Fakulta zemědělská
a technologická
Faculty of Agriculture
and Technology

Jihočeská univerzita
v Českých Budějovicích
University of South Bohemia
in České Budějovice

UNIVERSITY OF SOUTH BOHEMIA IN ČESKÉ BUDĚJOVICE
FACULTY OF AGRICULTURE AND TECHNOLOGY

Department of Agroecosystems

Master thesis

Assessment of Long-Term Soil Loss on Selected Slopes Using the USLE Equation

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České Budějovice
2024

Declaration

I, Itthanan Suttikhana, hereby declare that I am the author of this graduation thesis and that I used only sources and literature displayed in the list of references in its preparation.

In České Budějovice on ....

Signature

Abstract

This study presents an assessment of long-term soil loss on selected slopes in both the Czech Republic and Thailand utilizing the Universal Soil Loss Equation (USLE). Soil erosion poses a significant threat to agricultural productivity and environmental sustainability worldwide, highlighting the importance of understanding erosion dynamics and implementing effective mitigation measures. The research focuses on experimental plots in the Czech Republic's South Bohemia region and Thailand's Sadao district, examining factors contributing to soil erosion and evaluating the efficacy of soil conservation practices. Results indicate notable disparities in soil erosion rates between the two regions, influenced by varying environmental conditions, land use practices, and topographical features. Despite comprehensive soil conservation measures recommended by the Department of Land Development in Thailand, challenges in implementation persist due to limited resources and expertise. The study underscores the urgent need for tailored soil conservation strategies to address specific erosion challenges faced by each region. By integrating site-specific data and recommendations, policymakers, land managers, and researchers can collaborate to promote sustainable land management practices and safeguard soil resources against erosion threats. Continued monitoring and assessment efforts are crucial to track the effectiveness of mitigation measures and ensure the long-term resilience of ecosystems and agricultural systems.

Keywords: soil erosion, soil loss, USLE equation, sustainable land management

Acknowledgment

I want to express my heartfelt gratitude to all those who have supported and contributed to the completion of my master's thesis titled "Assessment of Long-Term Soil Loss on Selected Slope Using the ULSE Equation."

First and foremost, I am deeply thankful to my thesis advisor, Ing. David Kabelka, Ph.D., for his invaluable guidance, encouragement, and unwavering support throughout this research journey. His expertise, insightful feedback, and dedication have been instrumental in shaping this study and enhancing its quality.

I extend my sincere appreciation to the participants of this study, whose cooperation and willingness to share their knowledge and experiences have been crucial in gathering the necessary data and insights for analysis.

I am grateful to my family and friends for their unwavering support, understanding, and encouragement throughout this academic endeavor. Their belief in my abilities has been a constant source of motivation.

Lastly, I express my gratitude to the academic institutions, libraries, and research articles that provided access to resources essential for conducting this study.

To all those mentioned and the countless others who have played a part, thank you for your invaluable contributions to this thesis.

Itthanan Suttikhana

Content

1 Introduction

In the past and present, human intervention has had unexpected consequences when it comes to managing, utilizing, and manipulating environmental resources for the comfort of living. It is becoming increasingly evident that this planet's soils are being washed away, destroyed, and contaminated. Land degradation is a major environmental issue affected by many factors such as climate change and inappropriate human practices (Mihi et al., 2019). Multilateral and national institutions are also recognizing the inverse relationship between economic development and environmental degradation including conserving and protecting the environment for future generations at the same time.

Land degradation involves deterioration in soil properties due to natural and accelerated factors associated with crop production, infrastructure maintenance, and environmental quality (Lal, 2001). It can be the loss of soil organic matter (SOM), a decline in soil fertility, and structural condition, erosion, adverse changes in salinity, acidity, or alkalinity, and the effects of toxic chemicals, pollutants, or excessive flooding and loss of biodiversity. Multiple processes lead to land degradation caused either directly or indirectly by human activities. Land degradation, including soil erosion, is a major challenge for the management of land in the world, especially with about one-third of the world's land area considered to be degraded. In particular, soil erosion poses major concerns around the world and is considered one of the most pressing environmental issues.

We cannot ignore the importance of soil and water. Although soil is a non-renewable resource, it is a valuable resource for the environment and for producing a wide variety of products. However, soil loss is the most common type of land damage. In every country, its severity is affected by land use and management methods. Due to this, soil loss has a detrimental impact on natural resources, reducing agriculture output and causing water quality degradation (Pal, 2016).

Since the Czech Republic has a hilly terrain and large fields there is a major problem with soil erosion on its cropland. The country has a long agricultural collectivization history (Van et al., 2007); the average farm size in the Czech Republic is 133 ha, whereas the EU average is 16.1 ha (Eurostat Statistics Explains, 2022). In turn, large areas of the landscape are saturated with monocultures, which reduces landscape biodiversity, increases soil erosion, and reduces landscape water retention (Knápek et al., 2020). The Universal Soil Loss Equation (USLE) modelling is used to assess soil risk and develop soil protection in the Czech Republic (Novotný et al., 2016).

Several methods have been developed to quantify the relationship between soil properties and plant growth. Conservation practices in agriculture have been extensively studied worldwide and have been shown to significantly increase soil infiltration. Thus, surface runoff and erosion are significantly reduced. There are various types of agricultural conservation practices, including reduced or no tillage, mulch covers and crop residues, cover crops, and herbicide application reduction.

However, only a few of these studies have assessed the long-term soil loss effect on slope land supported by direct measurements. Since the USLE development, original crop factor values may have changed due to new agriculture techniques and different crop varieties. In the Czech Republic, the original values are usually used without further validation and without any changes. We are focused on the experimental derivation of the USLE and runoff parameters of recent farming techniques that can be implemented to promote soil protection strategies (Herlina et al., 2003).

2 Literary review

2.1 Physical properties of soil

Soil is a complex physical entity with a variety of physical properties that have a profound influence on its fertility and productivity. These physical properties include texture, structure, porosity, permeability, resistance to compaction, and bulk density (Foth, 1978). Texture is an important soil physical property because it affects the relative amounts and size of soil particles, which controls a soil’s ability to absorb and store water and nutrients. Structure refers to the arrangement of soil particles into larger aggregates and influences the porosity and permeability of the soil, ultimately controlling water, air, and nutrient availability. Porosity is the measure of the amount of air and water-filled spaces present among soil particles and affects the rate of water infiltration and water-holding capacity of the soil. Permeability is the rate at which soil can transmit water, whereas resistance to compaction is a measure of the compactness of soil, affecting the rate of water and air movement (Hillel, 2003). Finally, bulk density is the dry weight of soil per unit volume and is related to the porosity, texture, and structure of the soil.

The physical properties of soil are closely linked to soil erosion. A soil's structure, texture, and color can all influence the amount and rate of soil erosion (Bünemann et al., 2018). Soils with a higher cohesion can better hold onto the soil particles and erode more slowly than soils with a lower cohesion. Soil structure along with soil porosity and permeability also influences how quickly water can move through a soil and carry away particles. High clay soils are less permeable and erode more slowly than soils with a higher percentage of sand and silt (Knapen et al., 2007). Finally, darker-colored soils are usually higher in organic material, which increases a soil's cohesion and stability. Physical properties of soil, therefore, have a direct effect on soil erosion and need to be taken into account in efforts to control it (Hillel, 2012).

2.2 Chemical properties of soil

Soil is composed of a variety of different materials, each of which exhibits unique chemical properties. Soils are made up of minerals, organic matter, water, and air.

Each of these components has a series of chemical properties that contribute to fertility, moisture availability, and the exchange of nutrients within the soil (Norton et al., 2018). Minerals have various properties such as a high capacity for cation exchange, which helps soil to retain essential nutrients for plant growth. Organic matter also has numerous chemical properties, such as the capacity to store nitrogen, phosphorus, and sulfur (Brady and Weil 2005). Water held in soil is composed of a variety of chemicals such as dissolved carbon dioxide, oxygen, nitrogen, phosphorus, nitrogen, calcium, chloride, sodium, magnesium, and many more. Each of these chemicals contributes to pH, soil structure, availability of nutrients, and other plant-available characteristics.

The chemical properties of soil have a significant impact on its potential to erode Tale and Ingole, 2015). Soils with higher concentrations of clay and other small particles are more susceptible to erosion than soils that are made up of larger particles. This is because the larger particles are better able to hold together and resist the force of flowing water. Additionally, soils with higher organic matter content are less likely to be eroded because organic matter retains more water, thus slowing down the movement of water within the soil. Finally, soils with a greater quantity of bases or alkalis are generally more robust in their structure and have higher shear strength, which helps reduce erosion (Foth, 1978).

2.3 Water in the landscape

Hydrology, as a field of study, delves into the intricacies of water movement across the Earth's surface. In the broader global context, water doesn't undergo a net loss but rather engages in a perpetual cycle of continuous circulation and dynamic state changes (Ghulam M. et al., 1995; Stephens et al., 2021). This fluid resource is intricately retained within various environmental compartments, deeply woven into the fabric of the perpetual hydrological cycle. The ongoing nature of this cycle is perpetuated by a complex interplay of region-specific factors, introducing significant variations in hydrological processes across diverse landscapes.

These influential factors encompass a spectrum of elements such as rainfall patterns, topographical features, vegetation cover, land use practices, and the inherent physical and chemical characteristics of the soil (Gao et al., 2018). The resulting regional disparities manifest in distinctive water balance dynamics. Watersheds endowed with natural fertility tend to adeptly retain rainwater, a feat facilitated by the presence of protective vegetation cover that mitigates the impact of rainfall droplets, allowing water to effectively permeate the soil surface. Consequently, a portion of this water may embark on a journey back into the atmosphere through evaporation, eventually contributing to the formation of clouds and subsequent precipitation (Rast et al., 2014).

Conversely, certain regions may witness soil moisture infiltrating the subsoil, fostering groundwater recharge that sustains the natural flow of springs, streams, and rivers. This intricate interplay establishes a harmonious water supply for the watershed throughout the year. On the flip side, in degraded watersheds characterized by insufficient soil cover, rainfall is more susceptible to surface runoff (Pla,1997). This heightened runoff propensity amplifies the risk of soil erosion, facilitating the transport of nutrients and chemicals into natural water bodies. These phenomena significantly elevate the likelihood of hydrological disasters, posing substantial environmental challenges that directly impact human livelihoods (Morgan, 2009). Consequently, these challenges present societal and economic hurdles that prove unavoidable and demand strategic mitigation efforts.

2.4 Erosion process

Soil erosion is a natural process characterized by the gradual dislodgment and movement of soil particles from their source, typically brought about by natural changes on the Earth's surface (Toy et al., 2002). Conversely, human-induced soil loss arises from alterations in the physical characteristics of the soil cover, often associated with activities such as deforestation through logging and certain agricultural practices. The removal of natural vegetation exposes the soil surface to direct impact from elements like rainfall and wind, resulting in the destruction of soil structure and the displacement of soil particles (Foster et al.,1985).

The process of soil erosion involves detachment, transport, and deposition (Panizza, 1996), posing a hazard traditionally linked to agriculture in tropical and semi-arid regions. This phenomenon significantly impacts the long-term productivity and sustainability of agriculture (Morgan, 2005). The term "erosion" originated from the Latin word "erodere," meaning to eat away and excavate. Over time, it evolved to encompass all forms of earth's surface destruction caused by water (Zachar, 1982).

Zachar (1982) classified erosion into two categories: natural processes and anthropogenic processes. In natural conditions without human intervention, soil productivity remains relatively constant, and erosion maintains equilibrium within acceptable limits. Even when anthropogenic activities, such as agriculture with conservation techniques, are introduced, the impact on soil erosion can be minimal or nil. However, this equilibrium may be disrupted by exceptional natural events like heavy rainfall, prolonged drought, earthquakes, or landslides, leading to abnormal erosion. Acceleration of soil erosion occurs when abnormal conditions coincide with anthropogenic activities, such as deforestation, non-conservative farming, and earth-moving (Panizza, 1996).

