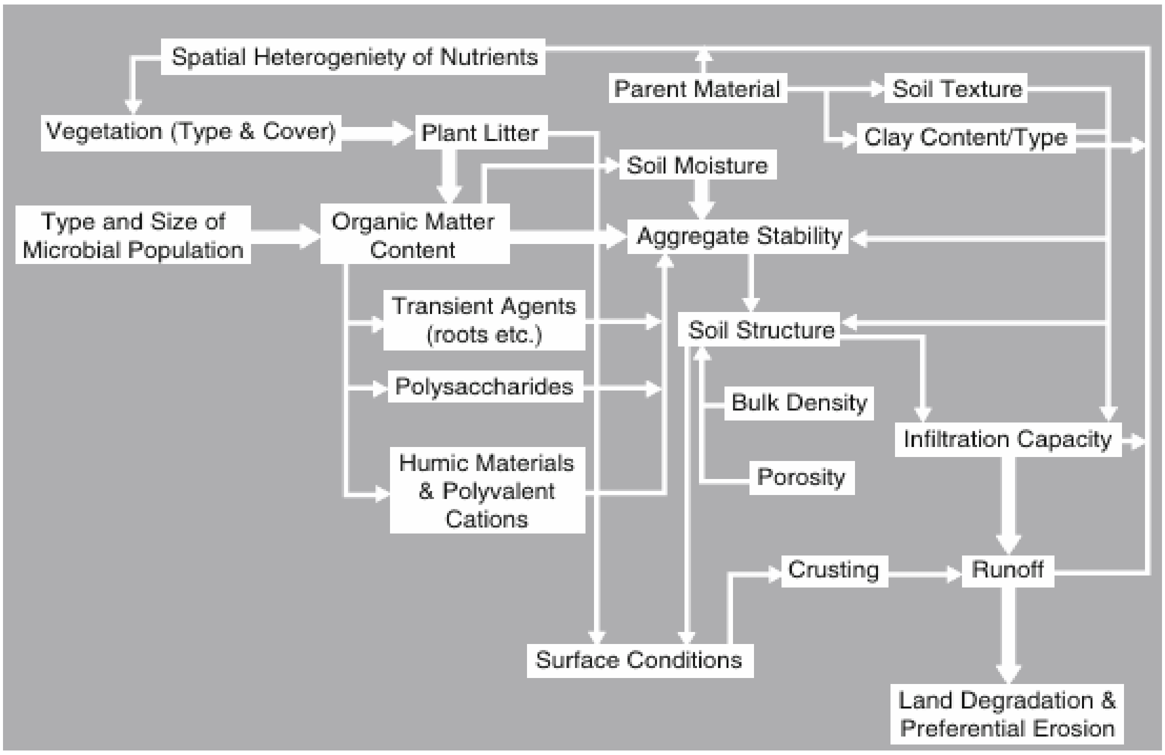
Soil organic matter (SOM) includes the naturally occurring compounds found in the soil that result from the disintegration of animal and plant remains (Averill, 2016). (Soong et al., 2021) statement compliments this definition by stating that a diverse mixture of plant and animal leftovers, microbial biomass, and other soil sources makes up soil organic matter. It contains partially degraded plant debris and microbial residues and helps maintain soil fertility, nutrient cycling, and health. Soil fauna and saprotrophic fungi have a vital function in decomposing macrobes in the soil layers. This process liberates nutrients that are bound in organic matter, making them more accessible for further processing by the soil food web and for absorption by plants (Bender et al., 2016). The study conducted by Sierra et al. (2015) examines the effect of temperature and moisture change on the breakdown of organic matters in soil. However, the study emphasizes the difficulty in accurately anticipating the impact of environmental global change on the rates of soil carbon decomposition and the continued challenge of establishing precise mathematical models.

Soil is known for the ability to store carbon for a long period of time. Soil organic carbon is a major reservoir of carbon in the Earth's carbon cycle, three times bigger carbon storage than the Earth's atmosphere (Hicks Pries et al., 2017). Aggregate stability and organic carbon are significant markers of soil structure and functionality, among other soil characteristics. Soil's physical structure is composed of various components, and one of the critical aspects is aggregate stability (Rabot et al., 2018). The natural chemical contents in organic fertilizer can help the development of crops. In large macro-aggregates, nitrogen treatment can enhance soil aggregation and carbon occlusion. This may enhance carbon sequestration by slowing down soil organic matter decomposition and stabilizing it against microbial degradation (Riggs et al., 2015).

Organic matter is an essential constituent of soil that significantly impacts its physical, chemical, and biological characteristics (Medina-Méndez et al., 2019). It provides essential nutrients, enhances microbial activity, improves soil structure, and helps retain moisture. Its quality is significant factors that impact soil health and productivity where it serves well-being of the soil. In agricultural practices, ensuring that soil organic matter levels are maintained at adequate levels is vital for sustainable crop production and environmental conservation (Te et al., 2022). In annual agricultural systems, particularly those that are intensive and mechanized, tendency for a reduction in soil organic matter does exist. Tillage increases soil aeration and removal, promoting the breakdown and mineralization of organic materials by soil microbial flora (Davidson & Ackerman, 1993; A. J. Miller et al., 2004).

3.3 Land Degradation

Optimal soil health is crucial for agriculture and to fulfil essential human requirements such as sustenance, livestock feed, textile production, uncontaminated water, and breathable air. Which also essential for ecosystems and foremost ecosystem services (Borrelli et al., 2017). Thus called land degradation refers to the decrease or loss of yield in many types of land, such as forest, agriculture and uncultivated land. This definition is in line with the UN Sustainable Development Goals indicator system, highlighting the influence of land degradation on the productivity and sustainability of various land cover types (Kussul et al., 2023). Land degradation is also about soil organic carbon (C) and nitrogen (N) storage loss, impacting services and productivity. Soil organic C is heterogeneous, varying in physical, chemical, decomposability, and its cycle (Dlamini et al., 2014; Traoré et al., 2015; von Lützow et al., 2007).



Land degradation can be caused by natural catastrophes such as earthquakes, tsunamis, droughts, and volcanic eruptions, as well as by human activities like deforestation, overgrazing, urban sprawl, and pollution. It diminishes productivity, stimulates migration, harms ecosystems, leads to food poverty, and results in biodiversity loss. Various indicators used to detect land degradation in arid areas, with vegetation being the most frequently recognized. (Mueller et al., 2014) explained two reasons according to this issue. Vegetation change is the most readily apparent alteration in the landscape. In most dry locations, the main land use is the practice of grazing for domesticated cattle. The close association that exists between vegetation and other biophysical functions of the environment. Any shift in vegetation will result in a concurrent change to these functions.

Figure 2. conceptual scheme showing the relationships between the physical and chemical markers of land degradation in the soil
Source: (Dickie & Parsons, 2012; Hochstrasser et al., 2014)

Another factor that makes degradation becoming worse is because the role of stakeholders. Montfort et al., (2021) study on Mozambique's land degradation assessment highlights stakeholder definitions' impact on quantitative evaluations. It provides a methodological framework for assessing land degradation status, offering insights for mitigation policies. When discussing land degradation in rangelands, (Inman et al., 2020) highlight the strain and diminished capability for critical functions. To address this pressing environmental concern, the necessity of mapping rangelands are stressed, taking into account community perceptions, and coordinating ecological conditions with community perceptions.

By restoring natural processes to humanized landscapes, plant and microorganism-based treatments can reduce land degradation. These solutions boost biodiversity, decontaminate, and restore degraded land. These measures, which entail major cultural, organizational, and governmental changes, may reduce urban land degradation, especially in abandoned industrial regions (Fernandes & Guiomar, 2018). McKinley et al., (2017) highlights the significant role of citizen science in conservation efforts, natural resource management, and environmental protection. They emphasize its role in building scientific knowledge, informing policy decisions, and encouraging public engagement, showcasing its rigorous nature.

3.4 Soil Erosion

Soil erosion is the separation of soil particles from the soil mass and their transportation by erosive factors like water and wind. Historically, earth's surface and landscapes have been shaped by soil erosion over millions of years. Early Earth crust formation and weathering processes created soil, which led to soil erosion. Soil erosion has been affected by climate change, vegetation cover, land use, and human activity (Jäger et al., 2015).

Rain splash causes soil separation, although strong rainstorms, weathering, tillage, and livestock trampling also contribute. Transportation agents include rainsplash, surface runoff, overland movement, wind, and rill water. Erosion is measured by how much material eroding agents remove and carry. The most apparent type of land degradation is water-induced soil erosion caused by storms and soils with inadequate surface structural stability. (Barman et al., 2013).

Ayoub (1998) on his study in Sudan summarized that the dry zone experienced severe soil degradation primarily due to wind erosion. Soil erosion issues continue worldwide, even if efficient conservation measures are accessible. In the US, the Soil Conservation Service advocated for contour planting and no-till technology, but farmers stopped using crop rotations and hedgerows, leading to soil erosion levels staying consistent since 1935. Human population increase and the utilization of crop wastes for fuel are other factors contributing to soil erosion in many nations (Pimentel, 2009).

3.4.1 Wind Erosion

Wind erosion is the initial cause of storm-related soil erosion, which is also the most noticeable kind. Wind erosion is a serious global concern. The phenomenon of wind erosion presents considerable obstacles as it leads to the depletion of soil fertility, air pollution, impaired road maintenance, hindered seedling growth, diminished crop marketability, and the alteration of desert landscapes. In addition, have significant negative impacts on the environment, including soil fertility, air quality, road maintenance, seedling growth, crop marketability, and the development of desert landscapes (El-Baz & Hassan, 1986).

Parameters favorable for wind erosion are present when the soil is characterized by looseness, dryness, and fine granulation; the soil surface exhibits smoothness and lacks vegetation cover; and the prone region is sufficiently large. Semiarid and arid climates frequently exhibit these conditions (Lyles, 1988). The process of wind erosion is a significant environmental concern that affects numerous regions, resulting in land degradation and a negative impact on air quality. Dust emission is a critical factor that influences atmospheric conditions and the global climate. Multidisciplinary approaches and computational modeling efforts are essential in the research on wind erosion, emphasizing its importance (Mysak et al., 2009).

Several measures can be employed to mitigate wind erosion, such as narrowing the field width, preserving vegetation residues on the soil surface, employing stable soil aggregates or clods, roughening the land surface, and leveling the ground (Tibke, 1988).

3.4.2 Water Erosion

Water erosion is a significant process when soil particles become separated and transported by erosive substances, including rainfall and runoff. It is an important factor contributing to land loss and soil damage worldwide (Arabameri et al., 2018; Borrelli et al., 2020; Wu et al., 2022). The mechanisms of water erosion are linked to the routes followed by water as it flows through the vegetation and across the ground. During rainfall, a water descends directly onto the land, either because of the absence of vegetation or as it permeates through openings in the plant canopy. The canopy absorbs precipitation, which can evaporate into the sky or flow down the plant stems as streamflow or drip from the leaves. The direct throughfall and leaf drainage generate rain splash erosion. Small indentations or hollows on the surface or seepage into the soil might store precipitation. When the soil exceeds its water absorption limit, any more water causes surface runoff, which causes overland flow or rills and gullies (Morgan, 2005).

Unsustainable land use, unfavourable climate patterns, and population increase diminish ecological resilience. This impacts global ecosystems, food security, livelihoods, and societal stability. Degraded drylands need rehabilitation, including passive and active restoration, soil reclamation, and forest landscape restoration, according to the evaluation (Yirdaw et al., 2017).

The Universal Soil Loss Equation (USLE) started accelerated erosion, which has been linked to civilization collapse, over 70 years ago.

Approximately 1 billion hectares of land are damaged by water erosion in global amount, with 750 million seriously affected. Himalayan-Tibetan ecology, Loess Plateau, sub-Saharan Africa, Central America, Andes, Haiti, and Caribbean are regional hotspots. Raindrops separate and transfer soil particles, causing rill and inter-rill erosion (Dagar & Singh, 2018). Land cover categories, including forests, cultivation, neighborhoods, and mines, may impact erosion rates, with various agricultural practices dominating different classifications. Therefore, water erosion varies in intensity and is classified into distinct groups ranging from very light to very heavy based on the amount of soil loss per hectare per year (Nurlina et al., 2022).

Water erosion reduces soil quality and production by reducing infiltration, water-holding capacity, nutrient content, organic matter, soil biota, and depth (Panagos et al., 2015). Artificial water-resistant soils made from organ silanes can be used to form semi-permeable barriers on natural slopes to prevent infiltration, but they can also enhance soil erosion. (Zheng et al., 2019). Recent study of Zhang et al., (2023) stated that Fires and polydimethylsiloxane can make soil hydrophobic. This can cause soil erosion and debris flows after wildfires. Measure the contact angle between water droplets and solid particles to evaluate hydrophobicity.

Zornoza et al., (2015) discuss soil quality factors such as organic matter loss, salinization/alkalinization, compactness, structural damage, sealing, contamination, and acidification. These causes degrade soil, affecting productivity and sustainability. Sustainable land use and human health depend on understanding and monitoring these variables, stressing the necessity for comprehensive soil quality studies.

Because erosive materials like rainfall and runoff separate and move soil particles, water erosion is a major worldwide problem that results in soil loss and damage. The process is related to the paths that water takes through vegetation and the earth; surface runoff generates rills or overland flow, while direct rainfall causes erosion from raindrop splashes. Population growth, unsustainable land use, and changing climatic patterns all reduce ecological resilience, which has an effect on livelihoods, global ecosystems, food security, and social stability.

By lowering infiltration, water-holding capacity, nutrient content, organic matter, soil biota, and depth, water erosion lowers soil quality and production. In-depth investigations of soil quality are necessary for both human health and sustainable land use, since these variables must be understood and closely monitored.