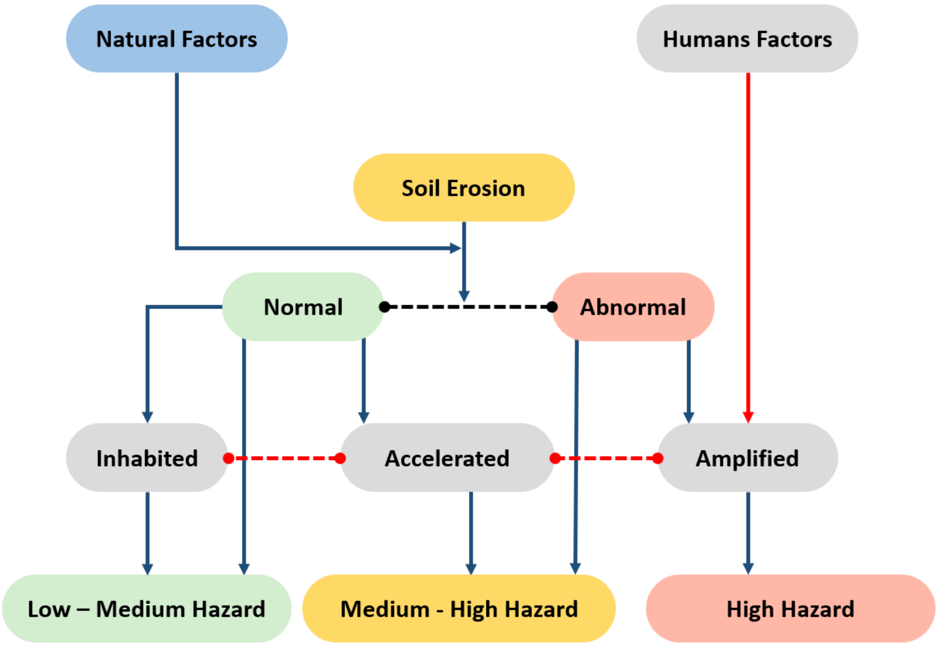

Figure 2.1: The relationship between soil erosion type and related hazard levels (Panizza, 1996).

Humans, in this context, can be likened to catalysts, accelerating the soil erosion process and impeding the soil's natural ability to regenerate (Nearing et al., 2017). This phenomenon becomes particularly pronounced in areas with agricultural activities, such as the United States, where studies have indicated an annual soil loss of approximately 10 tons per hectare per year, surpassing the natural erosion rate of around 9 tons per hectare per year (E-Swaify et al., 1982). The severity and rapidity of the impact of human activities on soil erosion are evident, highlighting the urgent need for proper soil conservation practices. Previous research has revealed that inadequate knowledge and unsustainable land management practices contribute to accelerated soil degradation caused by human-induced erosion (Pimentel, 2006).

It is noteworthy that soil erosion can be categorized into two main types based on its causative factors. Natural erosion processes, driven by environmental changes, represent a slow and gradual form, while human-induced erosion emerges as a more immediate and intensified consequence of anthropogenic activities (Terrence et al., 2002).

Wind erosion

Soil erosion induced by wind constitutes a natural phenomenon that instigates the degradation of soil integrity. The primary catalyst for this process is the force of wind itself. Wind currents, endowed with the ability to abrade and transport minute soil particles, contribute significantly to the erosion phenomenon. This erosive action results in the removal of fine soil particles, leaving behind predominantly coarse sediment in the affected area (Duniway et al., 2019). Notably, soil erosion by wind is most prevalent in geographical regions situated between latitudes 20 and 45 degrees north and south. These areas are characterized by arid conditions, marked by scant vegetation cover, and are typically associated with high temperatures. The prevalence of soil erosion by wind is particularly pronounced in regions characterized by dry climates and strong wind currents, such as deserts or coastal areas. In such environments, the combination of limited vegetation and elevated temperatures creates conducive conditions for wind-induced soil erosion to occur, further emphasizing the intricate interplay of climatic and topographic factors in this natural process (Zobeck & Van Pelt, 2011).

Water erosion

Water erosion, a globally significant type of soil erosion, occurs when the rate of precipitation surpasses that of water infiltration, resulting in the detachment and transportation of soil (Rose & Hairsine, 1988). This process is facilitated by the impact of raindrops and the runoff of water, particularly prevalent in regions with humid or sub-humid climates featuring frequent rainstorms, as well as in arid and semi-arid areas experiencing intense storms on exposed soil (Bryan, 2000).

A particularly destructive manifestation of water erosion is concentrated gully erosion, capable of causing extensive damage in a single high rainfall event, including the washing away of crops, exposure of plant roots, lowering of the groundwater table, and disruption of plant growth and landscape stability (Beutler et al., 2003).

Simultaneously, gully erosion significantly contributes to the loss of sediment and nutrients, resulting in altered landscape aesthetics and substantial removal of sediment. Frequently observed at the lower ends of fields, sedimentation from gully erosion buries crops, contaminates water and alters the shape of field borders. Notably, gully erosion is a major contributor to non-point source pollution, especially sediment and chemicals, and is more prevalent in mountainous terrains and soils that are structurally fragile (Cogo et al., 2003).

The process of soil erosion by water initiates the degradation and depletion of soil. In the absence of a protective surface cover, the kinetic energy of rainfall directly impacts the soil surface, causing severe damage to its structure and the detachment of soil particles. These detached particles form sediment, and when rainfall intensity surpasses soil infiltration rates, water runoff ensues (Conrad et al., 2006). This runoff, guided by the natural slope of the terrain, can erode the soil surface, transport sediment, and carry away nutrients and organic matter, ultimately depositing them in natural water bodies (Lal, 2001). This phenomenon leads to waterlogging, chemical contamination, and disruptions in natural environmental systems within water sources.

Effective control and management of soil erosion are paramount, as the loss of topsoil reduces soil productivity even with consistent inputs (Zuazo and Pleguezuelo, 2009). While complete prevention may be impractical, mitigating erosion to a manageable or tolerable level is essential to avoid significant impacts on productivity. The magnitude and impact of soil erosion on productivity depend on various factors, including soil profile, horizonation, terrain, soil management practices, and climate characteristics (Pimentel, 2006).

2.4.1 Factors affecting soil erosion

Climate factors

Soil erosion is primarily caused by water or rain. As a result of the raindrop impact, the soil is split apart. Water runoff is still occurring as a result of falling water and particle movement caused by falling water may appear in solid and liquid form such as rain, snow, hail, fog, or dew, depending on the nature of the rain, which is an important factor in contributing to soil erosion and the climate of each country, such as the amount of rain falling each time, the shape of the raindrops, size, speed, duration, and distribution for each season (Zaw, 2013). There is also a change in temperature during the seasons or between day and night. As a result of the temperature change, it is not the same as before which has a significant effect on the adaptation of soil structure (Monte et al., 2005). This is because the soil has changed its shape to be different from the original structure, causing the soil to have particles that bind or have less binding force.

Terrain factors

The slope of the area. This is the most significant factor in soil erosion. The steeper the slope, the higher the soil erosion rate. Because areas with slopes let the water run off the ground quickly according to the earth's gravity. However, the constant water flow is very influential if the rains are light but intense. This will cause soil erosion quickly by washing the soil down to a very low place (Shanshan et al., 2018).

Length of the slope. As the length of the slope increases, the amount of soil erosion is increased. As a result, the rate of runoff is increased. While it rains consistently in the area of the mountain ridge and the sloping slopes, soil erosion does not usually occur. We can see erosion of the soil in the lower areas. There is a wide ridge area that does not cause much soil erosion. Soil runoff is becoming more powerful than soil particles, resulting in high erosion depending on the width of each ridge, several factors may apply (Kinnell, 2000).

The shape of the slope. For each slope, the height may be straight, curved, convex, concave, etc. A sloppy area has an upward curve, just as the lowest area has a steep slope, which is an area where water flows at a rapid rate. This causes more soil erosion than the slope of other types. Areas with a concave slope are areas where precipitation is more than leaching soil erosion because there is a slight slope as a result of the rate of runoff on the surface decreasing rapidly (Rieke-Zapp & Nearing, 2005).

Soil factors

Resistance to erosion and movement. The difficulty of soil erosion increases with the size of the particles, but the difficulty of movement depends on the soil type, for example, clay is more difficult to be eroded than sandy soil, but clay soil is more easily carried away than sandy soil. The water permeability rate differs according to the physical properties of the soil which may have a loose coagulation structure. It also depends on organic matter, soil particle content, soil fertility, and soil moisture content (Knapen et al., 2007).

Soil water permeability. The properties of the soil are different, causing the water permeability rate to be different (Bryan, 2000). When the soil has a loose coagulation structure and the shape of the soil grains is round, this causes more space in the soil, but if the soil texture has fineness, it can clump together and absorb water well. This type of soil is resistant to erosion, the movement of water from the surface either through natural holes or holes dug by animals or soil fissures, which are called permeability through the soil surface (Terrence et al., 2002). Therefore, surface water runoff occurs when the land is fully wet.

Depth of topsoil. The area of the soil surface that used to be loamy soil is high in organic matter. When the soil surface is eroded, it is easy to wash away the soil. As a result, the remaining soil largely comprising organic matter does not absorb water well, thus causing soil runoff easily (Zhang et al., 2021).

Plant management factor

Covering the surface of the soil with vegetation or plant debris has a direct effect on reducing the impact of raindrops and reducing soil fragmentation and runoff of water on the surface, thus reducing soil erosion. Crop management is very variable and cannot be calculated because it is related to other factors resulting in different soil losses according to crop rotation, which is related to the period and season of cropping (Wischmeier and Smit, 1965). Therefore, it can be concluded that the process of planting and crop management can reduce soil loss. Many forms of soil erosion occur in nature. Humans benefit more than the disadvantages from natural forms but human actions will result in increased soil erosion if we are not controlled or prevented by climatic factors, topography, soil characteristics, vegetation characteristics, and human activities (Biddoccu et al., 2020). All of the above-mentioned factors are accelerating the occurrence of more severe soil erosion, such as abnormal rain, forest encroachment, inappropriate human practices, etc.

Human Factors

Though soil erosion is a natural process, it has existed since the beginning of time. This is a natural adaptation of the earth's surface. A geological erosion occurs without a human catalyst to help the process. When a human factor is present, the erosion is greater than when it is occurring naturally. A process like this is known as accelerated erosion. Deforestation, habitat loss, and agricultural activities such as removing trees and plants, plowing fields, and overgrazing livestock disrupt the roots that stabilize sediment and soil. The rate of erosion caused by these human activities can be 10 to 100 times greater than that caused by non-human geologic processes (Xiao et al., 2021). As a result, increased erosion decreases soil quality and reduces water quality by causing sediment and pollution to wash into rivers and streams.

2.4.2 Effects of soil erosion

Soil erosion is an important factor that lowers the earth's surface level due to nature. Despite this, the most significant factor causing more damage is inappropriate human activity, which negatively impacts economic and social sustainability (Issaka & Ashraf, 2017).

This causes the soil to become less fertile, unable to retain moisture well, and unsuited to agriculture due to its low water permeability. The soil also deteriorates in terms of chemical properties, biology, and physicality, changing from its former state. As a result of low soil structure and unsuitable water content, the soil is not able to store water, which leads to increased runoff of surface water. In turn, this makes it harder for soil to retain water, resulting in a decrease in infiltration rates. Heavy metals, pesticides, fertilizers, and other chemicals released into water sources pollute surrounding areas profoundly (Arna'eza et al., 2004).

All of the above have wide-ranging economic and social impacts. In areas upstream of dams, which have increased sedimentation levels. In addition to sedimentation, increased water flow through a river system negatively impacts land quality by causing erosion and sedimentation. It can negatively affect local ecosystems and decrease the quality of water in nearby rivers, streams, and other water sources (Nipon, 2002).

2.4.3 Organic matter and nutrients in soil

In studying soil erosion, besides evaluating the amount of soil erosion, researchers also studied the impacts or damages caused by soil erosion. It was found that damages from soil erosion in fertile soils lead to a decrease in soil structure strength and the loss of important organic matter and nutrients crucial for plants. Therefore, researchers reviewed the literature on soil organic matter and nutrient content to enhance knowledge and understanding of the impacts of losing organic matter and nutrients in the soil and then applied it to the study with the details as follows (Lal, 2009).

Organic matter

Organic matter is the residue obtained from the decomposition of organic substances, including plant residues, animal carcasses, as well as human and animal excreta. It is important in controlling the properties of soil, including physical, chemical, and biological aspects, as well as serving as a source of nutrition for plants and soil microorganisms (Midmore et al., 2004). If the soil lacks organic matter, it will suffer from a deficiency of plant nutrients, lack fertility, be prone to water erosion, and have adverse effects on various associated life forms.

Sources of Organic Matter in Soil

(1) Decomposition of plant and animal residues by various microorganisms, including important decomposers such as actinomycetes, fungi, and bacteria.
(2) Decomposition of plant debris such as stems, branches, and plant materials buried in the soil, such as crop residues left after harvesting, or specific crops grown for soil incorporation, such as green manure.
(3) Decomposition of various human and animal waste products.
(4) Decomposition of compost or manure added to the soil.

Cells of soil microorganisms, whether living or dead, as well as substances synthesized by soil microorganisms (Soane, 1990).

Impact of Organic Matter on Soil Physical Properties

1. Helps reduce the erosion of soil particles by raindrops on the soil surface.
2. Helps increase pore space and reduce overall soil density.
3. Helps reduce water evaporation from the soil.
4. Helps increase soil water retention capacity.
5. This causes the soil color to change from brown to black. Therefore, soils with brown or black color are considered to have a high organic matter content (Larson & Clapp, 1984).

Impact of Organic Matter on Soil Chemical Properties

1. Acts as a source of plant nutrients due to the decomposition process of organic substances, which releases plant nutrients through microbial activities in the soil.
2. Increases the ability to exchange positively charged ions, which prevents the loss of plant nutrients applied to the soil in the form of chemical fertilizers or natural soil nutrients from leaching away through the process of erosion, thus improving the efficiency of nutrient uptake by plants.
3. Helps reduce soil salinity (Senesi & Loffredo, 2018).

Impact of Organic Matter on Soil Biological Properties

1. Acts as a source of food for soil microorganisms, as the transformation of plant nutrients in the soil is largely influenced by microbial activities.
2. Helps control certain soilborne plant diseases. The addition of organic matter in the form of compost or manure helps increase soil microbial populations, which play a vital role in controlling the quantity and activity of fungal pathogens, which are a cause of plant diseases that rely on soil for survival (Esmaeilzadeh & Ahangar, 2014).

The presence of organic matter in soil is essential for maintaining soil fertility and productivity. In Thailand, organic matter decomposes easily due to factors such as the country's tropical climate, frequent rainfall, extensive agricultural practices without organic matter input, continuous land clearing, and the lack of appropriate soil and water conservation measures, leading to organic matter being washed away by surface runoff and eroded from the soil. Therefore, maintaining and enhancing organic matter content in soil is crucial for sustainable agricultural production and environmental conservation (Lal, 2009).

2.5 Soil conservation technologies

Soil conservation technologies are important tools used to prevent land degradation and erosion, and maintain the quality of soils. Through a range of techniques, farmers, landowners, and scientists are able to effectively protect and conserve soil for agriculture and other purposes. These technologies include crop rotation, cover cropping, contour plowing, conservation of crop residues, and reduced tillage. These methods are used to reduce the impacts of runoff, wind erosion, and cultivation on soils; while also capturing valuable nutrients and organic matter. By utilizing appropriate soil conservation technologies, agricultural productivity can be improved by reducing losses of topsoil and preserving the nutrient properties of soil (Xiong et al., 2018).

Manifesting in diverse forms and varying degrees of severity, soil erosion invariably results in land degradation and diminishes the productive capacity of the affected land. The optimal and most precise strategies for addressing soil erosion hinge on factors like topography, vegetation, atmospheric conditions, and more (Wolka et al., 2018). Nonetheless, there exist established methods and practices, either independently or in combination, that can be employed to forestall, alleviate, or diminish the effects of this erosive action such as;

Choose the suitable land utilization. The choice of land use for a specific area should align with the soil type and its susceptibility to erosion. The selection of land use must be guided by the location, as well as the physical and chemical attributes of the soil. For instance, steep slopes are well-suited for cultivating forage crops, whereas forests are a suitable land use option for marginal lands characterized by degraded and less productive soils (Gomiro, 2013).

Preserve organic matter content. Organic matter plays a crucial role in binding soil particles together, contributing to the stability of the soil. Soils with higher organic matter content exhibit enhanced stability, improved infiltration, and increased water-holding capacity, reducing their susceptibility to erosion. Additionally, organic matter is essential for fostering microorganism activities and promoting better vegetation production, reinforcing the soil's resistance to water-induced erosion, including rill erosion, sheet erosion, and tunnel erosion. To maintain optimal organic matter levels, it is essential to carefully manage the balance between the decomposition rate and the buildup of organic matter. Planned practices, such as minimizing soil disturbance and incorporating measures like adding manure or leaving crop residue, are effective in establishing and preserving this balance (Karlen & Cambardella, 2020).

Established the cover crop residue. Implementing ground cover through the retention of crop residues has proven effective in primarily mitigating splash erosion. This approach prevents rainfall from directly impacting the soil, thereby reducing its susceptibility to erosion. Additionally, it plays a role in controlling sheet erosion by moderating the surface water flow. Achieving crop residue cover can be accomplished by minimizing tillage activities or adopting conservation tillage practices (Zuazo & Pleguezuelo, 2009).

Tillage reduction. The use of intense tillage operations, intended to enhance soil arability, paradoxically renders the soil highly erodible. This practice disrupts the structural integrity of the soil, diminishes moisture content, and increases vulnerability to raindrop splashing. Consequently, reducing tillage operations or adopting alternative methods becomes imperative to address various forms of erosion and mitigate the adverse effects on soil structure and stability (Thomas et al., 2007).

Zero tillage or direct seeding. Zero tillage and direct seeding, when employed in tandem, constitute effective strategies for addressing soil erosion and enhancing agricultural productivity. In the practice of zero tillage, a significant portion of crop residue is evenly spread across the field, while stubbles remain intact. Direct seeding takes the approach of planting crops directly onto prior crop residues, utilizing fertilizers and herbicides instead of traditional tillage for weed management and nutrient cycling. This combined approach proves economical and advantageous, mitigating the adverse effects of soil erosion while concurrently fostering increased crop production (Dridiger et al., 2020).

Implement the practice of conservation fallow. Employing fallow periods has proven to be a successful approach to rejuvenating land productivity by allowing it to remain uncultivated for one or more vegetative cycles. Nevertheless, instances of moderate to severe erosion frequently occur in fallow areas devoid of any crop residue cover, as the soil's organic matter content diminishes due to heightened decomposition. In response to this challenge, the implementation of conservational fallow involves retaining crop residue within the fallow areas, ensuring a continuous supply of organic matter to the soil, and concurrently minimizing the need for extensive tillage operations (McKell, 1993).

Cultivate forage crops and implement crop rotations. Implementing crop rotations and incorporating forages within these rotations significantly mitigates water erosion on farms. Perennial forages, with their fibrous root systems, provide dual protection to the soil, preventing erosion both above and below the ground. Strategic timing of rotations and careful selection of crop varieties contribute to maintaining a robust nutrient cycle within the farm. Alternating legumes and cereals with forages in the rotation yields optimal results compared to non-rotated controls, enhancing the overall sustainability and productivity of the agricultural system (Shah et al., 2021).

Utilize direct seeding for the conversion of pasture. Directly seeding crops into sod presents a method that eliminates the need for intensive plowing and harrowing in pasture lands, all while maintaining consistent yields. This approach offers an alternative to traditional cultivation practices by allowing for direct seeding without extensive soil disturbance. Utilizing both disc and air drill methods, this technique proves to be efficient in optimizing agricultural processes and reducing the environmental impact associated with conventional soil preparation methods (Greenwood & McKenzie, 2001).

Waterways with a covering of grass. grassed waterways, as the name implies, are grass-covered channels within farmlands designed to efficiently transport substantial water volumes from the land to a safe outlet. Their primary purpose is to prevent excess water from eroding the farmland soil by providing a controlled pathway for its disposal. However, newly constructed waterways are susceptible to failure through water erosion. To ensure sustainability, it is crucial to maintain a robust grass cover on these waterways. The effectiveness of grassed waterways relies on their size, which should be sufficient to handle peak water volumes from storms and melting snow, taking into account historical records and the size of the land they are intended to drain. During the establishment of a grass waterway, careful attention should be given to providing a gentle slope, while adhering as closely as possible to the natural drainage pattern (Finer & Auerswald, 2003).

Terracing. In areas characterized by rugged terrain featuring steep and continuous slopes, terraces emerge as the optimal solution for addressing challenges associated with water erosion and consequential mass movements, such as landslides. Constructing channels on steep slopes proves to be challenging, and natural water channels often fail to efficiently drain the entire region. Consequently, water tends to follow the slope and permeate the soil downslope. To counteract this, terraces are strategically established along the contour, effectively controlling the flow of water and mitigating the risks of erosion and landslides (Deng et al., 2021).

Cross Section of Terrace. Implementing terracing in sloping areas involves creating structures that intercept runoff water. These terraces effectively capture and redirect the intercepted water through channels designed between the terraced levels. The construction of terraces on hilly terrain necessitates the excavation or removal of materials to shape channels, and the repurposing of these materials to establish flat areas known as berms for agricultural activities (Maetens et al., 2012). Despite the relatively high costs associated with terrace construction, especially in comparison to alternative methods, terraces stand out as one of the most effective solutions for managing erosion in sloping lands. Terraces not only aid in stabilizing the slope but also contribute to enhancing the soil‘s productive potential, making them a valuable investment for sustainable land management (Deng et al., 2021).

2.6 The Universal Soil Loss Equation (USLE)

The USLE is a widely used evaluation tool for predicting potential soil loss over a given period of time. This model was developed by Wischmeier and Smith (1965) soil erosion scientists to help measure erosion processes and quantify a given catchment area's soil erosion susceptibility. It is calibrated by integrating both local and regional factors such as climate, soil, topography, land use, slope length and steepness, and management practices into a single equation. which has studied 10,000 plots of soil loss experiments per year for several decades. Results in statistical data of various variables that are related to each other can be used to create an equation to predict soil loss and have been compiled and developed into the USLE. Which is the starting point that has been widely used around the world, methods and guidelines for using the universal soil loss equation by presenting a well-known form of the equation the factors used in calculating soil loss are:

$$\mathbf{A = R\times K\times L\times S\times C\times P} \qquad (1)$$

- A is the estimated amount of soil loss per unit area calculated from all 6 factors as in the equation, excluding erosion, the unit is tons/hectare/year.
- R is the rainfall erosivity factor (R-factor), a number representing the ability of rain to cause erosion in a given year, calculated from the EI30max, the unit is MJ ha^{-1} cm h^{-1}.
- K is the soil erodibility factor (K- factor), and each type is the soil loss per unit of rain erosion power that causes soil erosion in the experimental plot. It is limited to 21.13 m (72.6 ft) long on a 9% slope, tilled, and left empty.
- L is the length factor (L-factor) is the ratio of soil loss from crop plots to plots with a slope length of 21.13 m (72.6 ft).
- S is the slope factor (S-factor) is the ratio of soil loss from the desired plot. Compared to the standard plot with a slope of 9%.
- C is the crop management factor (C-factor), which is the ratio of soil loss from the specified cropping plots to the empty plowed plots. which have the same soil type and slope under the same precipitation.
- P is the practice management factor (P- factor) is the ratio of soil loss from soil conservation methods to crop cultivation up and down slopes (Wischmeier & Smith, 1978).

The USLE is used as a guideline for estimating the amount of erosion. The soil that is expected to occur in a particular area with one advantage It is, therefore, a tool it is one of the important tools for planning land use change and conservation methods. which is the best method at present (Nipon, 1984).

2.7 Basic information on study areas

The Czech Republic

The Czech Republic, located in central Europe, covers an expanse of 78,866 km^2, featuring predominantly hilly and highland terrain. With a temperate continental climate marked by westerly circulation, the country experiences annual mean precipitation ranging from 400 to 1500 mm, peaking during the summer months. Arable land occupies around 42% of the total area.

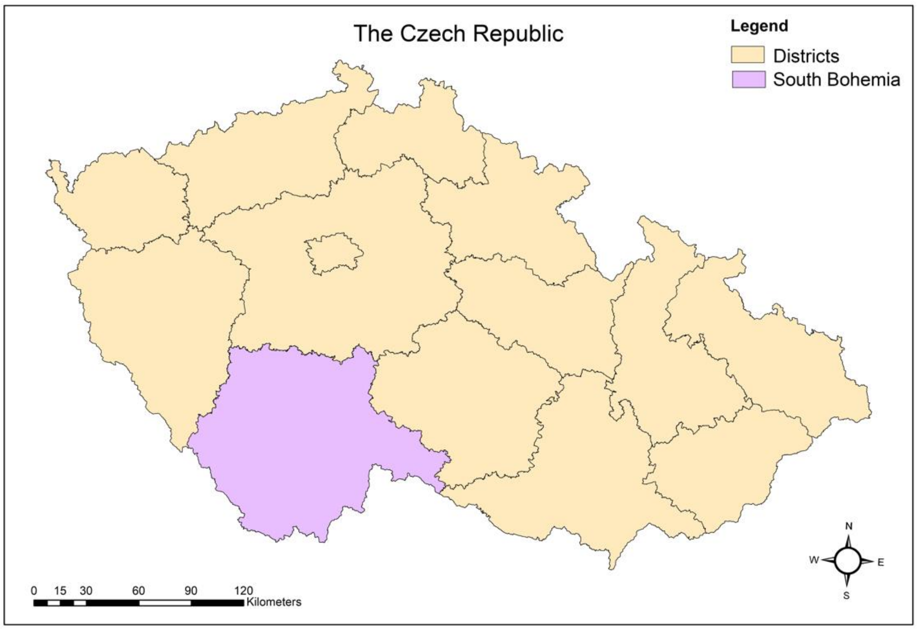

Figure 2.2: Map of the Czech Republic (ArcMap 10.6.1).