3.4.3 Snow Erosion

In snow landslides, impacts, abrasion, plowing, and blasting are the main causes of snow erosion (Gauer & Issler, n.d.). Certain factors, like snow properties and flow systems, influence this process, which is especially important in areas where snowfall occurs. Boulton (1979) asserts that plucking and abrasion play significant roles in glacier erosion, with plucking being the more prevalent mode of action. The possibility of abrasion-induced subglacial sediment deformation leading to self-repair is examined and it is concluded that this is a challenging task (Cuffey & Alley, 1996). Snow erosion processes can be understood and predicted with the help of the distributed snow-evolution modeling system SnowModel (Liston & Elder, 2006).

Environmental effects of snow erosion can be quite detrimental. Pokladníková (2008) found that the average rate of snowmelt erosion varied from 0.61 $t.ha^{-1}.year^{-1}$ to 30.08 $t.ha^{-1}.year^{-1}$ in different localities, indicating that it may result in soil loss. Furthermore, Freppaz (2010) emphasizes that snow avalanches have the potential to cause soil erosion, with the fine sediments fraction accounting for the majority of the sediment deposited on preexisting soil. This may result in distinct landforms and modifications to the chemical composition of the soil. According to (Pelletier, 2009), the evolution of the late Cenozoic landscape in places like the southern Rocky Mountains of the United States may have been significantly influenced by erosion caused by snowmelt. According to Rixen et al. (2003) the creation of artificial snow in ski resorts may also have detrimental effects on the soil and vegetation, such as mechanical damage, compaction of the snow cover, and modifications to the biodiversity and species composition.

3.5 Water Erosion Types

One of the most occurring water erosions is splash erosion, it refers to the separation and displacement of soil particles caused by the force of rainfall. This process is an essential preliminary stage in the wider range of soil erosion mechanisms(Fernández-Raga et al., 2019; Fu et al., 2019; Zumr et al., 2020). Different types of erosion, including splash, sheet, rill, and interrill erosion, can happen concurrently or independently and are frequently seen in agricultural areas (Di Stefano et al., 2013; Issa et al., 2006; W. Wang et al., 2016).

According to Boroughani et al., (2022)., splash erosion, the initial stage of erosive wash, involves the displacement of soil particles and clumps and is a major factor in the process of soil erosion.

3.5.1 Splash Erosion

Rain splash is a crucial detaching agent, causing soil particles to be thrown through the air. A study by (Malone et al., 2022) stated that cover crops can reduce the impact of raindrops or known as "splash erosion," which is particularly beneficial in regions like the Midwest that experience heavy rainfall. This demonstrates the crucial significance of cover crops in soil and water conservation methods in reducing soil erosion induced by the impact of raindrops.

Harmon & Doe (2001), stated that process of water erosion begins while the infiltrated water starts to pool on the surface. Water will start to flow in the direction of the steepest slope, which is unhindered after a certain depth is reached at the surface. This starts the hydrologic process known as runoff or overland flow. The process of sediment movement can start when soil particles dissolve or become suspended in the overland flow, as illustrated in Figure 3.

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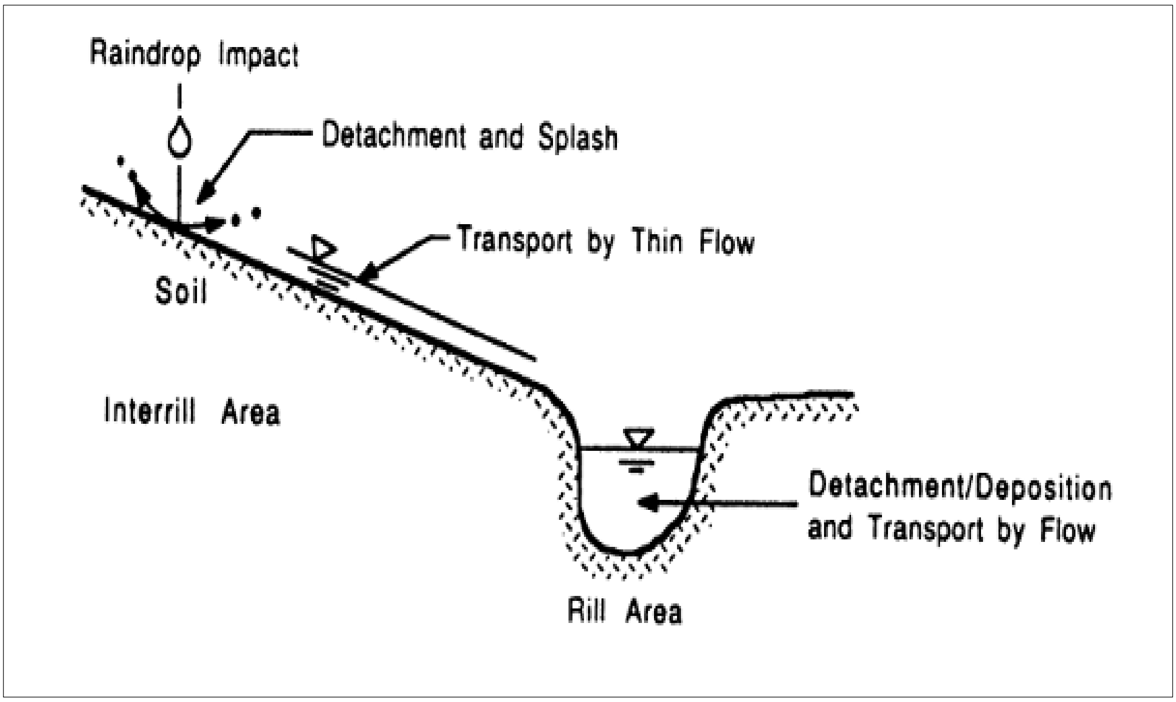
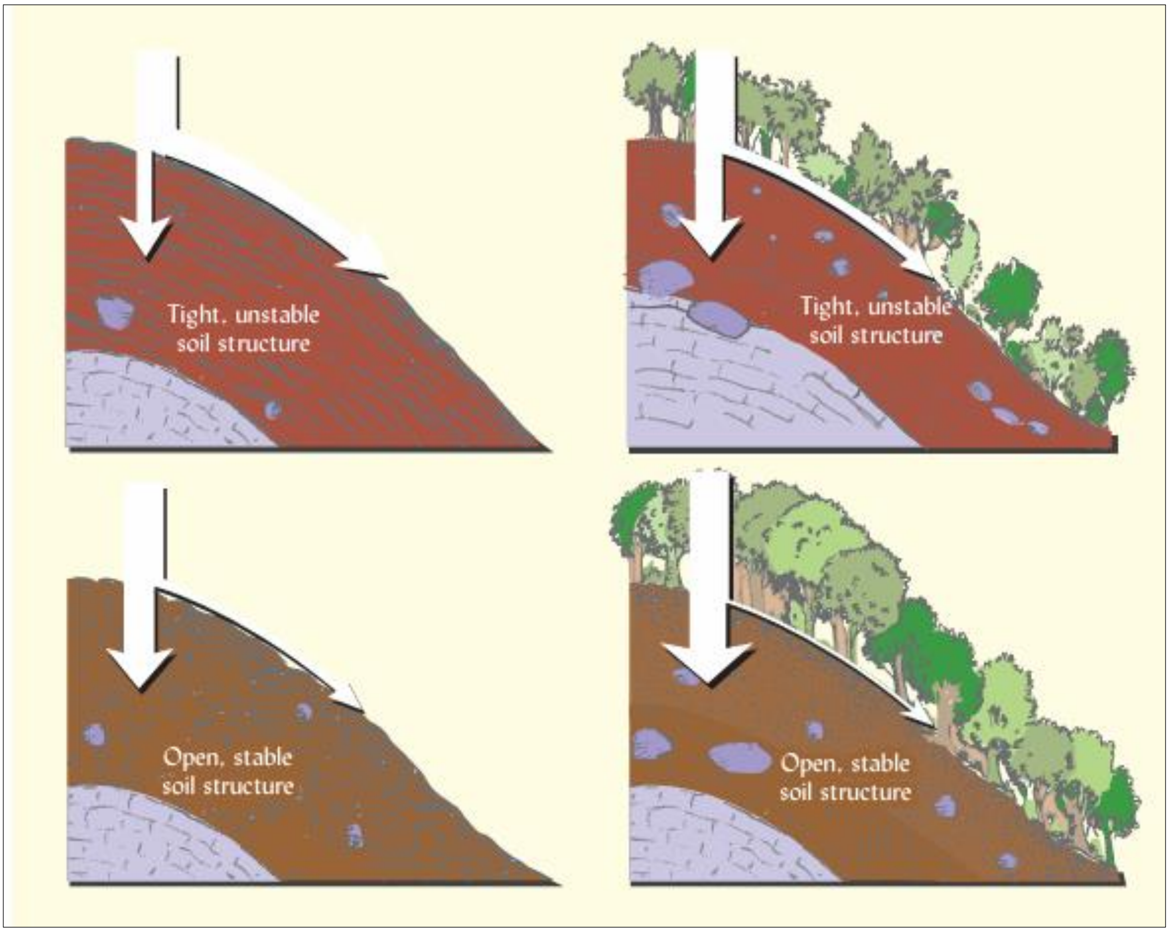
Figure 3. Transport and erosion in rill and inter-rill zones



Source: Hagen et al. (1990)

Extensive rainstorms weaken soil, while weathering processes, tillage operations, livestock trampling, running water, and wind also contribute to soil detachment, making it easily removed by transport agents Morgan, 2005). Environmental factors which influence severity of water erosion based on (Svoray, 2022) are rainfall characteristics, topography, vegetation cover, parent material and bioturbation. Huang et al., (2016) found that electrostatic and hydration forces also cause soil particle disaggregation, while van der Waals forces reduce aggregate breakdown on soil particle scales. Vegetation cover do make a huge impact on soil preservation from the direct rain splash and runoff. Inherent soil qualities also influence the eventual outcome of precipitation. When the soil is loose and porous, such as sands and well-granulated soils, a significant amount of the incoming water will penetrate the soil, whereas just a small portion will flow off. On the other hand, dense clay soils with unstable soil structures hinder the process of water infiltration and promote the occurrence of runoff (Ray & Nyle, 2017).

Figure 4. The impact of soil structure and vegetation on the distribution of rainfall between infiltration and runoff



Source*:* Ray & Nyle (2017)

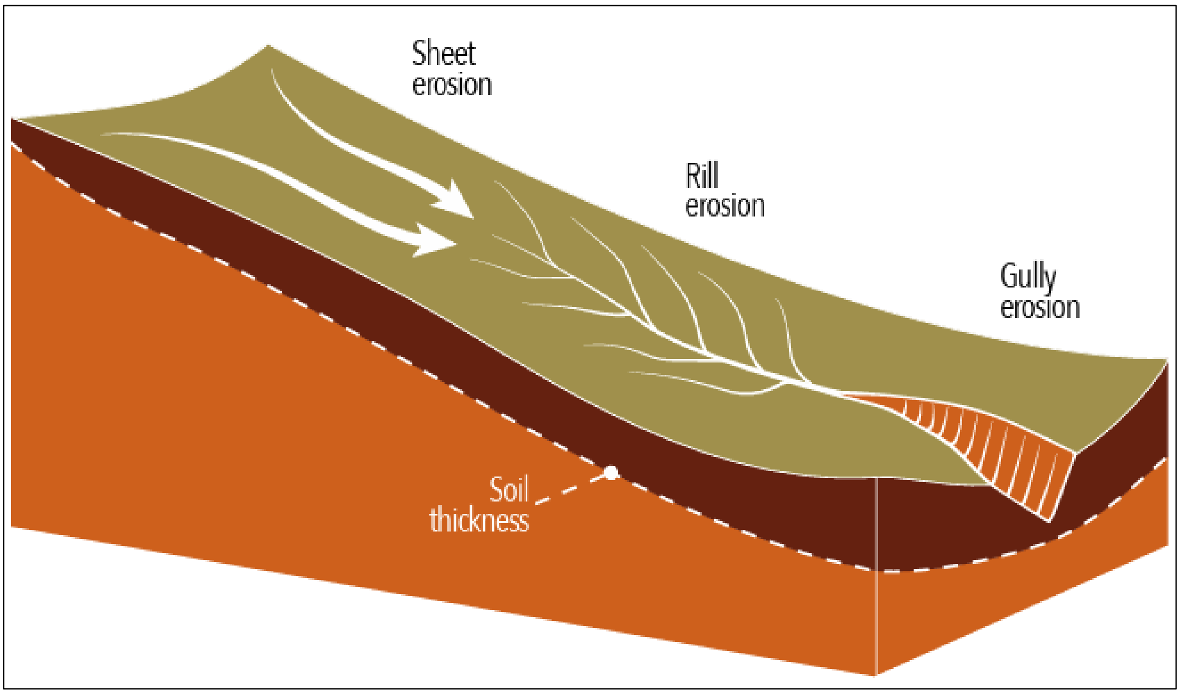
The top two figures depict soils characterised by a dense, unstable, or compressed structure that hinders the process of water infiltration and percolation. Uncovered soil is particularly susceptible to surface sealing, which leads to significant runoff and subsequent loss. Despite the presence of forest cover, the low-permeability soils are unable to absorb all the rainfall during a severe storm. The two lower diagrams demonstrate a significantly higher level of infiltration into soils that possess open, stable structures with substantial macropore space. The enhanced permeability of the soil structure, in conjunction with the shielding properties of the forest floor and tree canopy, effectively eradicates surface runoff.

According to Huang & Peng, (2015), splash erosion amount is related to rain diameter, slope and wind speed, the composition of the soil is the significant factor influencing splash erosion, different rammed earth splash depths and natural rainfall intensity form into different functional relation. Rainfall erosivity is a major cause of soil erosion. In erosion models, the R-factor measures rainfall amount and intensity. Rainfall erosivity in Europe and its effect on soil erosion risk are examined. One of the most important early stages of soil erosion is splash erosion, the first type of erosion, which is the separation and displacement of soil particles due to rainfall.