In the Czech Republic, water erosion stands out as a critical form of soil degradation, caused by factors such as agricultural practices, deforestation, and land use changes. Approximately 50% of arable land faces the risk of water erosion in the country (Janeček et al., 2012). Unfortunately, most agricultural land is exacerbated by the challenging topography and increased parcel sizes, especially during the period of intensified agricultural production from 1950 to 1990. The substantial size of agricultural plots resulting from land consolidation, soil compaction by heavy machinery, and the use of unsuitable farming methods leave these areas vulnerable to accelerated erosion (Dostál et al., 2006).

Verheijen et al. (2009) established that soil losses greater than 1 ton per hectare per year are generally considered irretrievable, surpassing the rate of soil formation and constituting unacceptable rates of soil erosion. According to the legislation, the maximum soil loss for standard soils in the Czech Republic in 2023 is 9 tons per hectare per year. The distribution of areas exceeding these critical values in the Czech Republic is detailed in Table 1. Records from the Database on Monitoring Soil Erosion of Agricultural Land (Kapička & Žížala, 2013) indicate that in cases of intense rain, losses can exceed tens of tons per hectare.

Table 2.1: Long-term assessments of annual soil loss (A) values in Czechia (Kapička & Žížala, 2013).

Average annual soil loss	A (t ha^{-1}year^{-1})	Distribution (%)	Area (km^2)
Very slightly threatened	below 1.0	49.55	20,688
Slightly threatened	1.1–2.0	18.26	7,623
Medium threatened	2.1–4.0	15.57	6,501
Heavily threatened	4.1–8.0	10.38	4,334
Very heavily threatened	8.1–10.0	2.00	834
Extremely threatened	above 10.1	4.24	1,771
Total		**100.00**	**41,753**

As of December 31, 2016, agricultural land resources (ALR) in the Czech Republic totaled 4,208,000 hectares, representing 53.4% of the country's total land area. In 2016, 70% of this agricultural land was under ploughing. The quality of these resources is assessed using the Classification of Agricultural Land Resources (CALR), revealing that around 60% of ALR comprises less to poor fertile soils, with approximately 54% of arable soils classified as average and below-average fertility, and 6% considered completely unsuitable for agroecosystems.

Thailand

Thailand, located in Southeast Asia, boasts diverse topography, including lush plains, rugged mountains, and coastal areas along the Gulf of Thailand and the Andaman Sea. The country's climate is typically tropical, characterized by monsoon rains from May to October and a dry season from November to April, with temperatures varying across regions. Agriculture plays a significant role in Thailand's economy, with rice being the primary crop cultivated in the central plains, while the northern regions specialize in crops like maize, fruits, and vegetables. Southern Thailand is known for rubber, palm oil, and coconut production, with fishing being another vital sector along the extensive coastline (FAO, 1995). Thailand's varied topography and climate support a rich agricultural sector that contributes significantly to its economy and cultural heritage.

In Thailand, soil erosion by water stands out as a leading factor contributing to land degradation, resulting in the depletion of surface soil and essential plant nutrients. (Land Development Department 2000). The Land Development Department (LDD), under the Ministry of Agriculture and Cooperatives, serves as the primary agency responsible for evaluating soil erosion and formulating soil conservation strategies in Thailand. Within its purview, the LDD advocates the adoption of the USLE as a pertinent empirical model for assessing soil erosion. The USLE considers six key factors in its estimation: the erosivity of rainfall and runoff, soil erodibility, slope length, slope steepness, land cover/management practices, and soil conservation measures.

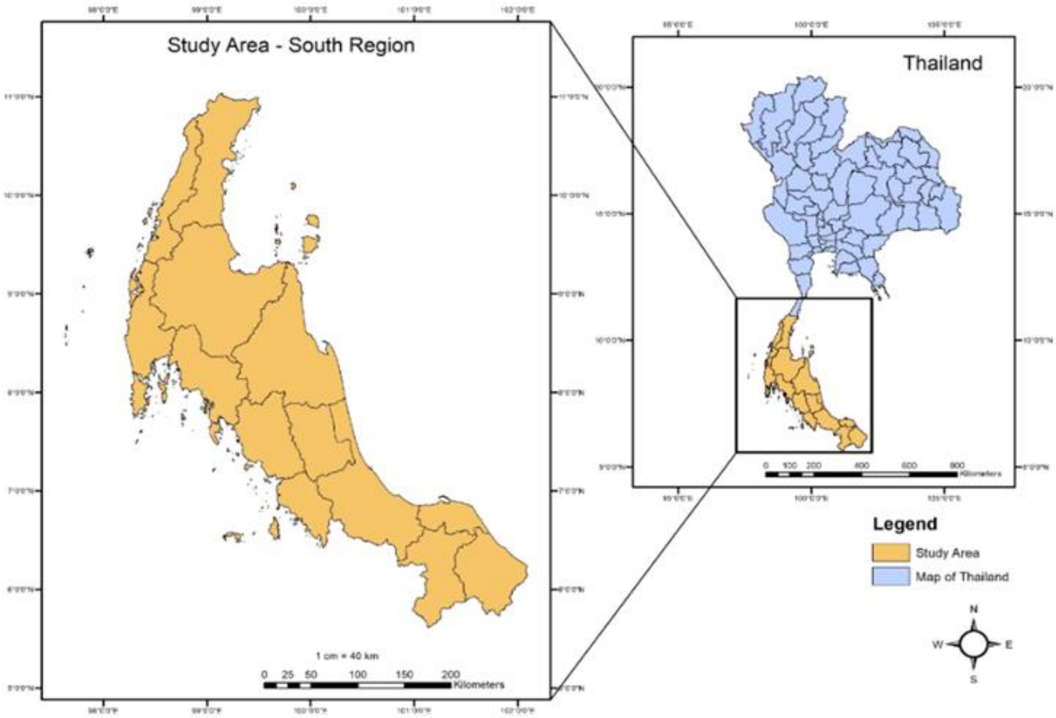

Figure 2.3: Map of the study area situated in southern Thailand (ArcMap 10.6.1).

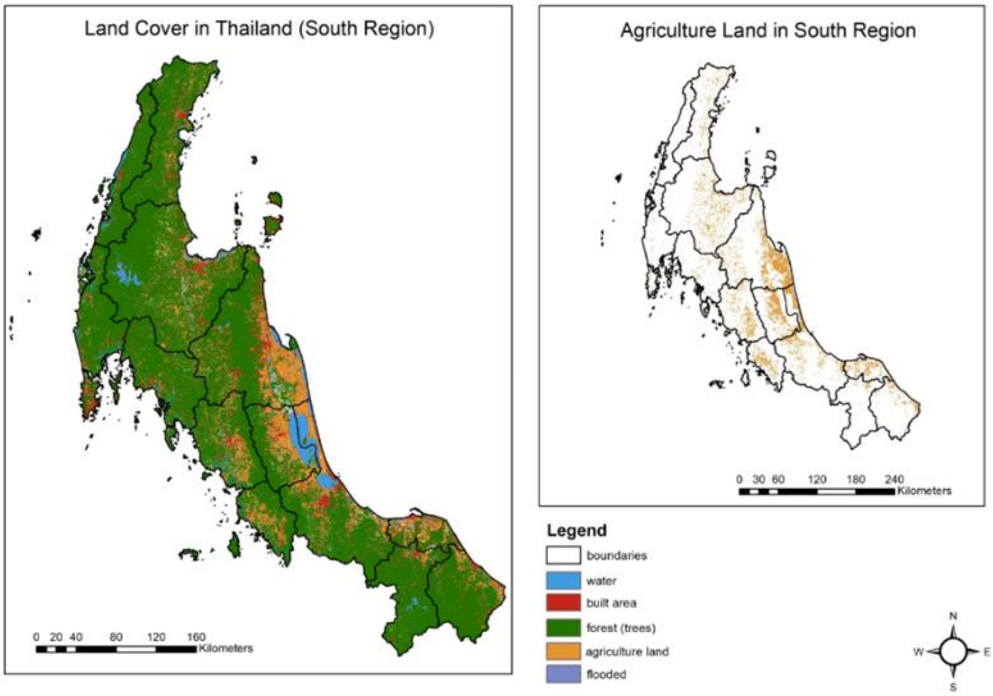

Figure 2.4: Land use of southern Thailand (ArcMap 10.6.1).

The soil conservation measures recommended by the LDD encompass both mechanical and agronomic approaches. Mechanical interventions include contour cultivation, tied ridging, bedding, and terracing, while agronomic measures involve practices such as cover cropping, mulching, intercropping, and the cultivation of vetiver grass. Despite these comprehensive recommendations, the widespread implementation of soil conservation measures faces challenges in Thailand. One major hindrance is the limited application of these measures, attributed to the scarcity of well-trained personnel and inadequate financial support (Phongpaichit & Baker, 1997). Additionally, the absence of thorough and spatially focused analyses of the soil erosion process in the country contributes to the inefficiency of soil conservation practices across most regions. Consequently, the soil erosion predicament has proliferated extensively throughout Thailand, underscoring the need for enhanced initiatives and resources to address this critical environmental concern (Sthiannopkao, 2006). Thailand is divided into 5 levels, with the details of each severity level outlined in Table 2.2.

Table 2.2: Classification of soil erosion severity in Thailand (The LDD 1983).

Levels	Average annual soil loss (t ha−1year−1)
Very slightly threatened	below 1.0
Slightly threatened	1.01-5.00
Medium threatened	5.01-20.00
Heavily threatened	20.01-100.00
Very heavily threatened	Above 100

The DLL (2002) reported that Thailand has a total area of 51.33 million hectares. The majority of areas experience soil loss ranging from 0-30 tons per hectare per year. The southern region has higher soil loss compared to other regions, with the majority experiencing soil loss between 0-312 tons per hectare per year. In contrast, the northern region mainly experiences soil loss between 0-238 tons per hectare per year. The central region mostly experiences soil loss between 0-107 tons per hectare per year, the eastern region between 0-100 tons per hectare per year, the western region between 0-63 tons per hectare per year, and the northeastern region has the lowest soil loss, with the majority experiencing soil loss between 0-25 tons per hectare per year.

3 Aim of work

This study aimed to evaluate long-term soil loss on specific plots of land, with the overarching goal of refining land management strategies to mitigate soil erosion in both the Czech Republic and Thailand. Furthermore, in the context of the selected Thai lands, the research sought to identify suitable alternative crops that not only thrive on the specified terrain but also contribute to reducing soil loss. Traditionally designated as rubber plantations, the Thai lands faced economic challenges due to a decline in rubber prices. Consequently, the research endeavors to identify and recommend alternative crops that are well-suited to the land, ensuring sustainable cultivation practices in light of changing economic conditions. The specific aims of this research include:

i. *Surface Runoff and Drainage Analysis:* To characterize surface runoff lines, assess their directional flow patterns, and identify potential issues related to the length and direction of drainage pipes.

ii. *Land Division and Management Strategies:* To facilitate the proposed division of the land into sections, each with a tailored management plan. This involves employing the Universal Soil Loss Equation (USLE) method to quantitatively analyze soil loss for bare soil, selected crops, and soil conservation management technologies.

iii. *Optimal Land Division:* To propose an optimal division of the land-based on calculated soil loss, enhancing land management strategies, and contributing to sustainable practices.

iv. *Threat Assessment to Infrastructure:* To assess the vulnerability of key elements such as roads, villages, and water supplies to erosion, providing valuable insights into potential threats to infrastructure and resources.

v. *Integrated Analysis and Recommendations:* To integrate the findings into a holistic understanding of soil erosion, contributing to the quantitative analysis of long-term soil loss on slopes in the Czech Republic and Thailand. Additionally, to provide recommendations for region-specific conservation measures, aiming to reduce soil erosion rates and promote sustainable land-use practices in both study areas.

4 Material and Method

4.1 Selection of study sites

In the selection process of study sites within the Czech Republic, the primary focus will be on identifying agricultural land adhering to conventional management practices prevalent in agriculture. These practices typically involve traditional tillage methods, monoculture cropping systems, and minimal implementation of soil conservation techniques. The selection criteria will prioritize areas based on slope characteristics, aiming to encompass a range of slope steepness levels to effectively capture the spectrum of erosion vulnerability. Furthermore, consideration will be given to land use patterns, with particular attention directed towards agricultural regions where conventional management practices predominate. Preference will be given to sites characterized by uniform land cover types and limited human-induced disturbances to ensure consistency in the assessment and comparison of soil erosion levels.

Similarly, the selection process for study sites in Thailand will follow a comparable approach, with an additional focus on areas occupied by rubber and palm plantations managed under conventional practices. These sites will be chosen based on a combination of personal interest and economic factors, taking into account the specific requirements associated with the cultivation of rubber and palm plants, such as optimal slope gradients and soil compositions. Land use patterns will also factor into the decision-making process, with priority given to regions where rubber plantations are widespread and subjected to conventional management methods, including practices like herbicide application, soil disturbance, and limited soil conservation measures. The inclusion of sites featuring rubber plantations aims to explore the distinctive dynamics of soil erosion within landscapes dominated by this economically significant crop. This approach allows for a contrast with the predominantly agricultural land use patterns observed in the selected study sites within the Czech Republic.