Numerous elements, including parent material, vegetation cover, terrain, rainfall conditions, and bioturbation, have an impact on it. Raindrop impact can be lessened by cover crops, particularly in areas with high rainfall. The intensity of water erosion is also influenced by environmental factors such as parent material, bioturbation, vegetation cover, terrain, and rainfall characteristics. Splash erosion is influenced by several variables, including soil composition, wind speed, slope, and natural rainfall intensity.

3.5.2 Sheet Erosion

Figure 5. Diagram illustrating the arrangement of sheet, rill, and gully erosion in a basic hillslope system



Source: Pennock et al. (2019)

Second type of erosion is called sheet erosion. According to Wang et al., (2018) sheet erosion is identified as the predominant erosion process on steep rangelands of the Loess Plateau, especially after the reclamation of abandoned croplands. Sheet erosion, as defined by (Miller & Juilleret, 2020), refers to the downhill movement of soil caused by activities including ploughing, rill erosion, sheet erosion, and mass movement and creep. Sheet erosion, or interracial erosion, relates to soil loss and transport in unchanneled sediments caused by broad and shallow overland flow (Svoray, 2022). An unavoidable risk of sheet erosion for farmers is its ability to remain undetected for an extended period due to its shallow and inconspicuous nature (Svoray, 2022). Splash and sheet erosion are forms of erosion that gradually wash away soil in tiny layers. Their movement is driven by the impact of raindrops and water flow over the land, both of which contribute to the separation and movement of particles (H. Wei et al., 2009). Sheet erosion is a prevalent erosion process on steep rangelands, particularly after cropland reclamation. It involves downhill movement of soil caused by ploughing, rill erosion, and mass movement. Farmers face risk due to its inconspicuous nature.

3.5.3 Rill Erosion

Third type of erosion is rill erosion. Svoray (2022) explains that Soil texture abnormalities may direct overland flow into little channels known as rills. The farmer typically eradicates little rills during the cultivation process, only for them to reappear in the subsequent season, resulting in further soil erosion from the land. Rill erosion is characterized by a concentrated flow, resulting in substantially quicker rates compared to the shallow flow associated with sheet erosion.

3.5.4 Gully Erosion

The fourth type is the gully erosion. Gully erosion, a severe form of water-induced soil erosion, as an important global concern that can cause enormous devastation to landscapes and ecosystems (Arabameri et al., 2018b). Gully erosion is characterised by the detection of a receding head scarp and internal erosion mechanisms, such as mass movement and erosion of the sidewall slopes. It also involves the movement of soil components within the gully void (Thwaites et al., 2022). The characteristics associated to water erosion play a crucial role in comprehending, quantifying, and simulating the process and consequences of soil erosion caused by water. These characteristics aid in evaluating the extent of erosion, devising soil conservation plans, and assessing the efficacy of erosion control techniques.

Gully erosion is a type of soil erosion where soil and sediment are removed by concentrated water runoff, resulting in the creation of substantial channels or gullies. A gully is a canal with steep sides that is formed by erosion from intermittent water flow, typically during and soon after heavy rainfall. It is characterised by a steeply sloping and actively eroding head scarp (Poesen et al., 2003). There are two types of gully erosion, named ephemeral gullies and bank gullies. According to Poesen et al. (1998) Ephemeral gullies form when water runoff becomes concentrated, either in pre-existing drainage channels or in linear features such as drill lines, dead furrows, tractor tracks, or unpaved access roads.

Xu et al., (2017) discover that upslope inflow enhances runoff velocities in ephemeral gully (EG) channels more than rainfall intensity alone. This higher runoff velocity from upslope inflow worsens soil erosion, demonstrating its function in sheet erosion. Meanwhile bank gullies erosion is influenced by the density of banks in the landscape, the level of the banks, and the circumstances that promote piping and the beginning of bank gullies, among a number of other factors (Poesen et al., 1998).

3.5.5 Pipe Erosion

The last type is pipe erosion. Soil pipes are isolated channels that allow water to flow selectively below the soil's surface. These channels are built parallel to the gradient of the hillslope (Wilson et al., 2018).

There are key parameters influencing water erosion, such as rainfall intensity, soil erodibility, slope length, and land cover, emphasizing the impact of climate change on soil erosion processes and the implications for water security and ecological conservation**.** The study explores the use of concrete lozenge channels to reduce water erosion by up to 49%, emphasizing the importance of optimizing control measures, particularly in terms of ditch and channel dimensions (Bouanani et al., 2022).

The factor denotes the impact of land cover and management techniques, encompassing prior cultivation and management practices, vegetation canopy cover, and surface roughness. The impact of soil erosion management measures, such as contouring, terracing, bunding (Silverstone), trenching, and planting vegetation strips, is significant in preventing structural and cross-slope erosion (Hammad et al., 2004; Wischmeier & Smith, 1978; Xin et al., 2019).

Erosion is determined by the multiplication of five distinct factors that represent different aspects of erosivity. These factors include the climatic erosivity (rainfall erosivity, the R-factor), soil erodibility (the K-factor), topography (slope length and steepness, the LS-factor), land cover management (the C-factor), and cross-slope erosion control practices (support practices, the P-factor). The yearly soil loss rate (in metric tonnes per hectare) can be calculated using the formula: R x K x LS x C (Ebabu et al., 2022). A few methods have been used to measure water erosion. Measuring these factors is important to shaping a policy in order to improve risk management. A study by (Arar & Chenchouni, 2014) revealed that water erosion in the eastern Aures region is typically not a cause for concern, since only modest and moderate threats were observed, which affect a substantial section of the land. These elements, including smooth slopes, high-quality vegetation, stable foundation materials, and limited human activity, were identified as the reasons for this phenomenon.

The research conducted by Khademalrasoul & Amerikhah (2022) explores the analysis of geomorphometric characteristics to streamline water erosion modelling, with a specific emphasis on the Emamzadeh watershed in Iran. The research emphasises the importance of basic and secondary geomorphic features, such as slope, curvature, flow characteristics, and stream power index (SPI), in predicting water erosion using the Water Erosion Prediction Project (WEPP) model, showcases the efficacy of geomorphometric parameters in estimating erosion using linear models, highlighting their potential to improve soil erosion predictions and management approaches. Another model can be used is named Environmental Policy Integrated Climate (EPIC). Carr et al., (2020) study emphasizes the significance of slope inclination and daily precipitation in the EPIC model's water erosion equations, enhancing precision and accuracy in forecasting water erosion processes.

Santos et al., (2003) suggested applying the SCE-UA method to calibrate erosion model parameters and determine erosion parameter values suitable for a semi-arid location like Brazil. The primary discoveries encompass implementing the SCE-UA approach to enhance erosion model parameters, experimentation of this technique in a semi-arid locality, and providing suggested erosion parameter values for analogous regions.

3.6 Fertilizer

A fertilizer is any substance, whether natural or synthetic, that is introduced into the soil to provide one or more critical nutrients necessary for the optimal development and growth of a plant (Gowariker et al., 2008). Fertilization is a common agricultural technique wherein both organic and inorganic fertilizers are applied with the primary goal of enhancing plant nutrition and, consequently, crop productivity (Francioli et al., 2016). In the current global situation where conventional fertilizer is giving negative impacts, it is necessary to increase soil fertility using the organic fertilizers.

3.6.1 Organic Fertilizer

Organic fertilizers, such as biofertilizers is important for in maintaining soil fertility in organic agriculture (Dar et al., 2010). It can be an environmental-friendly approach for sustainable agriculture. Additionally, to improving soil quality, the conversion of biomass waste into organic fertilizers provides a sustainable waste management solution (Chew et al., 2019a). Biofertilizers are recognized for their significant contribution to maintaining soil condition, as well as enhancing crop output through the mobilization of nutrients that are available via their biological activities (Bhardwaj et al., 2014; Chew et al., 2019b; Li et al., 2017).

Examples of green or organic fertilizers are organic amandments, compost, manure, biochar, and green manure. However, the main sources of organic fertilizers consist of peat, animal byproducts (often obtained from slaughterhouses), and agricultural and sewage waste from plants. Examples of organically produced fertilizers that are organic are slurry, peat, and animal waste products from the meat industry (Assefa, 2019).

By increasing soil nutrient levels and organic matter concentration, the application of organic amendments typically improves soil fertility and structure (Reganold et al., 1987). The choice and amount of fertilizer amendment have a combined effect on both crop yields and the physico-chemical characteristics of the soil. Over time, these factors greatly influence soil fertility and productive capacity (Saha, Gopinath, et al., 2008). By these, meaning that fertilization enhances plant nutrition and crop productivity by applying organic and inorganic fertilizers, affecting soil fertility and structure, and ultimately influencing crop yields and productivity. A key element in the pursuit of sustainable agriculture is soil organic fertilizer, which is made from organic materials like plant and animal waste.

Biofertilizers are a very safe option to reduce the risk of carbon release. A study by Wei et al., (2020) resulting the replacement of mineral fertilizer with organic fertilizer in corn systems resulted in a substantial rise in the rate of soil organic carbon sequestration by 925 kg C ha−1 yr−1 and a decrease in global warming potential by 116 kg CO^2 eq ha−1, as compared to the use of mineral fertilizer. The research on how cowpea crops respond to mineral and organic fertilization, as reported Sánchez-Navarro et al., (2021), shows that although mineral fertilizers improve soil fertility by increasing a variety of soil properties, organic fertilizers are advantageous for preserving or enhancing soil organic carbon and total nitrogen stocks, which helps mitigate the effects of climate change.

According to the research, cowpea crop output and quality were identical for both fertilizer types, indicating that organic fertilizers may be a viable substitute for sustaining crop productivity. Biofertilizers, like organic fertilizers, can reduce carbon release and improve soil organic carbon sequestration, reducing global warming potential. They also preserve soil organic carbon and nitrogen stocks, thereby mitigating climate change effects.

One benefit of using organic fertilizers is the gradual release of phosphate and nitrogen, which are insoluble in water. The slow-release reduces the amount of nutrients that leak out. Because they don't include soluble salts, organic fertilizers can be applied in huge amounts without harming the crops, unlike inorganic fertilizers. In certain circumstances, organic fertilizers may even provide crops with more nitrogen and phosphorus than artificial fertilizers(Gowariker et al., 2008). In addition, a study result conducted by Yu et al., (2016) in China explain that organic fertilizer promotes highly reactive minerals including allophane, imogolite, and ferrihydrite, improving soil carbon storage and fertility.

Aside of the advantages, review from (Timsina, 2018) explain the myth of using organic fertilizer. The report does point out several common misunderstandings, though, including those organic fertilizers can be used everywhere, that they are inexpensive, and that there is a risk of soil organic matter building up too much. In addition, the disadvantage of using organic fertilizer is since temperature and soil moisture substantially impact organic material decomposition, nutrients may be released when the plant does not require them.

Due to poor nutrient content and restricted availability of organic material, organic fertilizers alone are not sufficient to supply crop nutrient needs (Morris et al., 2007). Organic fertilizers are popular due to their versatility, cost-effectiveness, and potential for soil organic matter accumulation. However, they may not meet crop nutrient needs due to limited availability.

3.6.2 Manure

Manure, a residual product of animal agriculture, is a valuable asset with potential advantages and difficulties. It has the potential to transmit infectious agents, requiring meticulous handling (Millner, 2009). In the context of sustainable and organic crop production, the utilization of both raw and composted manures holds significant value, with guano serving as a comparable substance (Kuepper, 2003). The utilization of manure as a biomass resource is currently limited, but it holds promise for its conversion into biochemicals within a biorefinery (Chen et al., 2005). Additionally, it serves as a highly beneficial source of nutrients for plants and as a soil amendment. However, it is crucial to exercise caution when applying it to prevent excessive nutrient accumulation and minimize any negative effects on the environment (H. Zhang & Schroder, 2014).

3.6.3 Digestate

Numerous studies have demonstrated that digestate, which is a by-product of biogas production, possesses significant potential as a fertilizer for crop cultivation. According to Koszel (2015), the application of digestate has been observed to enhance the concentration of macroelements in plants. Similarly, Alburquerque et al. (2012) emphasized the significant fertilizing capabilities of digestate. Nevertheless, the utilization of this substance may be limited due to its high concentration of heavy metals, salinity, and biodegradability. Lee et al. (2021a) provided additional evidence that the application of digestate can improve crop growth and nutrient composition, especially when used in conjunction with biochar. According to Alburquerque et al. (2012) , it has been observed that digestate has the potential to enhance soil characteristics and serve as a nutrient source. However, the efficacy of digestate may differ based on factors such as the specific crop and prevailing environmental circumstances.

3.6.4 Compost

According to Roy & Food and Agriculture Organization of the United Nations (2006), secondary products of crops, or auxiliary plants, are resources that have a low nutrient value and are used to improve soil fertility. Composting has the potential to enhance the value of organic materials as a nutrient supply. The nutritional content of legume crop residues is higher and their carbon-to-nitrogen ratio is lower, making them easier to break down into minerals compared to cereal residues. Processed residues provide more nutrients compared to conventional crop residues like straw and stover.

Several studies proved that organic compost from agri-industrial wastes can improve soil fertility and increase wheat productivity. Similarly, de Albuquerque Nunes et al. (2015) reported that organic compost from slaughterhouse waste can enhance soil fertility and increase soybean and corn yields. Ahmad et al. (2008) demonstrated that enriched compost can improve wheat growth and yield, and reduce the need for nitrogen fertilizer. These studies collectively suggest that compost can be a beneficial organic fertilizer for monoculture crops like corn and wheat.