In the following, we will outline the research process systematically, detailing the successive steps involved in the study. These steps will be organized into clear stages. For instance, the identification of sloping lands susceptible to erosion will be conducted utilizing the Land Parcel Identification System (LPIS) in the Czech

Republic. Conversely, in Thailand, the researcher will scrutinize designated lands based on personal interests and economic considerations, as these lands are under her ownership and necessitate crop alteration due to economic exigencies. The geographical locations of each parcel will be ascertained using orthophotography tools, followed by data acquisition for the application in calculations utilizing the USLE and subsequent assessment of soil erosion impacts. Additionally, the study will delve into strategies aimed at amending and optimizing crop management practices on the selected lands.

4.2 Collection of necessary data for USLE parameters

In the collection of necessary data for the USLE parameters in both the Czech Republic and Thailand, a comprehensive approach will be adopted to ensure accuracy and reliability in soil erosion assessment. This process entails gathering specific data related to rainfall erosivity (R-Factor), soil erodibility (K-Factor), slope length and steepness (LS-Factor), cover management factor (C-Factor), and support practice factor (P-Factor) for each study area.

Rainfall Erosivity (R-Factor)

Extensive analysis of long-term precipitation data in the Czech Republic led to the reassessment of the rain erosion efficiency factor (R-factor), originally determined at 20 MJ ha^{-1} cm h^{-1} from records of Czech Hydrometeorological Institute stations. Through additional biographic data and methodical scrutiny accounting for extreme precipitation events like torrential rains, the revised R-factor was established, ranging from 30 to 45 for agriculturally utilized areas, excluding mountainous regions. Variations in specific zones such as rain shadows and foothills were observed. Due to methodological complexities, regionalizing the R-factor was deemed unfeasible, resulting in a recommended uniform value of 40 MJ ha^{-1} cm h^{-1} for application in the USLE across Czech agricultural lands, marking a twofold increase from previous suggestions (Janeček et al., 2013).

In Thailand, the Land Development Department (LDD) adjusted and validated this model to be appropriate to the local conditions (Land Development Department 2000). According to the study of LDD (2000), each factor can be defined as follows. The rainfall and runoff erosivity (R) is determined as a function of the total storm kinetic energy (E) and its maximum 30-min intensity (Imax30). Due to this definition, LDD (2000) developed many equations and then proposed an equation that is suitable for the amount of rainfall in Thailand;

$$R = 0.4669X - 12.1415 \qquad (2)$$

Where;

R – rainfall and runoff erosivity (MJ/ha/year)

X – average annual rainfall (mm/year)

The average annual rainfall for the study area was determined by aggregating the monthly precipitation volumes in 2023 obtained from the nearby weather station.

Table 4.1: The average annual rainfall in Sadao City, Thailand for the year 2023.

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg
Volume (mm.)	123	0	0	27	0	65	123	70	291	225	429	136	**124**
Rainy days	11	0	0	2	0	2	7	7	16	10	17	8	**7**

By utilizing the formula provided in Table 4.1, we can compute the R-factor using the average annual rainfall as follows:

$$R = 0.4669X - 12.1415$$

$$R = 0.4669\,(124)-12.1415$$

$$R = 46 \text{ (MJ/ha/year)}$$

This calculation reveals that the R-Factor in Thailand is estimated to be 46 MJ/ha/year.

Soil Erodibility (K-Factor)

The soil erodibility factor (K-Factor) serves as a quantitative measure of a soil's inherent susceptibility to erosion, reflecting its propensity for detachment and transport by rainfall and runoff. Determining the K factor involves assessing topsoil properties, landforms, and physical geography (Srikajon, 1984), along with geographical considerations (Land Development Department, 2000). Various studies by Stewart et al. (1975), Mills and Thomas (1985), Mitchell and Bubenzer (1980), Novotny and Chesters (1981), and Goldman et al. (1986) have developed tables illustrating the general magnitude of the K factor based on organic matter content and soil texture.

Additionally, Goldman et al. (1986) suggested that if significant variations in soil erodibility are observed through site inspection or data analysis, different K factors can be assigned to distinct areas within the site.

The K-factor values typically range from 0.02 to 0.69 (Goldman et al., 1986; Mitchell & Bubenzer, 1980). In the Czech Republic, the BPEJ code (agroecological evaluation of soil) or Point Parcel Identification Number serves as a unique identifier for cadastral parcels. Each parcel of land within the Czech cadastre is allocated a BPEJ code, comprising a blend of numbers and letters. This code is crucial for identification in land registration and property management systems, encompassing various details, including the K-factor. Another alternative is to use K-factor values by soil type (Table 4.2).

As per the national database provided by the LDD (2000), the K-factor for soils in Thailand ranges from 0.04 to 0.56. The LDD, at the forefront of research in this domain, has been actively working on assessing the K-factor value of Thai soil using nomographic maps. This assessment relies on data from five key properties of representative soil series, with samples collected and analyzed in laboratory settings to determine the K-factor value. This thorough process covers a diverse range of soil types found in Thailand, offering convenience and efficiency for users needing this information in scenarios where it hasn't been previously studied. Furthermore, consideration is given to soil texture and regional factors in determining the K-factor value.

Table 4.2: Values of K-Factors for soil type, subtypes, and varieties according to the Taxonomic Classification System in the Czech Republic (Janeček et al., 2012).

Soil Type	Subtype	K-factors
Ranker	modal	0.26
	cambic	0.25
	podzolic	0.24
Rendzina	modal	0.22
	cambic	0.30
Leptosol	modal	0.26
	cambic	0.36
	oguljena	0.24
Regosol	modal	0.22
	psefitic	0.18
	arenic	0.17
Gray soil	modal	0.57
	luvish	0.59
Brown Soil	modal	0.53
	luvish	0.58
	oguljena	0.53
Luvism	modal	0.60
	oguljena	0.56
	arenic	0.31
Cambium	modal	0.33
	modal	0.32
	luvish	0.50

	pelican	0.18
Fluviz	modal	0.40
	glue	0.42
	arenic	0.26
Vertisol	modal	0.28
Chernozem	modal	0.40
	luvish	0.54
	blackberry	0.35
	arenic	0.16
	pelican	0.28
Phaeozems	modal	0.30
	glue	0.34
	pelican	0.32
	oguljena	0.34
	cambizem	0.32
	arenic	0.20
	pelican	0.30
	psefitic	0.30
Andosome	modal	0.20
Podzol	modal	0.25
	arenic	0.20
pseudoglue	modal	0.42
	luvish	0.54
	glue	0.24
Glue	modal	0.42
	modal	0.46

Table 4.3: The K-factor values in various regions of Thailand (the LDD, 2000).

Regions	**Southern**		**Northern**		**East northern**		**Eastern**		**Central and Western**	
Soil Texture	**High**	**Low**	**High**	**Low**	**High**	**Low**	**High**	**Low**	**High**	**Low**
Sandy	0.04	0.04	-	-	-	-	0.05	0.05	-	-
Loamy sand	0.04	0.04	0.05	0.06	0.40	0.05	0.07	0.08	0.08	0.07
Sandy loam	0.20	0.30	0.27	0.30	0.24	0.26	0.19	0.34	0.34	0.26
Loam	0.33	0.34	0.33	0.35	0.29	0.35	0.30	0.33	0.33	0.43
Silty Loam	0.40	0.30	0.49	0.34	0.37	0.30	0.21	0.44	0.56	0.47
Silty	-	0.57	-	-	-	-	-	-	-	-
Sandy Clay Loam	0.19	0.21	0.21	0.22	0.24	0.20	0.25	0.23	0.20	0.21
Clay Loam	0.29	0.31	0.24	0.27	0.25	0.36	0.30	0.25	0.28	0.29
Silty Clay Loam	0.31	0.21	0.35	0.42	0.46	0.43	0.37	0.38	0.38	0.29
Sandy Clay	-	0.81	-	0.17	-	-	-	0.18	0.15	0.17

Slope Length and Steepness (LS-Factor)

In the Czech Republic, accessing indicative LS factor values is facilitated through the SOWAC GIS geoportal, focusing on water and wind erosion of soils (eroze.vumop.cz). GIS tools, employed within the LPIS land record register and the SOWAC-GIS geoportal, enable the determination of LS factors on a per-square basis of raster digital terrain models (DMT). The uninterrupted slope length is substituted with micro catchment area data, calculated individually for each DMT square. Input parameters for calculations include digital terrain models with appropriate resolution and land use layers, facilitating the determination of slope and micro-watershed area. Local slope-based S-factor values are derived using the McCOOL (1989) equation, while land use information is sourced from various layers such as LPIS, landscape elements, and ZABAGED, complemented by terrace data provided by the Ministry of Agriculture (MoA). Additionally, the integration of technical anti-erosion measures and operational program initiatives further refines erosion risk assessment, accounting for complex terrain morphology and runoff patterns.

This approach enables localized evaluation of erosion risk, considering variations in land use and terrain features, including slope alterations and runoff convergence. Potential inaccuracies stem from input data discrepancies, necessitating continuous updates to ensure the reliability of erosion risk assessments. For the purpose of this work, formulas (3, 4, 5) applicable to USLE (Wischmeier and Smith, 1978; Renard et al., 1997) were used.

The slope length factor (L-Factor) is expressed as the ratio of expected soil loss to that observed for a field of 22 meters in length. In USLE, the L-factor is given by

$$L = \left(\frac{\lambda}{22.13}\right)^{m} \qquad (3)$$

Where;

λ - distance from the onset of overland flow to the location where deposition occurs or when runoff enters a channel that is bigger than a rill.

m - 0.5 when slope > 5%.

0.4 when the slope is between 3.5 - 4.5%.

0.3 when the slope is between 1-3%.

0.2 when the slope is < 1%.

In the USLE, m varies with the slope gradient. It has a value of 0.2 for gradients smaller than 1% and increases to a value of 0.7 for gradients greater than 21% (Wischmeier & Smith, 1978).

The slope steepness factor (S-Factor) is the ratio of expected soil loss to that observed for a field of the specified slope of 9%. If the gradient is smaller than or equal to 9%, the S factor in USLE is given by

$$S = 10.8 \sin \emptyset + 0.03 \qquad (4)$$

while if the gradient is greater than 9%, the S factor is given by

$$S = (\sin \text{Ø} / 0.0896)^{0.6} \qquad (5)$$

Where;

Ø - slope (rad) (Renard et al., 1997).

The national database of both L and S factors for all slope gradients corresponding to soil series found in Thailand has been summarized by LDD as LS factor. The LS factor of land in Thailand ranges from 0.226 to 4.571.

Cover Management Factor (C-Factor)

The impact of vegetation cover on soil erosion is twofold: it shields the soil surface from the erosive force of raindrops and reduces surface runoff speed. Additionally, vegetation indirectly influences soil properties, particularly porosity and permeability, by preventing pore clogging with fine soil particles and mechanically reinforcing the soil through root systems. In the Czech Republic, the efficacy of vegetation's protective role is directly correlated with coverage and density, particularly crucial during periods of heavy rainfall. Grasses and clovers offer optimal erosion protection, whereas conventionally cultivated wide-row crops like maize, root crops, orchards, and vineyards provide inadequate soil protection. In erosion modeling such as the USLE, the protective impact of vegetation cover is quantified by factor C, with specific values listed in Table 4.4 corresponding to various crop types cultivated in the Czech Republic.

Table 4.4: C - factor values of various types of plants grown in the Czech Republic (Janeček et al., 2012).

Types of crop	C- Factor	Types of crop	C- Factor
Winter wheat	0.12	Hops	0.80
Winter rye	0.17	Winter rapeseed	0.22
Spring barley	0.15	Sunflower	0.60
Winter barley	0.17	Poppy	0.50
Oat	0.10	Late rapeseed	0.22
Maize	0.61	Maize for silage	0.72
Legumes	0.05	Annual forage	0.02
Potato	0.60	Perennial forage	0.01
Late potatoes	0.44	Vegetables	0.45
Grassland	0.005	Sets	0.45

In Thailand, this factor indicates the extent to which plant features and farming practices contribute to soil protection. Despite being the same plant type, the values of this factor can vary among regions and even within the same timeframe due to differences in rainfall intensity. Therefore, accurately assessing this factor for each plant type in every region entails understanding rainfall patterns over different periods and considering factors such as the presence of decomposed organic matter on the soil surface and the cultivation methods adopted to combat soil erosion. Refer to Table 4.5 for the C-Factor values applicable in Thailand.

Table 4.5: C-factor index values of various types of plants grown in Thailand (Watanasak, 1978).