3.7 Effects of Organic Fertilizers on Soil Properties

To begin with, on physical properties, organic fertilizers have impacts on the soil structure, water holding capacity and soil thermal or temperature. Modern sustainable agriculture faces a promising challenge in reducing unnecessary fertilization rates without compromising plant nutritional requirements, crop yields, or product quality (Chatzistathis et al., 2021), in particular the over use of inorganic fertilizers, which has contaminated surface and groundwater, degraded soil, and increased greenhouse gas emissions (Miao et al., 2011).

Ma et al. (2018) ‘s study explores the impact of organic manure on bacterial communities in Chinese Mollisols. The research highlights the positive effects of organic manure over inorganic fertilizers, such as reduced soil acidity, increased organic matter, and improved plant development, highlighting the significant impact of organic fertilizers on soil structure. In another study, the impact of organic amendments and mulching on squash plant growth and fruit quality in silty loam soils. The study examines wheat straw mulch and organic fertilizers in wooden boxes, focusing on soil fertility and plant growth. The result shows that organic fertilization help increase soil organic matter content significantly while also supporting the soil properties and resulting in the balancing of the soil nutrients (Youssef et al., 2021).

Lekfeldt et al., (2017) explains the lasting side effects of organic leftovers fertilizers on the structure of soil. The study shows that applying sewage sludge to soil results in a decrease in the quantity of large holes (macroporosity) and an increase in the number of microscopic pores (microporosity).On the other hand, fertilisation with organic household waste compost raises both the overall porosity and the absolute porosity of the soil. According to the research, various organic fertilizers have an impact on soil structure parameters. In addition, the study by Czachor et al., (2015) conducted an assessment of the porosity and pore size distributions of aggregates by employing micro-tomography analysis on loamy soil. They utilized lognormal pore size distributions as an approximation. The findings revealed that water-stable aggregates displayed higher porosities and larger pores in comparison to methanol-stable aggregates. The primary causes of aggregate instability under rapid wetting were not solely due to pore air compression, but rather due to the reduction in attractive forces between aggregate particles caused by water.

Ankenbauer & Loheide (2017) study in Sierra Nevada, California, there exists a notable association between soil water retention and organic content, indicating that the presence of organic matter has the potential to augment water retention by a maximum of 8.8 cm, resulting in a duration of 35 days without water stress. Another study proofs the advantage of soil organic matter in keeping moisture is one held by Cristina et al. (2020), the application of anaerobic digestates from sewage sludge (SSADs) encouraged plant development and enhanced soil properties by supplementing the soil with organic matter. Furthermore, the application of organic matter (OM) has been found to improve certain soil physical properties, such as Cation Exchange Capacity (CEC), soil structure, soil moisture content, and moisture retention (Epstein, 2002).

Organic fertilizers significantly impact soil structure, water holding capacity, and thermal or temperature. Sustainable agriculture faces challenges in reducing unnecessary fertilization rates without compromising plant nutritional requirements, crop yields, or product quality. Studies show that organic fertilizers reduce soil acidity, increase organic matter, and improve plant development. Organic waste fertilizers also affect soil structure parameters, with studies showing that sewage sludge increases microporosity and organic household waste compost increases porosity. Organic matter enhances soil water retention and moisture retention.

It is important to breakdown the effect of organic matters on soil thermal properties. Rising temperatures in the soil enhances soil nitrogen mineralization rates by boosting microbial activity and accelerating the decomposition of organic materials in the soil. Soil is a significant heat storage system, functioning as a reservoir of energy during the day and providing heat to the surface at night (Onwuka, 2018). The temperature of the soil is determined by the proportion of heat received to heat lost from the soil. The phenomenon's fluctuations occur yearly and daily, primarily influenced by changes in air temperature and solar rays (J. Wu & Nofziger, 1999).

The range of soil temperature between 10℃ and 28℃ enhances soil respiration by breaking down organic matter. In contrast, a temperature range of 10℃ to 24℃ stimulates the metabolic activity of soil macro-organisms, leading to increased feeding or fat accumulation (Conant et al., 2008). Open and absorbent structures of the soil's organic matter layer have significant effects on soil thermal conductivity, providing insight into the role of organic matter in controlling heat transfer within soil layers (He et al., 2021).

In other words, soil thermal properties are influenced by organic matter, with rising temperatures boosting nitrogen mineralization rates and accelerating decomposition. Soil acts as a heat storage system, providing energy during the day and providing heat at night. Soil temperature fluctuates yearly and daily, influenced by air temperature and solar rays. The organic matter layer's open structures affect soil thermal conductivity, revealing its role in controlling heat transfer.

On the chemical properties, organic fertilizers have impact on the nutrient availability, soil pH, and cation exchange capacity. Organic fertilizer, rich in organic matter and nutrients, enhances soil physical characteristics by reducing bulk density, enhancing aggregate stability, optimizing microbial community structure, and improving biological and biochemical properties (Diacono & Montemurro, 2010; H. Zhang et al., 2009). The application of organic manures, when combined with inorganic fertilizers often results in higher amounts of soil organic matter (SOM), improved soil structure, greater water retention capacity, enhanced nutrient cycling, and aids in the preservation of soil nutrient levels, cation exchange capacity (CEC), and biological activity (Saha, Mina, et al., 2008).

A study by Mahmood et al. (2017) conducted a comparison between organic and inorganic fertilizers in terms of their impact on soil quality and nutrient availability. The findings indicated that the use of organic fertilizers led to an enhancement in the levels of soil organic carbon, nitrogen, phosphorous, and potassium. The application of organic fertilizer however had a negative correlation with grain yield, while it had a beneficial impact on corn grain production. The sustainable enhancement of agricultural yield can be achieved by integrating inorganic fertilizers with organic manures.

Organic fertilizers improve soil quality and nutrient availability, but negatively impact grain yield. When combined with inorganic fertilizers, they enhance soil organic matter, structure, water retention, and nutrient cycling. Sustainable agricultural yield enhancement can be achieved by integrating inorganic fertilizers with organic manures.

3.8 Impact on Water Infiltration and Runoff

The utilization of organic fertilizers is vital in improving soil health and agricultural output, while also having a substantial impact on water dynamics within the soil environment. Organic fertilizers can impact water infiltration rates and decrease surface runoff, which are important aspects of sustainable water management and erosion prevention. This can be achieved by enhancing soil structure and increasing the amount of organic matter present.

According to Peng et al. (2023), investigating soil water infiltration using muddy water irrigation and bio-organic fertilizer, addressing water scarcity and soil fertility issues in arid and semi-arid regions. Results show increased muddy water sediment and fertilization concentration decrease wetting front distance and infiltration quantity but increase infiltration reduction rate. The use of compost and manure has significant impacts on both runoff and water penetration. (Ramos & Martínez-Casasnovas, 2006) found that runoff containing composted cattle manure exhibited elevated nutrient levels as a result of enhanced penetration rates and delayed initiation.

Anwar et al. (2018) reported comparable results, indicating that the composting of cow dung with leaf litter resulted in a reduction of nutrient losses in runoff. The optimal ratio for this composting process was found to be 1:3. In a study conducted by Johnson et al. (2006), it was shown that the use of composted dairy manure as a topdress to turf resulted in improved soil quality. However, this application did not result in an increase in nutrient release, save for ammonium nitrogen. In a study conducted by Lehrsch et al. (2014), it was found that the application of compost and manure had a significant influence on the concentrations of certain nutrients in sprinkler irrigation runoff. However, no observable impact was observed on runoff or sediment losses.

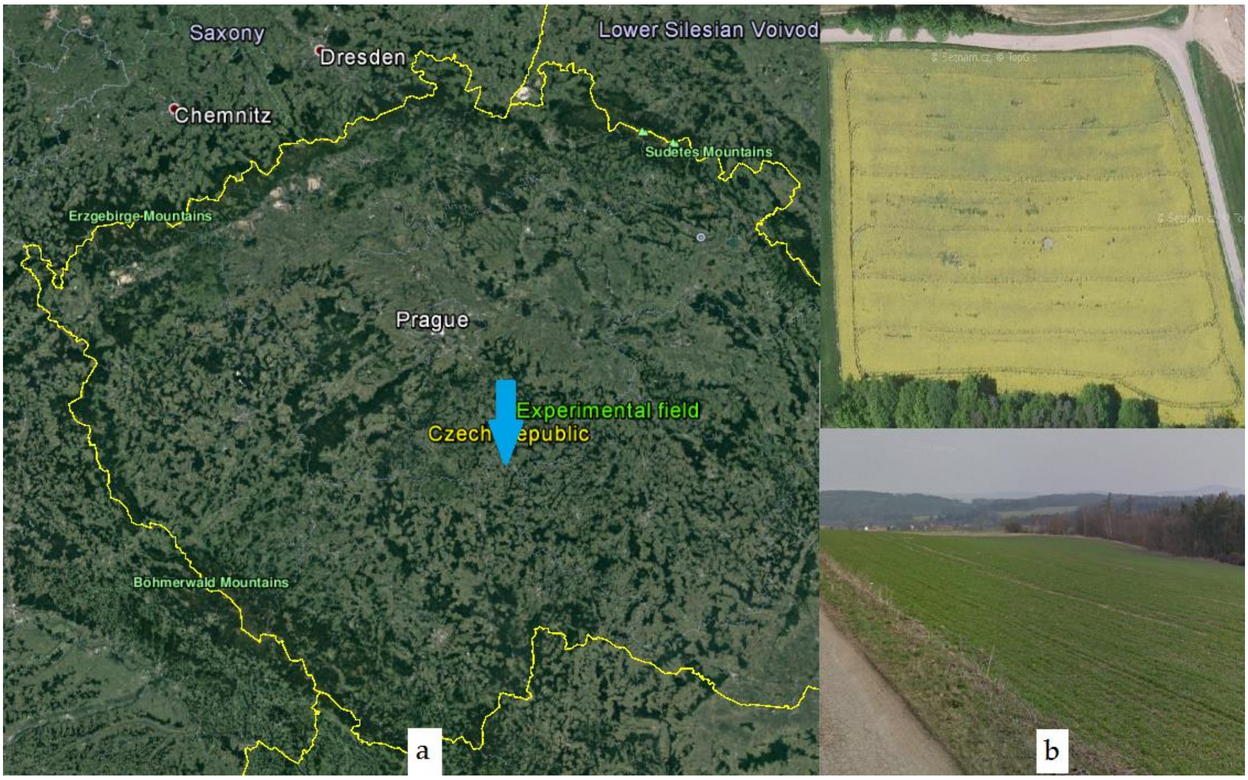
4 Materials and Methods

4.1 Study Area

The experiment examined the impact of organic fertilisers on corn output and the corn stand's ability to resist erosion. A field trial was set up to assess the results. This field experiment was conducted nearby the village of Nesperská Lhota (GPS 49.6904063 N"; 14.8134006 E") in 2023. The exact location of the experiment is shown in Figure 6. The plot is located at an altitude of 447 m and with an average slope of 5.29°.

4.2 Materials

Figure 6. Experiment location (a) and precise field (b)



This study involved the application of organic fertilizers, including manure, digestate, and compost. The selection of organic fertilizer doses was based on a realistic range of 40 t/ha and an extreme range of 200 t/ha. Laboratory analysis was performed in accordance with the compost standard ČSN 46 5735 to ascertain soil properties, including dry matter, carbon (Ct), and nitrogen (N) content in dry matter. The Niton XL 3t X-ray gun was utilized to conduct precise elemental analysis of organic fertilizers. The experiment plots were ploughed using a Kromexim blade cultivator. The Vantage Vue weather station was utilized to conduct rainfall control measurements in close proximity to the field experiment.

4.3 Methods

Figure 7. Plots with fertilizers

The initial stage of this study involved using Kopecky cylinders to determine the basic properties of the soil. Therefore, the method of intact soil samples was used. Winter wheat was harvested as a pre-crop at the experiment field. The soil was then processed in the Fall season by ploughing to a depth of 0.2 m, and in the Spring, it was prepared using levelling bars and ridge gates. The trial site was divided into 8 experimental plots with a slope of 4.5-8.7°. The size of the experimental plots was set at 3x3 m. Organic fertilizers (manure, digestate, compost) were chosen for the experiment, see figure 7. The types and amount of applied organic fertilizers are shown in Table 1.

Table 1. Applied Fertilizers

Plot	**Fertilizer**	**Dose [t·ha^{-1}]**
1	Manure	40
2	Manure	200
3	Digestate	40
4	Digestate	200
5	Compost	40
6	Compost	200
7	Without fertilizer (WF)	0
8	Without vegetation (WV)	0

The dose of organic fertilizers was chosen to be realistic (40 t/ha) and extreme, unrealistic (200 t/ha) respectively. A large difference in doses was chosen for the possibility of easier assessment of the effect of the number of organic fertilizers on erosion in the corn stand. Table 2 records the properties of fertilizers that were determined from samples evaluated by laboratory analysis according to the compost standard ČSN 46 5735.

Table 2. Properties Of Organic Fertilizers

Fertilizer	**Manure**	**Digestate**	**Compost**
Dry matter [%]	6,18	22,58	32,88
Ct in dry matter [%]	38,27	37,79	23,65
N in dry matter [%]	16,021	2,341	1,829

Accurate elemental analysis of organic fertilizers was carried out with the help of a Niton XL 3t X-ray gun. The results of the analysis are shown in Table 3

Table 3. Values of The Number of Selected Elements of Used Organic Fertilizers

Elements	**Manure**	**Digestate**	**Compost**
Zn	44.39	8.15	46.8
Cu	11.02	9.95	6.97
Ni	22.39	20.93	10.43
Co	26.33	19.76	
Fe	990.42	144.03	992.12
Mn	95.12	54.1	
Cr	16.19	14.93	15.55
Ti	14.14	33.33	
Ca	3128.36	1837.28	
K	5925.96	4047.01	
Al	108.9	200.09	
P	1545.63	1010.94	
Si	1710.56	3088.32	
Cl	965.93	1013.29	
S	1137.55	556.22	1799.46
Mg	776.06	604.39	
MgO			44.35
P_2O_5			1429.91
K_2O			8605.75

Incorporation of organic fertilizers was carried out with a Kromexim blade cultivator. The travel speed during plowing was 12 ± 0.2 km/h with the set processing depth 0.15 m. Fertilizer incorporation took place 2-6 hours after application.