Types of crop	C- Factor	Types of crop	C- Factor
Rice	0.70	Coffee	0.30
Cassava	0.60	Fruits	0.30
Papaya	0.60	Millet	0.27
Pineapple	0.50	Maze	0.24
Sugar cane	0.45	Rubber	0.20
Coconut	0.40	Wheat	0.15
Cotton	0.35	Eucalyptus	0.15
Palm	0.30	Grassland	0.02

Support Practice Factor (P-Factor)

In all test catchments, the support practice factor or factor P of the USLE is uniformly assigned a single value based on the guidelines provided by various administrative bodies. If the specific soil conservation practices aimed at soil protection are not implemented on the land, the P-factor value is 1.

By systematically collecting and analyzing these data sets for USLE parameters, the study will be able to quantify and predict long-term soil loss on selected slopes in both the Czech Republic and Thailand, facilitating informed decision-making for soil conservation and land management strategies.

5 Results

This thesis examines a total of five plots, with three situated in the Czech Republic and two in Thailand. The study employed the USLE to analyze factors influencing soil erosion within the experiment plots. The primary goal was to evaluate long-term soil loss on specific land plots, aiming to enhance land management strategies for mitigating soil erosion in both the Czech Republic and Thailand. By integrating GIS with the USLE, the analysis considered various parameters including rainfall erosivity (R-Factor), soil erodibility (K-Factor), slope length and steepness (LS-Factor), crop management (C-Factor), erosion control practices (P-Factor) to calculate the annual soil erosion quantity (A-Factor) using the equation A = RKLSCP. The results were utilized to categorize the severity of soil erosion based on criteria specific to each country.

The long-term soil loss for bare soil was always calculated for all plots. Subsequently, the soil loss for selected agriculture crops with a resulting value below 9 t/ha/year (currently the maximum value under Czech legislation in 2024) was calculated. For three experimental plots in the Czech Republic, a subdivision of the land was also proposed. The aim of the subdivision was to reduce the resulting soil loss and to increase the diversity (biodiversity) of the landscape. The land division should be carried out perpendicular to the direction of the runoff lines in order to break their length. In Thailand, there is currently no serious legislation governing soil loss caused by water erosion. Therefore, a limit of 9 tons per hectare per year has been chosen in the calculation, as is the case in the Czech Republic. For experimental plots in Thailand, which are currently forested, the aim was to verify whether they could be deforested and used as arable land.

5.1 Experimental plots in the Czech Republic

The Czech plots are located within the South Bohemia region, which encompasses the south and western parts of the country. This region, characterized by hilly plateaus along the Vltava river, experiences a continental climate featuring hot summers, cold winters, and consistent rainfall conducive to hop cultivation, predominant in the area. To the south and west, low mountains, including the Sudeten and the Bohemian Forest bordering Austria, define Bohemia's landscape. In South Bohemia, June, July, and August typically offer comfortable weather with temperatures averaging between 20°C to 25°C, while January tends to be the coldest month.

Experimental plots in the Czech Republic: Land 770-1160 (1606/3)

The parcel of land is located in Český Krumlov a city in the South Bohemia region covers a total area of 24.32 hectares and is primarily used for arable farming under conventional management practices. The land features three main runoff lines, one of which is considered critical, necessitating a soil loss calculation using the USLE. These runoff lines channel water predominantly towards the southern section of the parcel. Adjacent to the southern boundary lies a pond, while significant portions of the eastern and southern boundaries are lined with trees. The western boundary is bordered by buildings, providing structural support, while the northern boundary is flanked by a field road. Fortunately, the road is not directly threatened by erosion, given its orientation relative to the drainage lines.

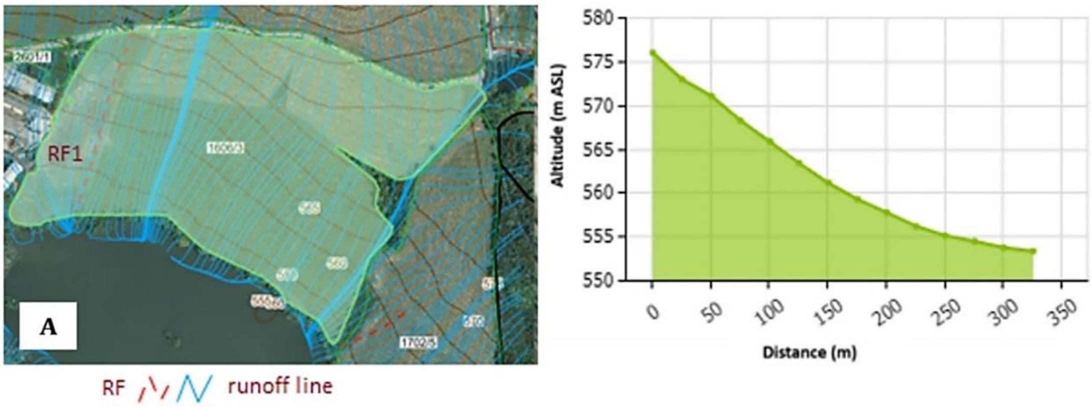

Figure 5.1: Experiment plot number 770-1160 (1606/3): Experiment plot with surface runoff line (left) and Runoff line profile (right).

Table 5.1: Calculation of L factor and S factor for experimental plot 1606/3.

Runoff line	Length (m)	Slope (°)	Slope (%)	Factor L	Factor S
RF 1	330	3.98	6.97	2.25	1.34

Table 5.2: Assessment of the present condition of the land (1606/3) and identification of appropriate crop suggestions.

Runoff line	Field section	Rainfall Factor	Soil Erodibility	Slope Lenght	Slope Gradient	Cropping Management*		Erosion Control Practice	Total soil loss (t/year/ha)
		R	K	L	S	C		P	A
RF 1	x	40	0.25	2.25	1.34	1	bare soil	1	30.15
						0.12	winter wheat		3.62

*C-factor values were taken from Janeček et al. (2012).

The land can be kept whole in order to achieve the maximum soil loss (less than 9 t/ha/year). However, it is necessary to choose crops that are not vulnerable to erosion (e.g. cereals). Therefore, it would be more appropriate to divide the land into two parts. This will allow more crops to be grown on the plots while ensuring maximum allowable soil loss. The proposed subdivision (Figure 5.2) and the resulting soil loss calculations for the two subdivisions (Tables 5.3 and 5.4) are shown below.

Figure 5.2: Proposal for division of plot 1606/3 (left) and runoff line profiles (right).

Table 5.3: Calculation of L-factor and S-factor for divided experimental plot 1606/3.

Runoff line	Field section	Length (m)	Slope (°)	Slope (%)	Factor L	Factor S
RF 1	F1	165	4.34	10.3	1.83	1.51
RF 1	F2	165	4.34	3.9	1.83	0.77

Table 5.4: Calculation of total soil loss for divided sections and identification of appropriate crop suggestions (1606/3).

Runoff line	Field section	Rainfall Factor	Soil Erodibility	Slope Lenght	Slope Gradient	Cropping Management*		Erosion Control Practice	Total soil loss (t/year/ha)
		R	K	L	S	C		P	A
RF 1	F1	40	0.25	1.83	1.51	1	bare soil	1	27.63
						0.12	winter wheat		3.32
	F2	40	0.25	1.83	0.77	1	bare soil	1	14.25
						0.22	winter rape		3.10

*C-factor values were taken from Janeček et al. (2012).

The analysis conducted on the experimental plot, Land 770-1160 (1606/3), using the USLE method revealed significant potential for soil erosion. Assessment of soil erosion under the current land condition, characterized by bare soil prior to division (as shown in Table 5.3), indicates a remarkably high level of threat at 30.15 tons per hectare per year. This surpasses the maximum allowable soil loss for standard soils in the Czech Republic, set at 9 tons per hectare per year as of 2023. Introducing crop recommendations, such as winter wheat, may reduce soil erosion to a moderate threat level at 3.62 tons per hectare per year. Alternatively, dividing the land into sections and identifying suitable crop suggestions (as shown in Table 5.4) reveals that field section F1 exhibits a total soil loss on bare soil at 27.63 tons per hectare per year, higher than F2's 14.25 tons per hectare per year. When considering crop suggestions of winter wheat for F1 and winter rape for F2, the potential reduction in soil loss is observed to be 3.32 and 3.10 tons per hectare per year.

Experimental plots in the Czech Republic: Land 750-1140 (3502/3)

The parcel of land is located in České Budějovice a city in the South Bohemia region covers a total area of 21.79 hectares and is primarily designated for conventional arable farming. The terrain features a main runoff line, necessitating a soil loss assessment using the USLE method. These runoff channels originate from the northwest and predominantly flow towards the eastern section of the parcel. Woodland borders the eastern and southern boundaries, while fields encompass the western and northern edges. It is surrounded by a field on the west and north sides, which is, however, directly affected by erosion because of the drainage lines.

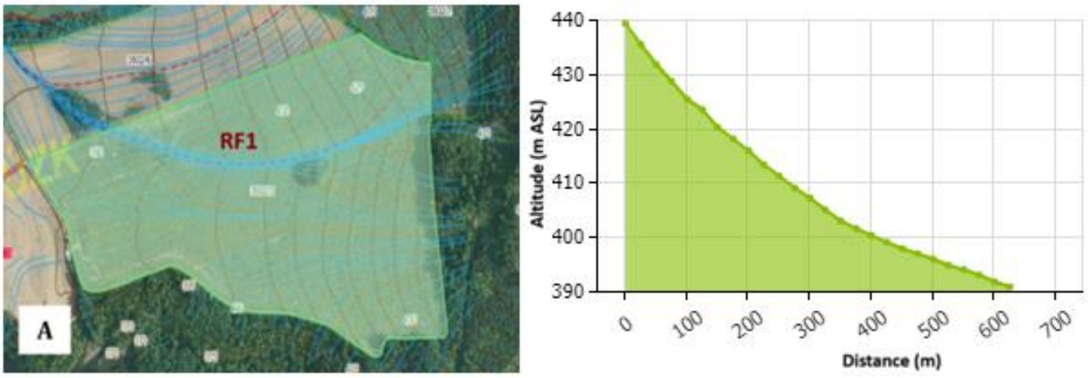

Figure 5.3: Experiment plot number 750-1140 (3502/3): Experiment plot with surface runoff line (left) and Runoff line profile (right).

Table 5.5: Calculation of L factor and S factor for experimental plot 3502/3.

Runoff line	Length (m)	Slope (°)	Slope (%)	Factor L	Factor S
RF 1	647	5.02	8.78	2.75	1.68

Table 5.6: Assessment of the present condition of the land (3502/3) and identification of appropriate crop suggestions.

Runoff line	Field section	Rainfall Factor	Soil Erodibility	Slope Lenght	Slope Gradient	Cropping Management*		Erosion Control Practice	Total soil loss (t/year/ha)
		R	K	L	S	C		P	A
RF 1	x	40	0.4	2.75	1.68	1	bare soil	1	73.90
						0.12	winter wheat		8.87

*C-factor values were taken from Janeček et al. (2012).

The length of the runoff line is quite long (647 m). In winter wheat cultivation, the resulting soil loss is close to 9 t/ha/year (see Table 5.6). In addition, the eastern part of the plot is more sloping. Therefore, it would also be suitable to divide the plot into two parts (see Figure 5.4). For the more sloping part (F1) it would be recommended to choose a grassed area. The second part (F2) will then allow the cultivation of more crop species while ensuring maximum soil loss. Winter rape was chosen as an example (Table 5.8).

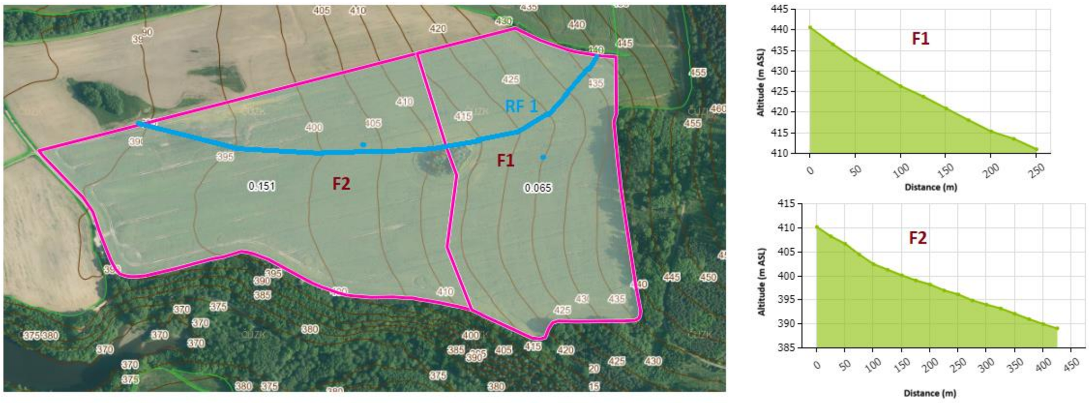

Figure 5.4: Proposal for division of plot 3502/3 (left) and runoff line profiles (right).

Table 5.7: Calculation of L factor and S factor for divided experimental plot 3502/3.

Runoff line	Field section	Length (m)	Slope (°)	Slope (%)	Factor L	Factor S
RF 1	F1	254	6.75	11.81	1.79	1.64
RF 1	F2	393	3.05	5.34	2.29	1.04

Table 5.8: Calculation of total soil loss for divided sections and identification of appropriate crop suggestions (3502/3).

Runoff line	Field section	Rainfall Factor	Soil Erodibility	Slope Lenght	Slope Gradient	Cropping Management*		Erosion Control Practice	Total soil loss (t/year/ha)
		R	K	L	S	C		P	A
RF 1	F1	40	0.4	1.79	1.64	1	bare soil	1	46.97
						0.005	grassland		0.24
	F2	40	0.4	2.29	1.04	1	bare soil	1	36.11
						0.22	winter rape		8.38

*C-factor values were taken from Janeček et al. (2012).

The analysis conducted on the experimental plot, Land 750-1140 (3502/3), utilizing the USLE method, reveals a significant potential for soil erosion. Evaluation of soil erosion under the current land condition, characterized by bare soil prior to division (as shown in Table 5.6), indicates an extremely high level of threat at 73.90 tons per hectare per year. This exceeds the maximum allowable soil loss for standard soils in the Czech Republic, set at 9 tons per hectare per year as of 2023. Introducing crop recommendations, such as winter wheat, may reduce soil erosion to a very heavily threatened level at 8.87 tons per hectare per year. Alternatively, dividing the land into sections and identifying suitable crop suggestions (as shown in Table 5.8) reveals that Field section F1 exhibits a total soil loss on bare soil of 46.97 tons per hectare per year, higher than F2's 36.11 tons per hectare per year. Considering crop suggestions of grassland for F1 and winter rape for F2, the potential reduction in soil loss is observed to be 0.24 and 8.38 tons per hectare per year, respectively.

Experimental plots in the Czech Republic: Land 760-1170 (9301/3)

The parcel of land is located in Český Krumlov a city in the South Bohemia region that covers a total area of 22.96 hectares and is primarily designated for conventional arable farming. The terrain showcases two runoff lines, necessitating a soil loss evaluation using the USLE method. These runoff lines originate from the northeast, predominantly directing flow toward the western section of the parcel. Woodland borders the southwestern boundaries, while fields surround the northwest and south. Additionally, a field road encircles the northern part of the land. Significant tree lines border a portion of the eastern parcel. However, the direction of the drainage lines poses a direct threat of erosion to the land.

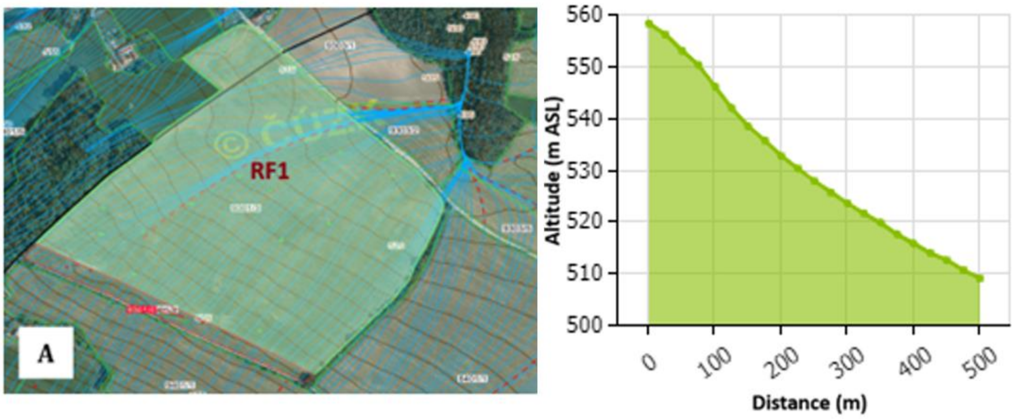

Figure 5.5: Experiment plot number 760-1170 (9301/3): Experiment plot with surface runoff line (left) and runoff line profile (right).

Table 5.9: Calculation of L factor and S factor for experimental plot 9301/3.

Runoff line	Length (m)	Slope (°)	Slope (%)	Factor L	Factor S
RF 1	504	5.67	9.92	2.55	1.48

Table 5.10: Assessment of the present condition of the land (9301/3) and identification of appropriate crop suggestions.

Runoff line	Field section	Rainfall Factor	Soil Erodibility	Slope Lenght	Slope Gradient	Cropping Management*		Erosion Control Practice	Total soil loss (t/year/ha)
		R	K	L	S	C		P	A
RF 1	x	40	0.43	2.55	1.48	1	bare soil	1	64.91
						0.12	winter wheat		7.79
						0.005	grassland		0.32

*C-factor values were taken from Janeček et al. (2012).

The site has a significant slope (9.92%). It is therefore recommended to subdivide the land and break the runoff line. In the upper part (F1) it is possible to grow cereals, but also winter rape (Table 5.12). The lower part should be grassed to ensure sufficient erosion protection.

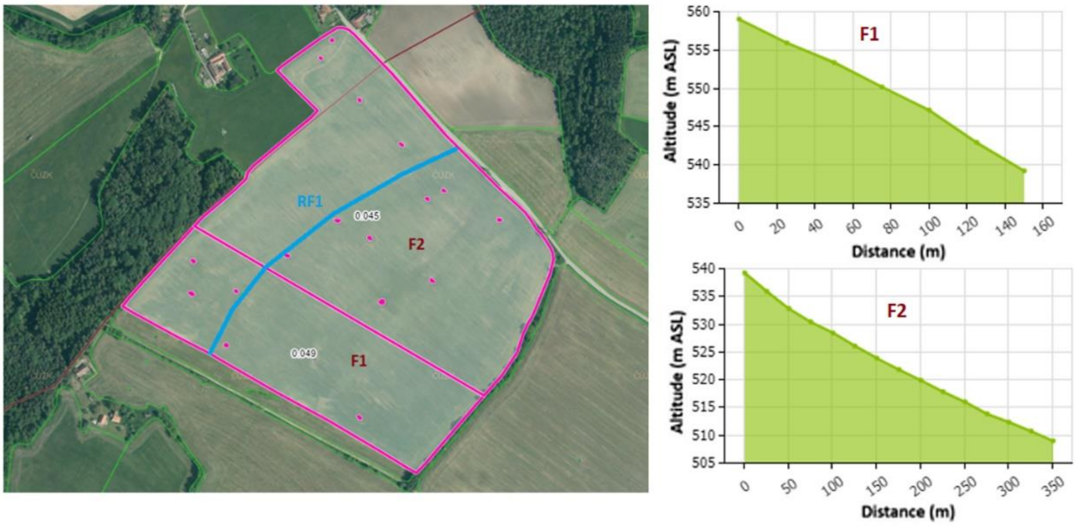

Figure 5.6: Proposal for division of plot 9301/3 (left) and runoff lines profiles (right).

Table 5.11: Calculation of L factor and S factor for divided experimental plot 9301/3.

Runoff line	Field section	Length (m)	Slope (°)	Slope (%)	Factor L	Factor S
RF 1	F1	154	7.42	12.99	1.79	1.74
RF 1	F2	350	4.90	8.57	2.29	1.64

Table 5.12: Calculation of total soil loss for divided sections and identification of appropriate crop suggestions (9301/3).

Runoff line	**Field section**	**Rainfall Factor**	**Soil Erodibility**	**Slope Lenght**	**Slope Gradient**	**Cropping Management***		**Erosion Control Practice**	**Total soil loss (t/year/ha)**
		R	**K**	**L**	**S**	**C**		**P**	**A**
RF 1	F1	40	0.43	1.79	1.74	1	bare soil	1	53.57
						0.22	winter rape		5.89
	F2	40	0.43	2.29	1.64	1	bare soil	1	64.60
						0.005	grassland		0.32

*C-factor values were taken from Janeček et al. (2012).

The analysis conducted on the experimental plot, Land 760-1170 (9301/3), using the USLE method revealed significant potential for soil erosion. Assessment of soil erosion under the current land condition, characterized by bare soil prior to division (as shown in Table 5.10), indicates an extremely high level of threat at 64.91 tons per hectare per year. This surpasses the maximum allowable soil loss for standard soils in the Czech Republic, set at 9 tons per hectare per year as of 2023. Introducing crop recommendations, such as winter wheat and grassland, may reduce soil erosion to a heavily threatened level at 7.79 tons per hectare per year for winter rape and very slightly threatened 0.32 tons per hectare per year for grassland. Alternatively, dividing the land into sections and identifying suitable crop suggestions (as shown in Table 5.12) reveals that Field section F1 exhibits a total soil loss on bare soil at 53.57 tons per hectare per year, higher than F2's 64.60 tons per hectare per year. When considering crop suggestions of winter rape for F1 and grassland for F2, the potential reduction in soil loss is observed to be 5.89 and 0.32 tons per hectare per year.

5.2 Experimental plots in Thailand

As for the plots in Thailand, they are situated in the southern part of the country, specifically in the Sadao district of the Songkhla province. The area exhibits slightly steeply undulating terrain with slopes ranging from 2% to 20% and good drainage. Natural vegetation includes rainforests, rubber plantations, and field crops, with the soil characterized as very deep sandy loam or sandy loam, predominantly acidic. The landscape features mountainous regions with gentle slopes towards the north, bordered by the Nam Dew Mountains, serving as a boundary between Thailand and Malaysia. Concrete walls and barbed wire fences delineate parts of the plains, while mountainous areas are rocky, and lowlands comprise clay or sandy clay surfaces.

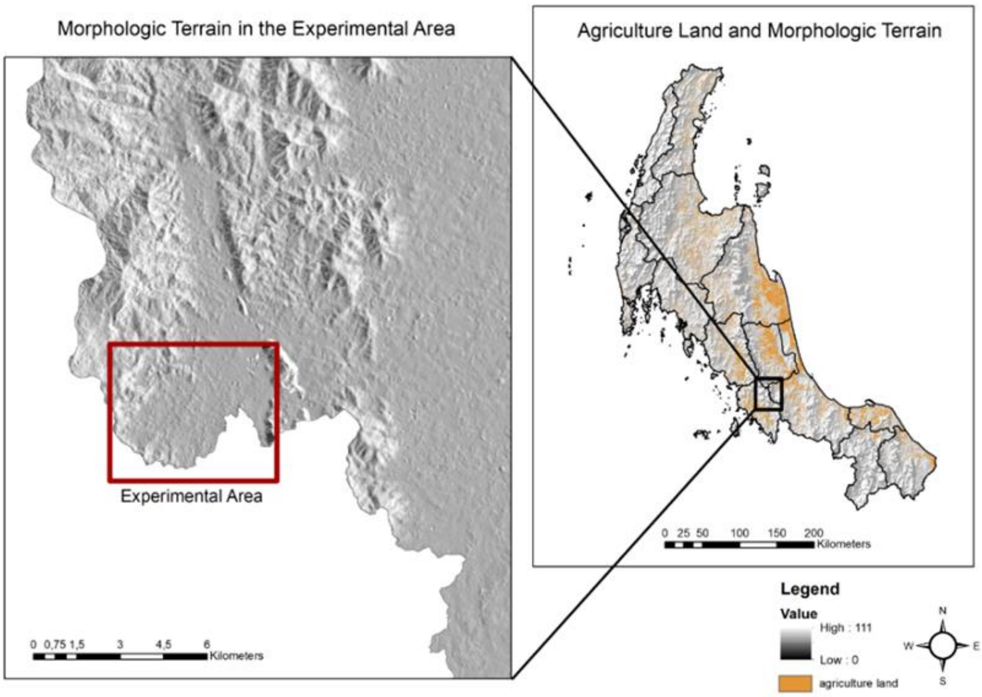

Figure 5.7: The topography of the research site is located in southern Thailand (ArcMap 10.6.1).