The mid-early KWS corn hybrid was selected for the experiment. Figure 8 shows hand sowing, which took place at an areal density of 80,000 seeds per hectare with a 55 mm depth of sowing, two row spacing of 17 cm 60 cm.

Figure 8. Sowing of corn

For better emergence of corn plants, the surface of the experimental plots was rolled with Cambridge rollers. After sowing, the herbicide “Akris” was implemented at a dose of 2 dm^3/ha. Akris is a selective herbicide that acts on weeds pre-emergently through the soil and post-emergently through the leaf. The measurement of greening in individual plants was conducted during the growing season using a SPAD-502 Plus chlorophyll meterThis portable sensor calculates the SPAD value, a numerical representation of the correlation between spectral absorbance in two electromagnetic spectrum regions.. The red band (600-700 nm) is considered one of the chlorophyll absorbance peaks, while the near-infrared band (700-1400 nm) is also considered.

After germination of the corn stand, measuring runoff micro-plots were installed in the space between the rows. Three runoff microplots were installed for each investigated variant to eliminate statistical errors. The drainage micro-parcels are bounded by a sheet with a thickness of 1.5 mm. The plate is partially embedded in the ground so that the measured results are not affected by the surroundings. The edge of the micro-plot is embedded 0.08 m into the ground and 0.04 m extends above the ground. The internal surveyed area of the micro plot is 0.16 m^2. The runoff water from the micro-plot is diverted to a collector, which then directs the water into a pre-buried plastic collection container (canister with a volume of 10 dm^3). The method of measurement using microplots (Figure 9) is similar to Hudson (1993) and Hůla J (2010).

Rainfall control measurements were carried out near the field trial using the Vantage Vue weather station. An example of the model is shown in Figure 10. During the field experiment, the weather station recorded both the amount of precipitation and its intensity. Recorded data was stored only after rains, which erosively threatened the soil surface.

Figure 9. Microplots on the variant

Figure 10. Weather Station

Source:https://www.conrad.cz/cs/p/davis-instruments-vantage-vue-dav-6250eu-digitalni-bezdratova-meteostanice-pocet-senzoru-max-8-672549.html

The quantity of precipitation and sediment collected with the aid of runoff micro-parcels in the collection containers were monitored and measured as soon as the rainfall that posed a risk of soil surface erosion ended. The volume of surface runoff captured in the tanks was measured using measuring cylinders. The amount of sediment contained was determined by subsequent filtration of the captured surface runoff. The final reading of the weight of the captured soil can only be determined after drying at 105 °C. Further data collections were analyzed using the comprehensive STATISTICA Application to translate the data.

The experiments took place at the laboratory of the Department of Mechanical Engineering, which is part of the Faculty of Engineering at Czech University of Life Sciences Prague.

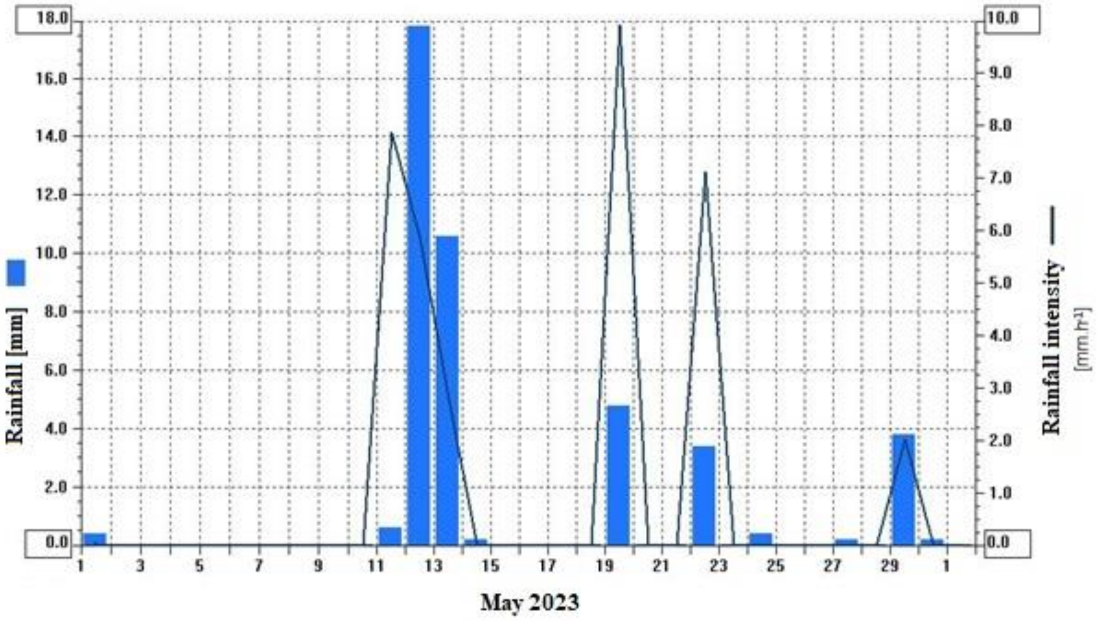
5 Result and Discussion

5.1 Result of The Field Experiment

5.1.1 Meteorological Condition

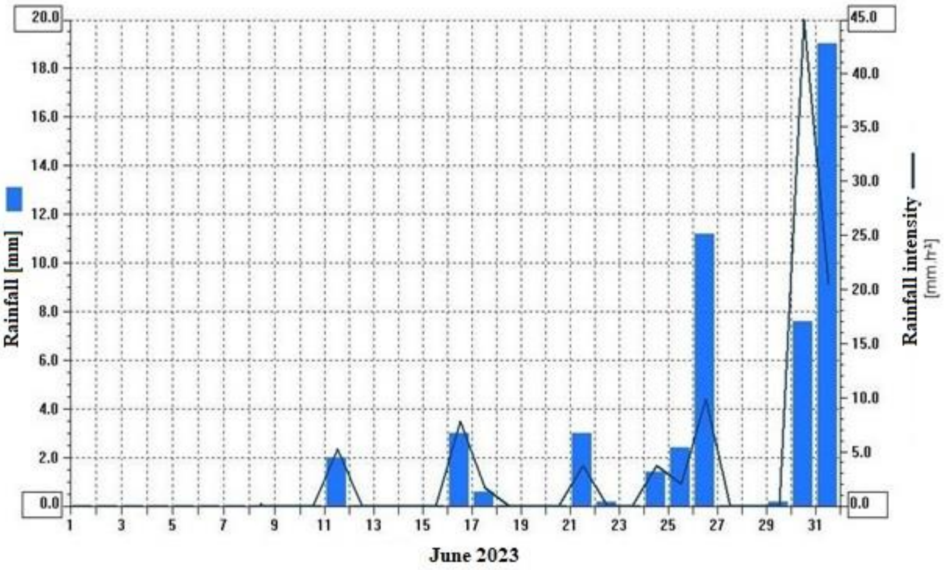
The weather station Vantage Vue, which is situated close to the experimental plot, provided the measurements that resulted in the meteorological data in this section. The first erosion event happened between May 11 and May 14, as a result of two periods of intense rain. During this time, 29 mm of precipitation fell overall. The level of precipitation intensity was comparatively low. The following image displays the amount and intensity of precipitation.

Figure 11. Total and intensity of precipitation in the month of May



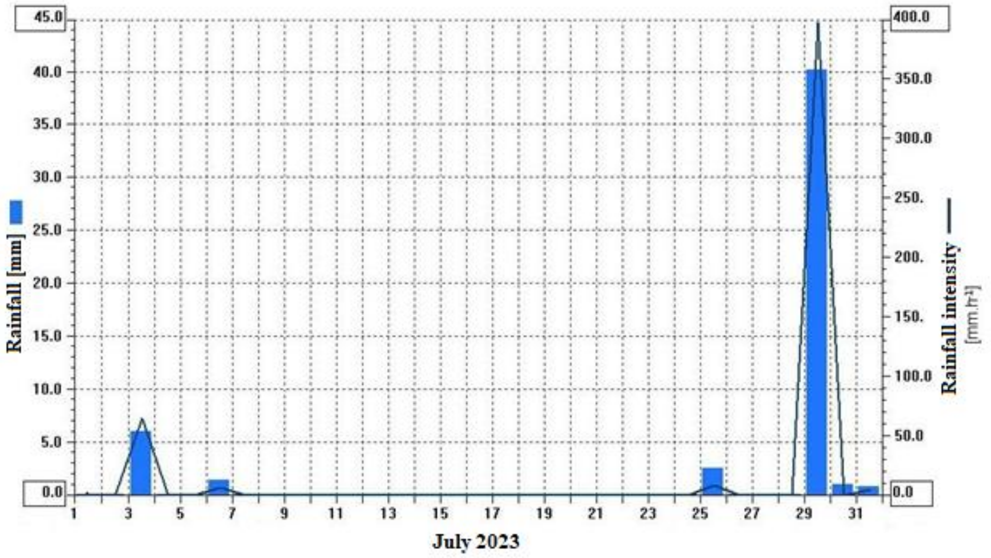
Two other erosional significant events occurred during June. The first event occurred in the period June 25-27, when rain and a short thunderstorm with a total of 15 mm of precipitation were recorded. The intensity of precipitation varied in low values. The second event was recorded at the end of June. Two storms occurred here with a total of 26 mm of precipitation. The intensity of these precipitations reached up to 45 mm/h. The total and intensity of individual precipitation is shown in the figure below.

Figure 12. Total and intensity of precipitation in the month of June



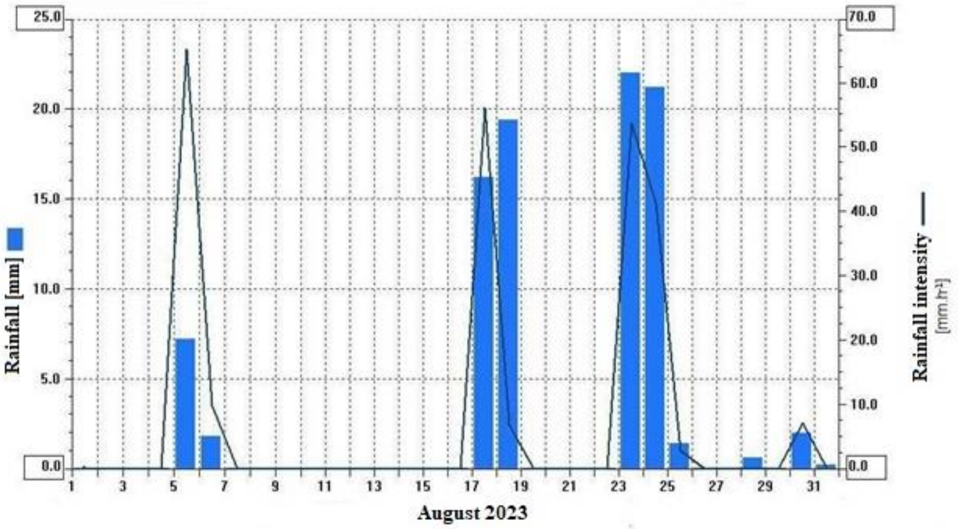
The fourth erosion event occurred at the end of July during a violent storm, when the total rainfall was 41 mm and the rain intensity reached very high values (short-term).

Figure 13. Total and intensity of precipitation in the month of July



The last two measured erosion events were recorded in the second half of August. They were two storms with heavy rains. The first of the August events was recorded on August 18-19. It was a heavier rain with a total of 35 mm. The second August event was torrential rain on the night of August 24 to 25. Here, the amount of precipitation slightly exceeded 44 mm. Both events were characterized by a relatively high intensity of rain, which is evident from the record from the meteorological station.

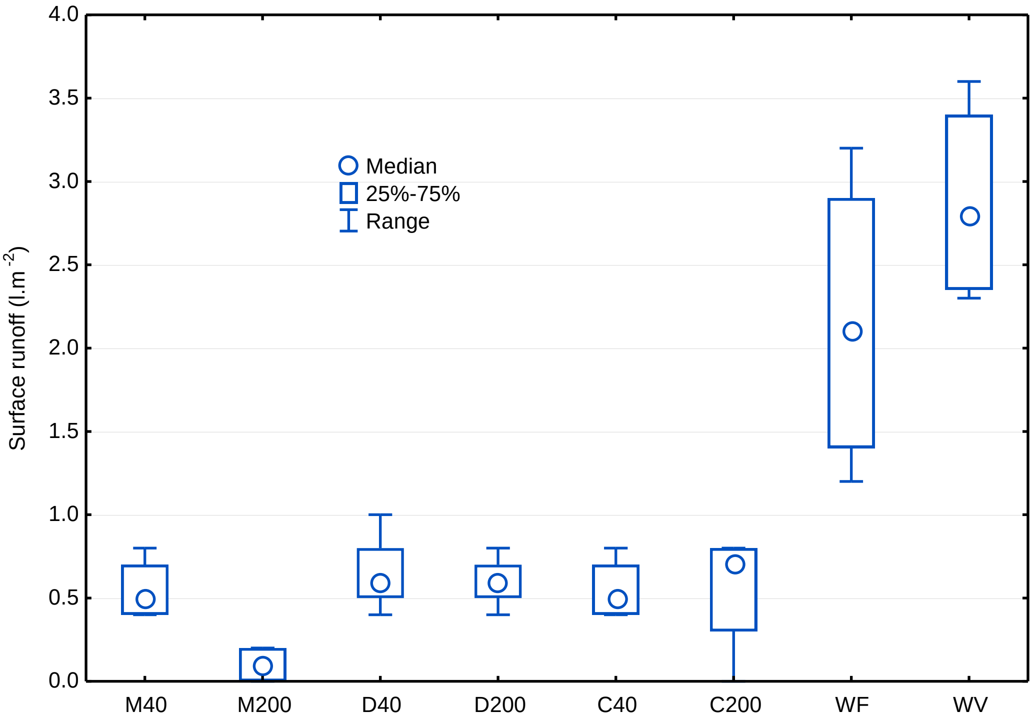
Figure 14. Total and intensity of precipitation in the month of August



5.1.2 Results of erosion parameters

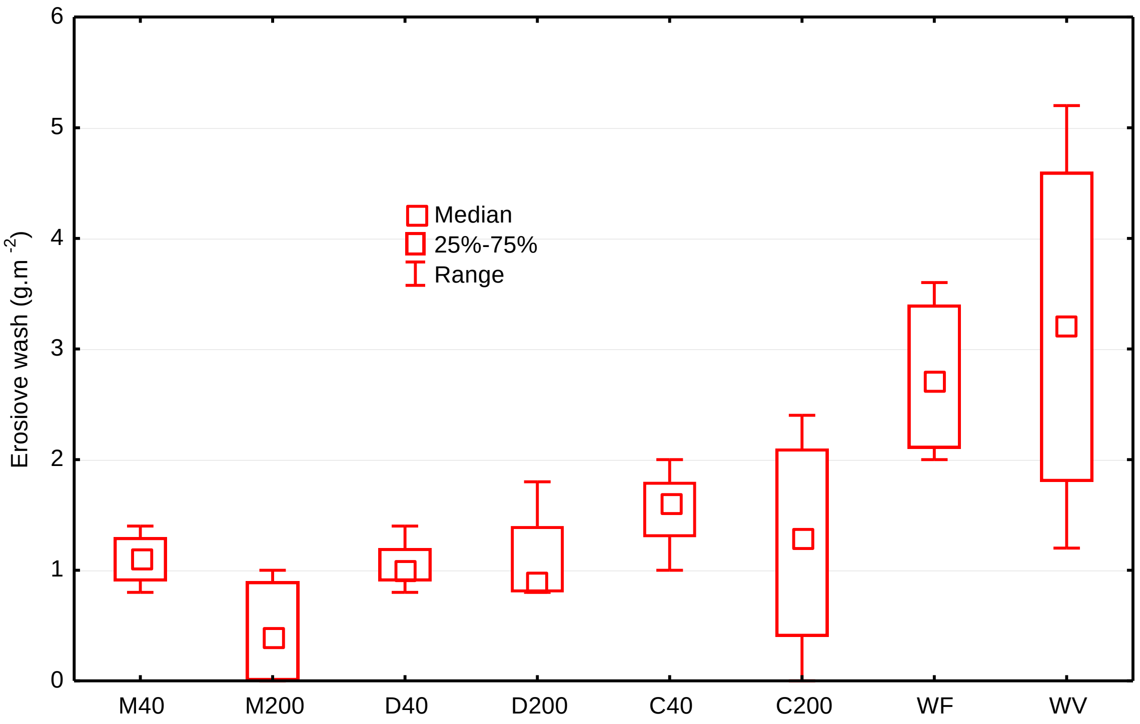
The erosion parameters such as surface runoff and erosive wash were measured in the field The first recorded event was rain in mid-May (Figure 15 and Figure 16). What is interesting about this measurement is the fact that the corn growth was in a very early stage. Therefore, it can be concluded that the measured values are primarily due to the fertilizer alone. In this case, the vegetation did not affect the falling drops on the soil surface in any way. The values of the surface runoff are relatively small, which was caused by only the average intensity of the rain. Nevertheless, differences between the variants can be found. In general, all types of organic fertilizers significantly reduce erosion indicators. The effect also varies depending on the dose, but not significantly. On contrast, increased values are visible in two control variants, where there is no influence of fertilizer. This confirms the beneficial effect of organic fertilizers.

Figure 15. Surface runoff during rain in mid-May



When analysing the erosive wash, the same effect as for surface runoff is evident. However, the differences are smaller. This is probably due to the short time since the stand was established. The soil was still significantly loosened and contained many macropores. In this case, the size of the differences is also influenced by the size of the measuring plot, when there is no rapid surface runoff. However, the beneficial effect of fertilizers is evident. This causes easier infiltration of water into the soil and thus reduces erosion parameters and contributes to soil protection.

Figure 16. Erosive wash during rain in mid-May



The table 4 below shows the results of Tukey's test. It confirmed the conclusions drawn from the graphs. There are statistically significant differences between variants, which confirm several homogeneous groups of variants. There are more significant differences in surface runoff.

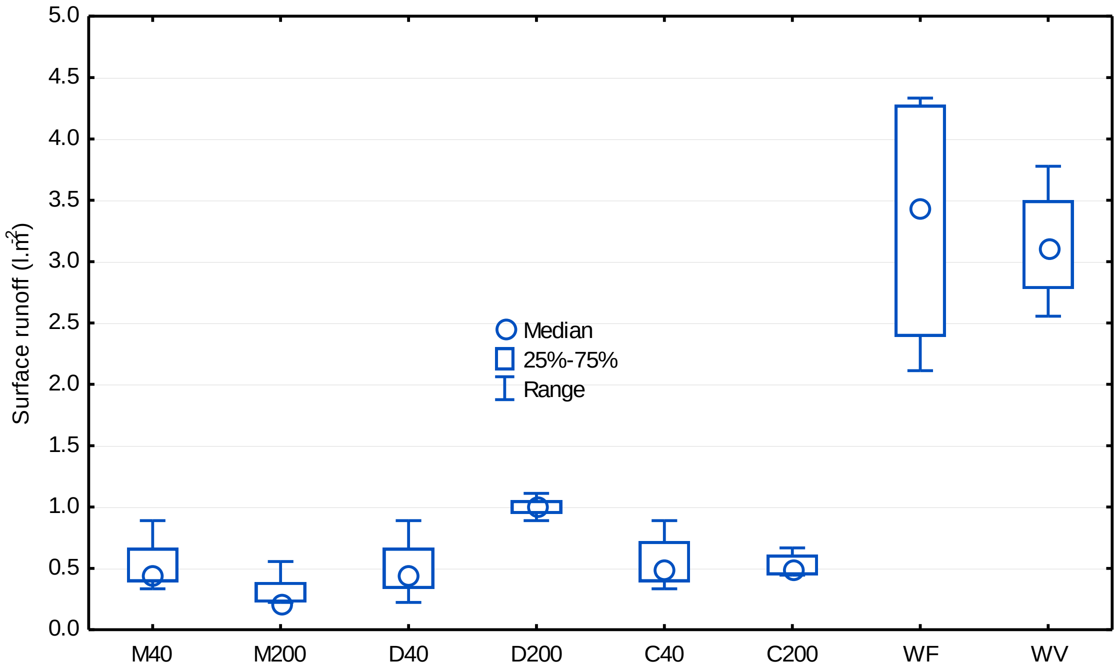
Table 4. Average values and homogenous groups for rain in mid-May

Variant	Surface runoff (l.m-2)	Erosive wash (g.m-2)
M40	0.6a	1.1a
M200	0.1a	0.5a,b
D40	0.7a	1.1a,b
D200	0.6a	1.1a,b
C40	0.6a	1.6a,b,c
C200	0.6a,	1.3 a,b,c
WF	2.2b	2.8 b,c
WV	2.9b	3.2c

a,b,c: homogenous groups

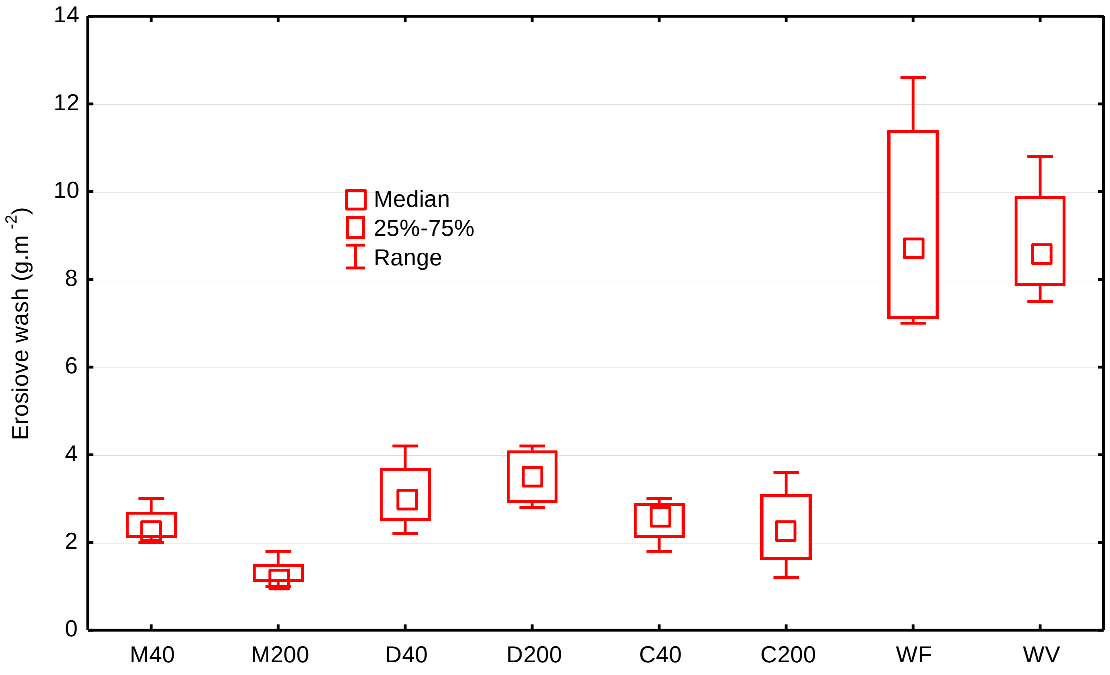
The second evaluated event was the heavy rain from the third decade of June. The corn growth already reached a height of approx. 0.2 m and thus influenced the measurement. The differences measured between variants have increased significantly. Especially in the control variants, the surface runoff increased sharply. There was no effect on the growth of the variant without fertilization either. Compared to the control variant without fertilization and without vegetation, no difference was recorded.

Figure 17. Surface runoff during rain on June 25



Erosive wash again did not differ so significantly, although the differences were larger than in the first measurement. Again, the protective effect of organic fertilizers was worth to be noted. All organic fertilizers significantly reduced the erosion parameters and thus prevented more major manifestations of water erosion. Even high dose digestate has demonstrated this ability. There was no sealing of the soil pores and the associated decrease in soil infiltration.

Figure 18. Erosive wash during rain on June 25



The results of the Tukey's test confirm the above conclusions. There are notable differences between the fertilized and control variants. The effect of the growth is already visible. At the same time, organic fertilizers significantly reduce water erosion parameters.

Table 5. Average values and homogenous groups for rain on June 25

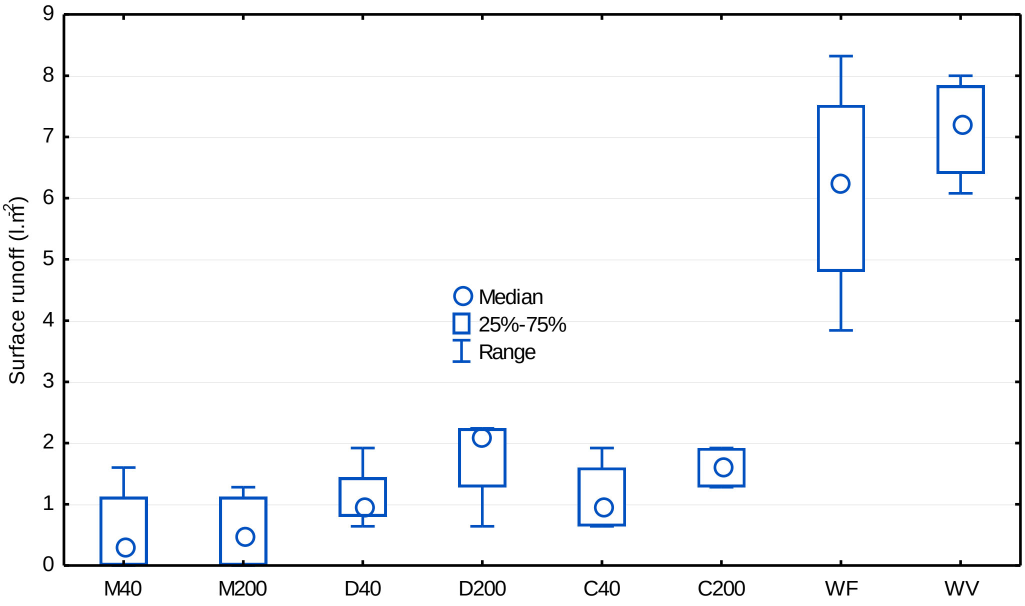
Variant	Surface runoff (l.m^{-2})	Erosive wash (g.m^{-2})
M40	0.5^{a}	1.1^{a}
M200	0.3^{a}	0.8^{a}
D40	0.5^{a}	1.2^{a}
D200	1.0^{a}	0.9^{a}
C40	0.6^{a}	$1.0^{a,}$
C200	$0.5^{a,}$	$1.4^{a,b}$
WF	3.2^{b}	3.3^{b}
WV	3.1^{b}	3.8^{b}

a,b,c: homogenous groups

Coincidentally, another event followed a few days later. It was a violent thunderstorm with high intensity rain and high kinetic energy of the falling drops. The total precipitation was about 25 mm, but due to the high intensity it was a significant erosion event. Despite the high intensity of the rain, there was a difference between the variants. The trend of previous measurements remained. Again, there is a noticeable difference between the control variants and the variants with fertilizers. It is interesting that in the partial measurements of the variants with manure, even zero surface runoff was recorded even at a very high intensity.

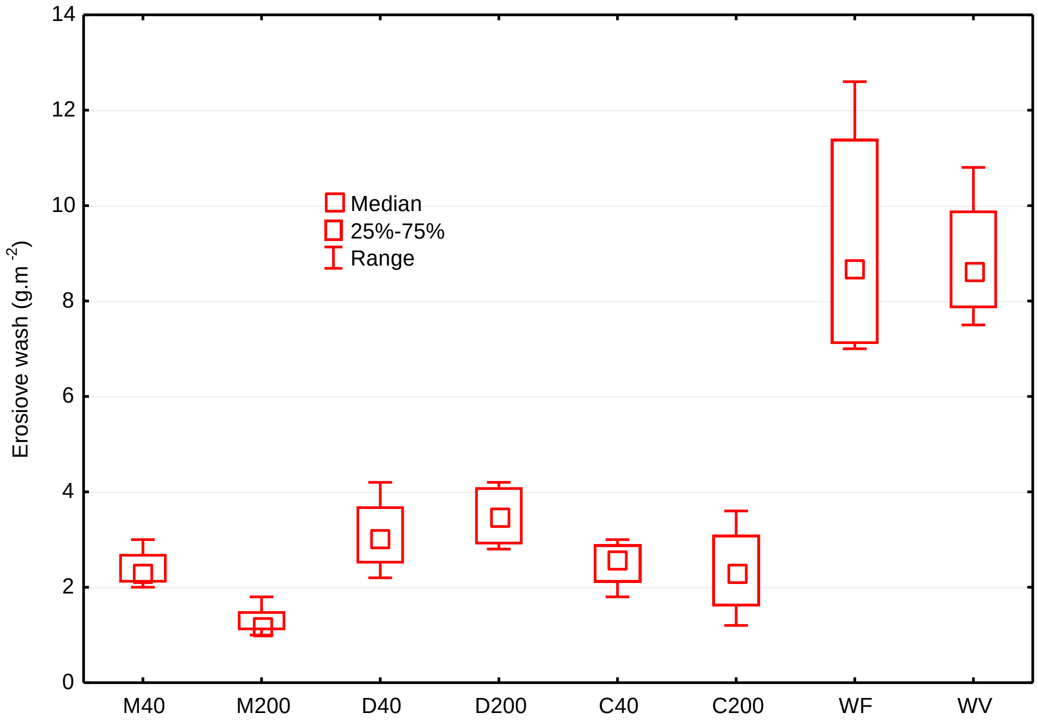
Manure particles apparently cause rapid infiltration into the subsurface layers of the soil and thus prevent the formation of surface runoff.

Figure 19. Surface runoff during rain on June 30



When evaluating erosive wash, it is interesting to note that there was no effect of the corn growth in the control variant without fertilizer. This is quite surprising. Presumably, the high-intensity drops were able to bend the leaves and landed directly to the soil surface. The results confirm the risk of leaving the soil without vegetation cover, but also the insufficient protection of wide-row crops during vegetation.

Figure 20. Erosive wash during rain on June 30



A statistically significant difference between fertilized and unfertilized parameters is revealed by Tukey's test. For both erosion parameters, this is true. They are directly connected to one another or affect one another.

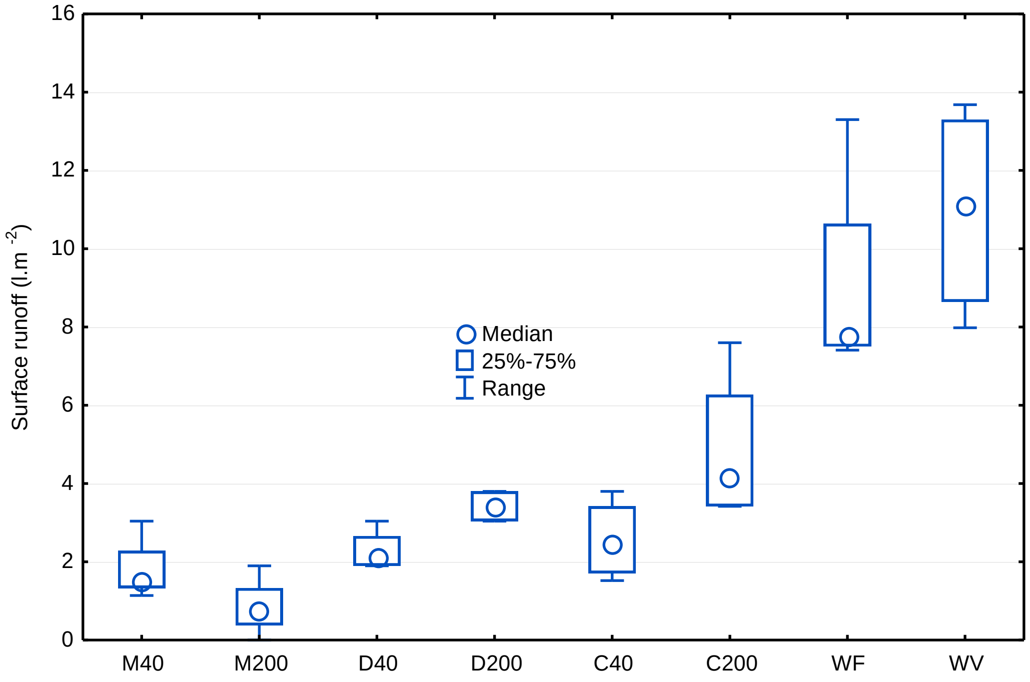
Table 6. Average values and homogenous groups for rain on June 30

Variant	**Surface runoff (l.m^{-2})**	**Erosive wash (g.m^{-2})**
M40	0.6^{a}	$0,8^{a}$
M200	0.6^{a}	$1,0^{a}$
D40	$1,1^{a}$	1.8^{a}
D200	1.8^{a}	2.2^{a}
C40	1.1^{a}	$2.2^{a,}$
C200	$1.5^{a,}$	2.7^{a}
WF	$6,2^{b}$	7.6^{b}
WV	7.1^{b}	5.6^{b}

a,b: homogenous groups

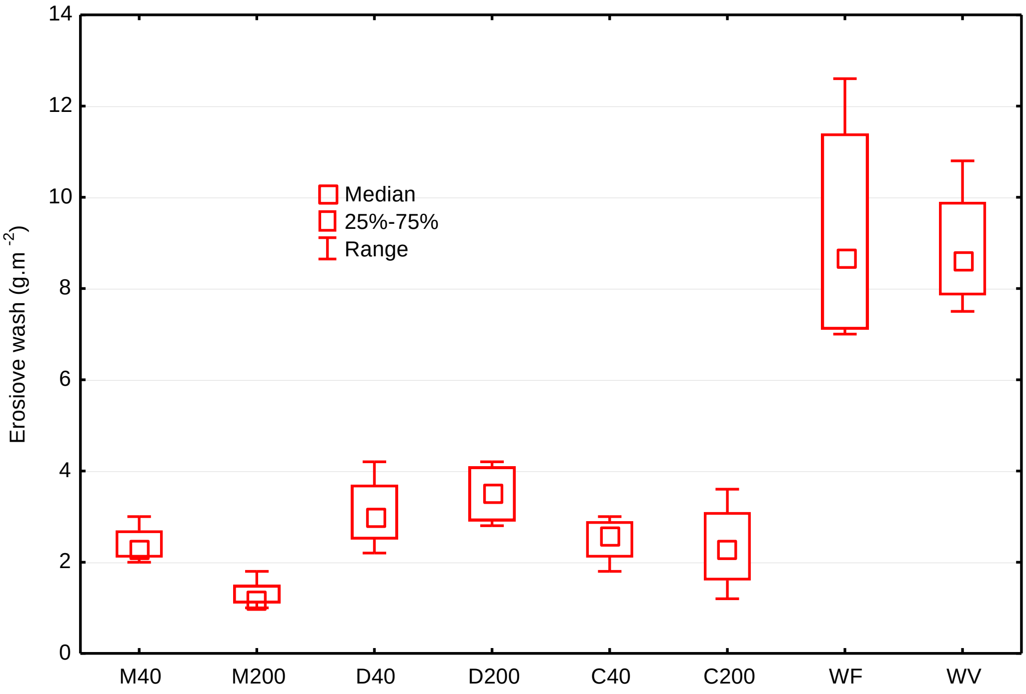
During July, one erosion event was assessed at the end of this month. It was a violent storm with a high amount of precipitation (41 mm) and a short-term very high intensity. It was the most significant precipitation of the entire season. Due to the long period between events, there was a decrease in the difference between variants. This was due to the development of the corn stand. Furthermore, the effect of loosening the soil and the associated change in the physical state of the soil ceases. This is clearly visible from the surface runoff graph. In the variant with manure, zero runoff was recorded for one parcel, but this is more likely a measurement error (damage to the container, etc.). The measurement trend supported the earlier findings in spite of the mentioned biases. Fertilization is an important long-term protective factor that shields the soil from the effects of erosion.

Figure 21. Surface runoff during rain on July 29



There was also an approximation of values for erosive wash. However, the measurement trend is still strongly visible. Even after the formation of a soil crust, soil particles are washed away during heavy rain. This is due to the high kinetic energy of the falling drops.

Figure 22. Erosive wash during rain on July 29



The reduction of differences is also evident from Tukey's test, when the situation is more complicated for erosive wash. However, even in July, the basic trends were maintained.

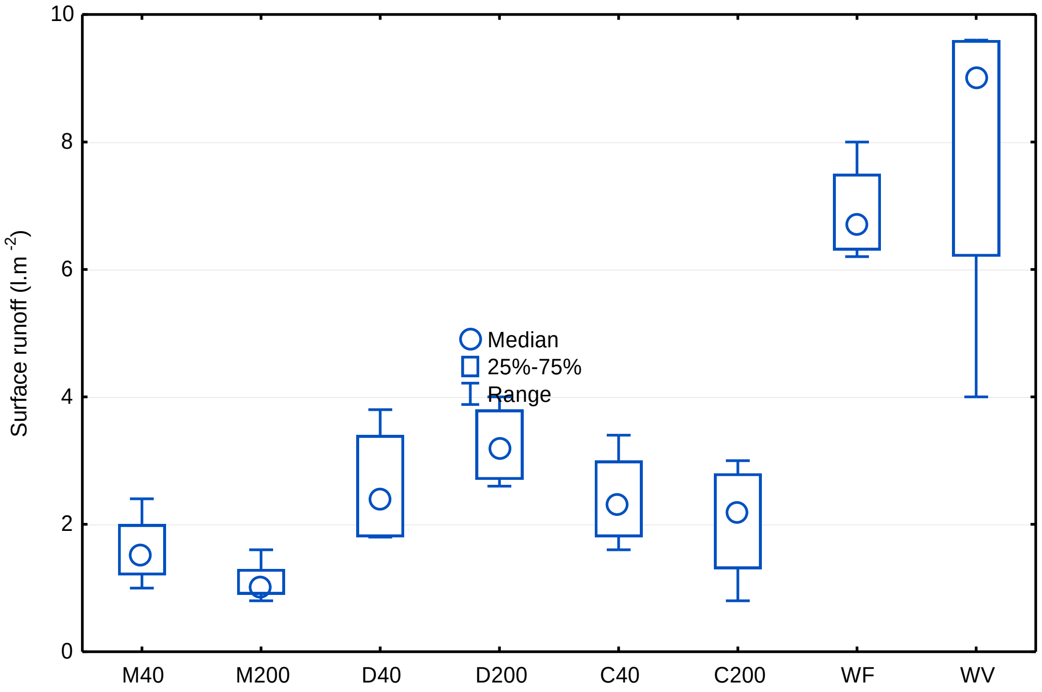
Table 7. Average values and homogenous groups for rain on July 29

Variant	Surface runoff (l.m^{-2})	Erosive wash (g.m^{-2})
M40	1.8^{a}	3.1^{a}
M200	0.9^{a}	1.3^{b}
D40	2.3^{a}	$3.4^{a,b}$
D200	3.4^{a}	$3.7^{a,b}$
C40	2.6^{a}	$3.4^{a,b,c}$
C200	$4.8^{a,}$	$4.9^{a,b,c}$
WF	9.1^{b}	$7.5^{b,c}$
WV	10.9^{b}	$11.5^{c,b}$

a,b,c: homogenous groups

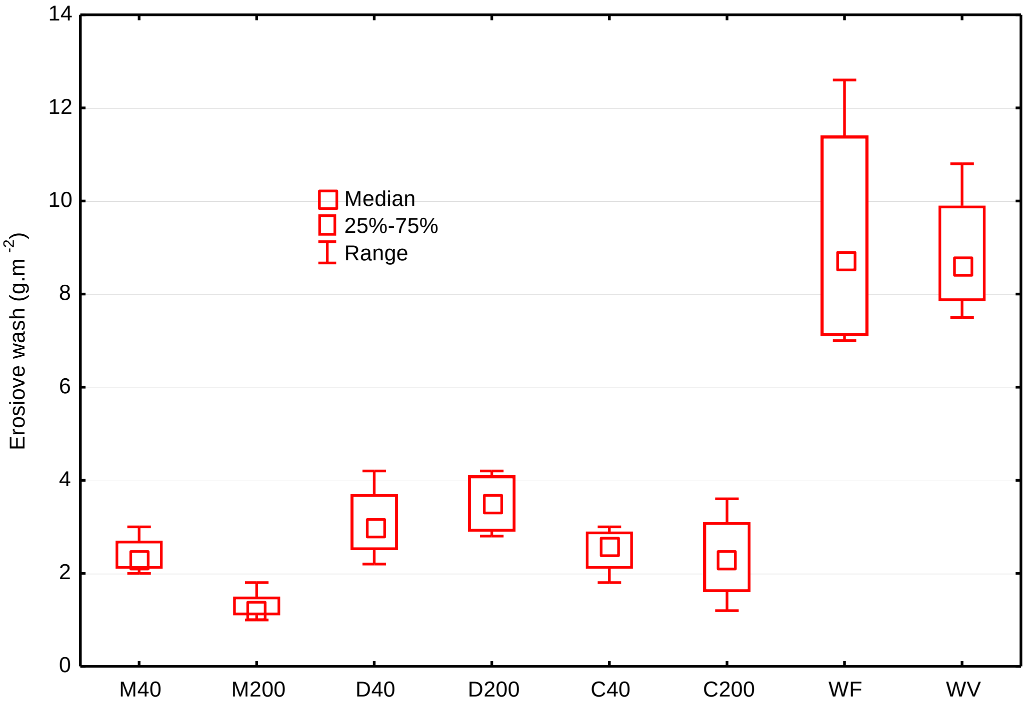
The penultimate event occurred after two days of rain in mid-August. It was persistent rain of medium intensity. The measurements did not bring any surprises. Conclusions from previous events were confirmed. The influence of the corn growth is lower than was expected at the beginning of the experiment. Even the fertilization effect slowly fades at the beginning of the season; such intensity of rain would probably be fully infiltrated by some variants. Higher values show variants with digestate. Its effect wears off the fastest.

Figure 23. Surface runoff during rain in mid-August



The results of erosive wash correspond only partially. The measurement trend is constant, but there is no direct correlation between surface runoff and soil loss. It is still pronounced in the control variants. However, higher soil loss due to higher surface runoff was not confirmed for the digestate. It is possible that the digestate increases the cohesive forces between the particles of the half.

Figure 24. Erosive wash during rain in mid-August



The results of Tukey's test are presented in the Table. They again confirm the stated conclusions. In slight contradiction are the variants with digestate, when the surface runoff increased in particular.

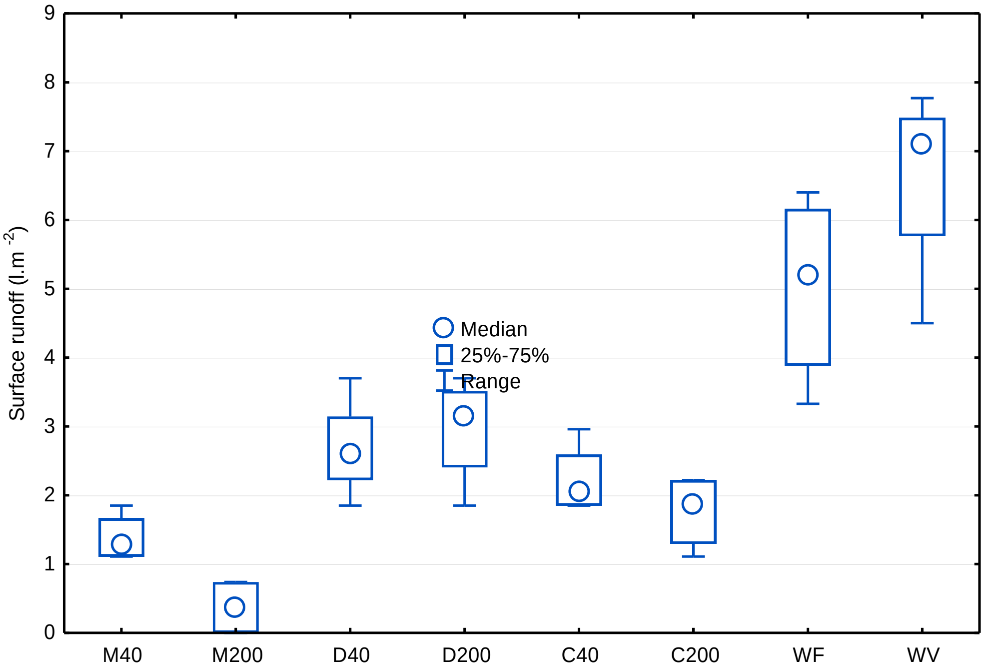
Table 8. Average values and homogenous groups for rain in mid- August

Variant	**Surface runoff (l.m^{-2})**	**Erosive wash (g.m^{-2})**
M40	1.6^{a}	2.4^{a}
M200	1.1^{a}	1.3^{a}
D40	2.6^{a}	3.1^{a}
D200	3.3^{a,b}	3.5^{a}
C40	2.4^{a}	2.5^{a}
C200	2.1^{a,}	2.4 ^{a}
WF	6.9^{b}	8.7 ^{b}
WV	7.9^{b}	8.9^{b}

a,b,: homogenous groups

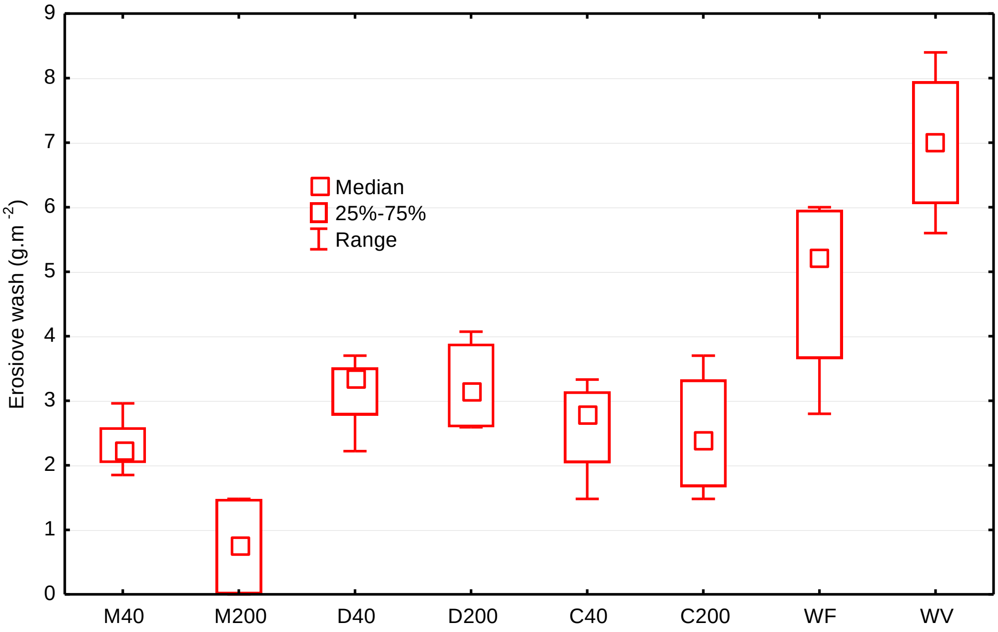
The last evaluated event was the rains around August 25.The total amount of precipitation exceeded 40 mm, the intensity was moderate. This rain followed relatively quickly after the previous one, so the soil was not dry. The values of erosion quantities are relatively low. There was also a further reduction in the difference between the variants.

Figure 25. Surface runoff during rain on August 25



Previous conclusions are also confirmed by data from erosive wash measurements.

Figure 26. Surface runoff during rain on August 25



The reduction of differences is also confirmed by the data from Tukey's test, when homogeneous groups are getting closer and the differences are decreasing (Table 9).

Table 9. Average values and homogenous groups for rain on August 25

Variant	**Surface runoff (l.m^{-2})**	**Erosive wash (g.m^{-2})**

M40	1.4^{a}	2.3^{a}
M200	0.4^{b}	0.7^{a,b}
D40	2.7^{a}	3.1^{a}
D200	3.0^{a,}	3.2^{a}
C40	2.2^{a}	2.6^{a}
C200	1.8^{a,}	2.5 ^{a}
WF	4.9^{b,c}	6.7 $^{b, c}$
WV	7.7^{c}	6.9^{c}

a,b,c: homogenous groups

5.2 Discussion

Researching the effects of organic fertilizers is one of the frequently addressed topics due to the importance of this issue. The effect from the point of view of crop yield and production quality is mostly addressed (Edmeades, 2003). Furthermore, the utilization of organic fertilizers has been linked to enhanced soil characteristics and the sequestration of carbon (Maltas et al., 2018). Macholdt et al. (2019) assumed that modifications in wheat agriculture have long-term effects. Fertilizers are in short supply overall, but Unc & Goss (2004) describes an interesting phenomenon. On one side, sometimes an area may have an overabundance of fertilizers because of a high concentration of livestock farms or other output (compost plants, biogas stations). However, in contrast, this may harm the local soil ecosystem.

The conducted research was focused on the measurement of soil erosion parameters after the application of organic fertilizers. Similar research was conducted by Gilley et al. (1999). The simulation of rainfall using a simulator resulted in a significant reduction of surface runoff by tens of percent. The application was developed within a temporal framework that closely resembled the simulation. The results correspond to the results obtained during the creation of this work. Gilley & Eghball (1998) in their previous study describe a slightly different behaviour of compost application than manure. They describe larger differences in soil structure that affect the resulting infiltration. Infiltration is significantly influenced by the macroparticles of the fertilizer, which serve as water conduits into the soil. The research was conducted depending on the dose of fertilizer per area, which results similarly to the the experiment at the Nesperská Lhota location.

Slurry or digestate, or liquid organic fertilizers, is frequently seen as problematic when it comes to water penetration (Lee et al., 2021b). Sewage sludge exhibits negative patterns as well (Ros et al., 2003). In our case, digestate from a biogas plant was used. A significant reduction in the infiltration capacity of the soil was expected, it was expected that there would be a notable decline in the soil’s infiltration ability, but this was not the case. On the contrary, this claim is supported by (Mayerová et al., 2023). The experiment carried out slightly contradicts the majority claim about a significant sealing of soil pores and thus a reduction in the infiltration capacity of the soil. This trend was slightly observed during some erosion events but did not reach statistically significant values.

During the measurement period, the influence of corn plants was also gradually manifested. In general, the crop acts as an imaginary ground cover on the plot. Indeed, the crop cover affects the intensity of water erosion (Wischmeier & Smith, 1978). Erosion models also work with crop parameters. The primary role of vegetation is to provide soil protection against the effects of raindrops. Additionally, it strengthens the soil through the root system of plants, particularly in the subsurface layers. Furthermore, the growth of the root system enhances the soil's infiltration capacity and contributes to the improvement of its physical, chemical, and biological properties. Moreover, the root system of certain plant species has the potential to disrupt the compacted soil layer primarily resulting from technogenic compaction, a phenomenon commonly observed in certain clovers. The selection of an appropriate crop for a specific plot of land is a significant concern.

During the second part of the growing season, there was a noticeable development of a soil crust, particularly in the variants that did not receive any fertilization. This phenomenon is primarily linked to a soil surface devoid of organic matter. Bresson & Boiffin (1990) describe an increased risk of soil crust formation with large surface runoff. This will cause the smoothing of the soil structure on the surface and a rapid decrease in porosity in the surface layer of the soil. The weather plays a major role in the formation of the crust, particularly the amount of precipitation that falls during each season. Therefore, it is not necessary for the soil crust to form in the same spot every season. Feng et al. (2013) describes a relationship with soil carbon content. Of course, this is influenced precisely by fertilizing with organic fertilizers - of course also by other measures and technologies. The results showed that the distribution of organic matter in the soil profile is more important than the total value of soil organic carbon in the soil. These ideas can be fully related to the measurements carried out at the Nesperská Lhota location.

To summarize the discussion, it can be noted that the massive application of high doses of fertilizers is not possible for the simple reason of the lack of these fertilizers. However, the anti-erosion effect may not be all-encompassing. This measure could be applied, for example, within several contour strips on the property, when these strips could serve as catchment strips with an emphasis on limiting the risk of excessive surface runoff. Locally differentiated dosing of organic fertilizers is not yet widespread in practice to the same level as industrial fertilizers. However, some benefits may lead to the spread of this technology over time. Here, in order to generalize these principles, the attempt must be repeated on sites with different soil properties, which may behave fundamentally differently.

6 Conclusion

The main task of this diploma thesis is the evaluation of a one-year field experiment, which dealt with the investigation of the effect of water erosion on the growth of corn. The current precipitation intensity and values were two of the parameters that were examined. Additionally measured were surface runoff and erosive wash. When the measured values are analyzed, the beneficial impact of organic fertilizers on the soil's resistance to erosion processes can be identified. Even with a lower typical dose of organic fertilizers, there was a noticeable increase in water infiltration. A field trial was established using three different types of organic fertilizers. Digestate, compost, and manure were these.

Even before starting the field experiment and the measurement itself, it was possible to assume a positive effect of organic fertilizers on the soil as anti-erosion protection. This idea was confirmed during the measurements. It was possible to observe the most differences at the beginning of the experiment when the soil crust still did not form on the surface and the vegetation was not affected. In the later part of the experiment, when the corn plant grew, the leaves of the plants began to act as protection, stopping large water droplets from summer storms.

Based on the evaluation of the measurements, it is possible to see that the manure turned out the best. There was a slight surprise with the digestate and compost variants with a dose of 200 $t.ha^{-1}$. The digestate is believed to have partially sealed the soil pores, reducing the soil's ability to infiltrate water. Compost infiltrated water more poorly than manure variants. This is probably due to the absence of larger macroparticles.

The impact of water erosion will continue to be relevant in the future. With the more frequent trend of summer rains occurring only in the form of intense, torrential rainfall, emphasis will be placed on protecting the soil from the wash-off of fine soil particles and subsequent soil degradation. In the future, it will be necessary to supplement the organic component in the soil to improve soil properties, but also to apply other anti-erosion measures to increase soil protection.

In addition, the importance of this work will increase over time. The ever-increasing population requires more food, and at the same time land is one of the hard-to-renew resources. The correct use of organic fertilizers is undoubtedly one of the future trends in agriculture.

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