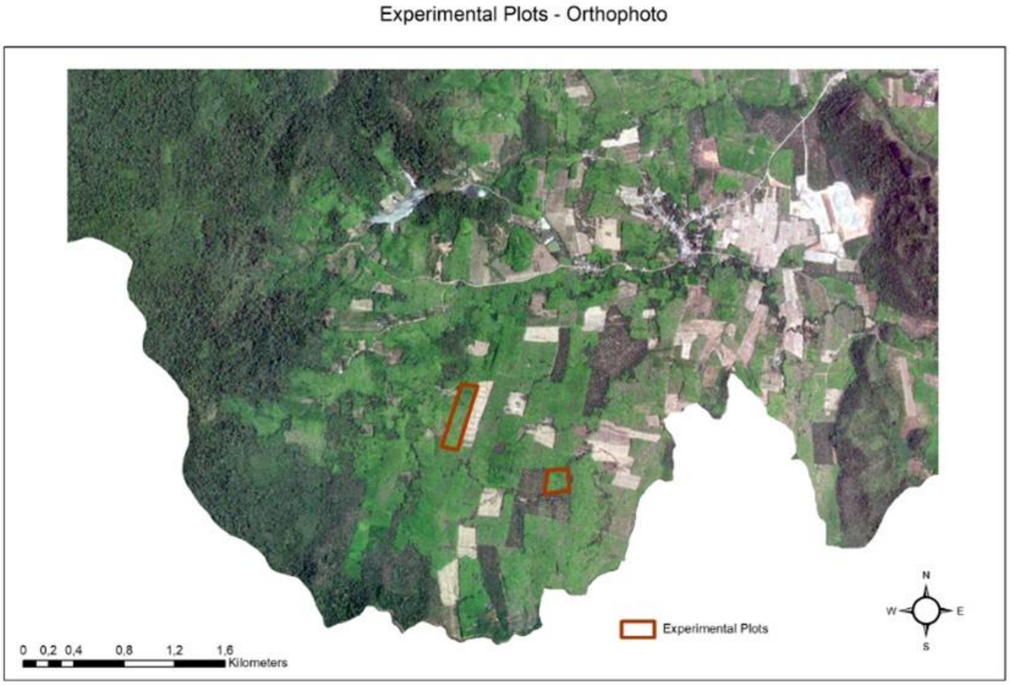

Figure 5.8: Experimental plots in Thailand (ArcMap 10.6.1).

Experimental plots in Thailand: Plot 1

The land covers a total area of 7 hectares and is primarily utilized for arable purposes, featuring conventional management practices for rubber and palm farming. It features an average slope of 8.78%. Geographically, it lies between latitudes 6°42'N to 6°32.5'N and longitudes 100°14'E to 100°17.3'E, with its highest elevation reaching 125.4 meters above mean sea level (refer to Figure 5.11). There are two primary runoff channels: Runoff Line 1 originates from the western side, predominantly directing flow towards the eastern section of the plot with a slope of 11.09% and an altitude of 129 meters. Runoff Line 2 also originates from the western side, predominantly directing flow towards the Southeastern section of the plot with a slope of 6.47% and an altitude of 153 meters. Despite being surrounded by rubber farms, the land is directly threatened by erosion due to the layout of the drainage lines.

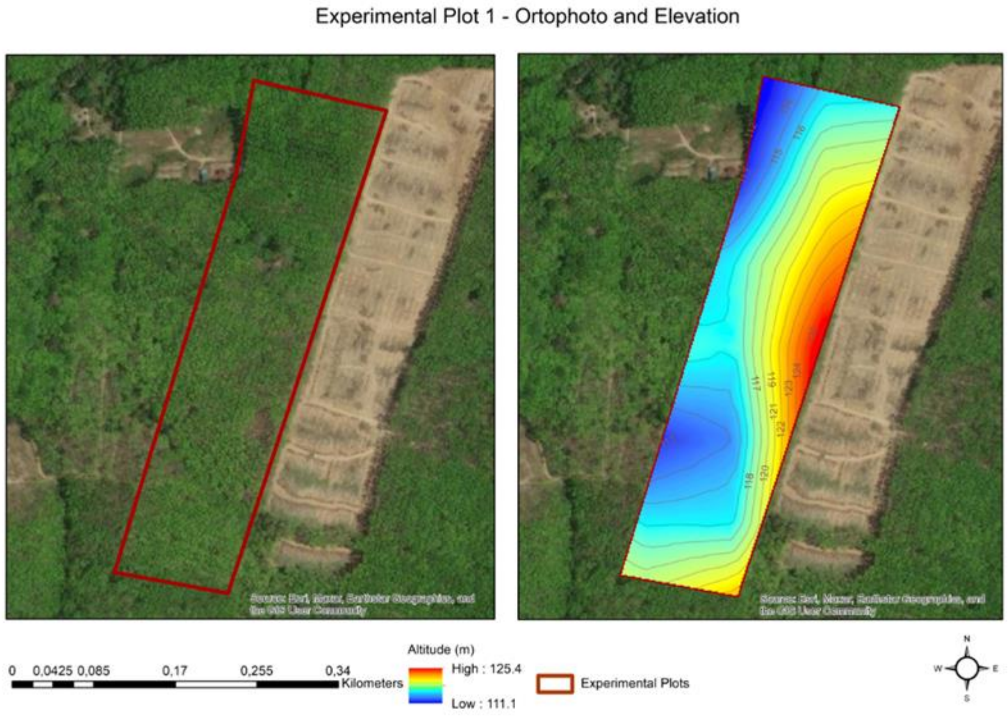

Figure 5.9: Experiment plot 1 with the terrain features (ArcMap 10.6.1).

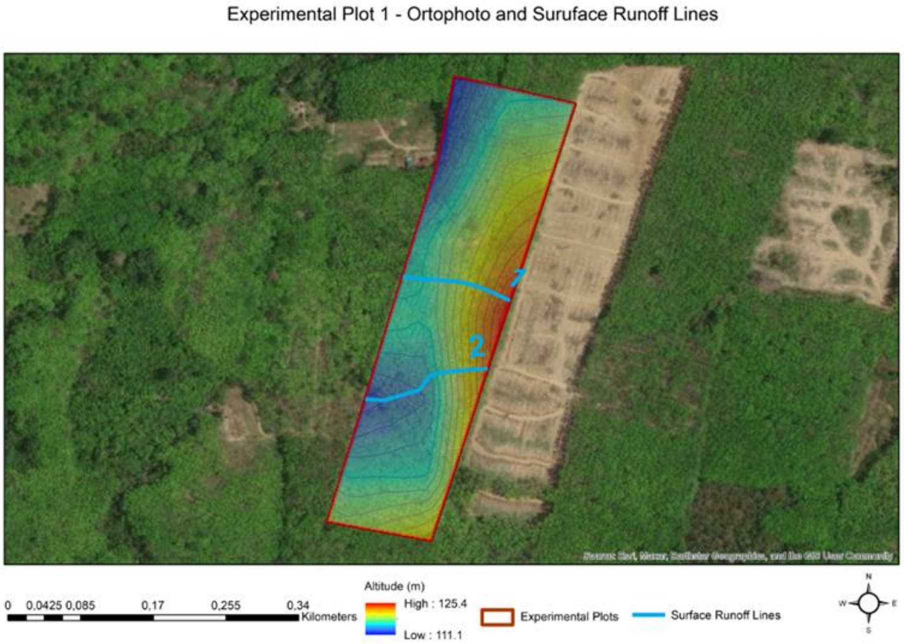

Figure 5.10: Experiment plot 1 with the terrain features and runoff lines (ArcMap 10.6.1).

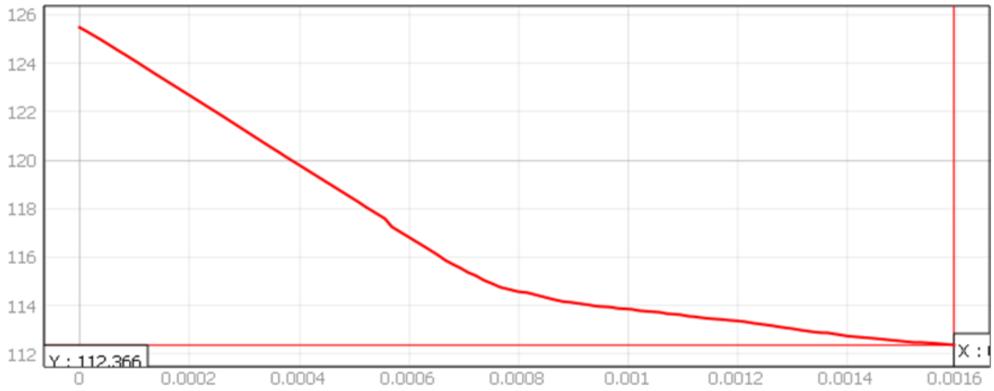

Figure 5.11: Runoff line 1 profile – plot 1 (QGIS 3.36).

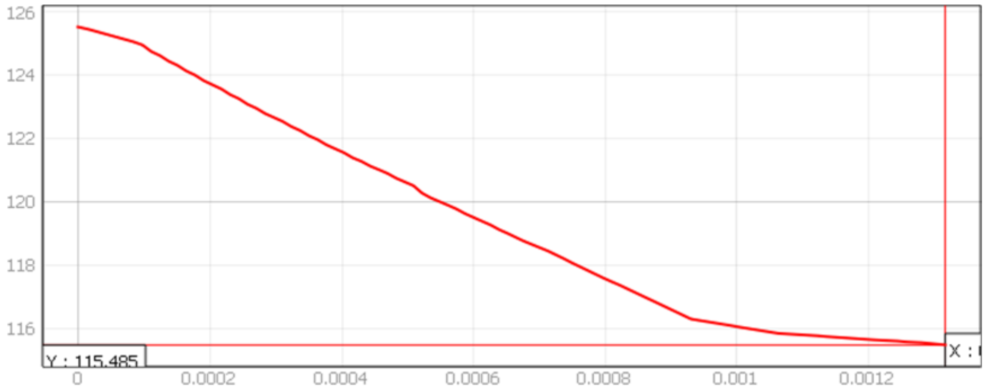

Figure 5.12: Runoff line 2 profile – plot 1 (QGIS 3.36).

Table 5.13: Calculation of L factor and S factor for experimental plot 1.

Runoff line	Length (m)	Slope (°)	Slope (%)	Factor L	Factor S
RF 1	129	5.94	10.39	1.70	1.52
RF 2	153	3.81	6.67	1.77	1.28

Table 5.14: Calculation of total soil loss for experimental plot 1.

Runoff line	Rainfall Factor	Soil Erodibility	Slope Lenght	Slope Gradient	Cropping Management*		Erosion Control Practice	Total soil loss (t/year/ha)
	R	K	L	S	C		P	A
RF 1	46	0.25	2.89	1.24	1	Bare soil	1	41.21
					0.2	Rubber		8.24
					0.15	Eucalyptus		6.18
RF 2	46	0.25	3.43	0.66	1	Bare soil	1	26.03
					0.2	Rubber		5.21
					0.3	Coffee		7.81

*C-factor values were taken from Watanasak (1978).

Table 5.14 provides a detailed assessment of total soil loss for experimental plot 1, considering essential factors such as rainfall intensity, soil erodibility, slope characteristics, cropping techniques, and erosion control methods. The data underscores notable disparities in soil loss across the field, particularly between Runoff lines 1 (RF1) and 2 (RF2). RF1, currently cultivated with rubber, exhibits higher rates of soil loss compared to RF2. Specifically, RF1 experiences soil loss ranging from 8.24 and 6.18 tons per hectare per year, indicating a moderate level of erosion that remains below the study's threshold limit of 9 tons per hectare per year.

As economic dynamics evolve, the waning profitability associated with rubber cultivation necessitates a reevaluation of land use strategies. This calls for a deliberate exploration of alternative approaches to maximize the land's productivity and sustainability. One viable solution entails transitioning or integrating rubber cultivation with other crop options, thereby diversifying agricultural practices and mitigating soil erosion more effectively. For instance, incorporating crops such as eucalyptus or coffee into the cultivation mix offers promising alternatives. These crops not only contribute to soil conservation efforts by reducing erosion but also maintain economic feasibility, ensuring a sustainable balance between environmental stewardship and economic viability. This strategic shift towards diversified agricultural activities not only addresses immediate concerns regarding soil erosion but also fosters long-term resilience and prosperity within the agricultural landscape. By embracing this transition, landowners can tap into new revenue streams while safeguarding the ecological integrity of the land, thus reaping both environmental and economic benefits in the process.

Experimental plots in Thailand: Plot 2

The land, spanning a total area of 3.48 hectares, is primarily dedicated to arable purposes, with conventional management practices tailored for rubber and palm farming. It maintains an average slope of 2.05%. Geographically, it extends between latitudes 6°42'00"N to 6°12'09"N and longitudes 6°10'00"E to 100°14'00"E, with its peak elevation reaching 106.8 meters above mean sea level (see Figure 5.15). Two principal runoff channels delineate its landscape: Runoff Line 1, originating from the southeast, predominantly directs flow towards the southwest section of the plot, boasting a slope of 1.33% and an altitude of 172 meters. Similarly, Runoff Line 2 originates from the northwest, directing flow towards the southwest section with a slope of 2.76% and an altitude of 188 meters. Rubber plantations encircle the north and west sides, while palm plantations border the east and south sides. Despite its configuration, the land remains largely unthreatened by erosion, thanks to the orientation of the drainage lines. This essentially flat terrain corroborates the lack of erosion concerns, rendering it suitable for deforestation. This confirmation stands as one of the objectives fulfilled through our calculations.

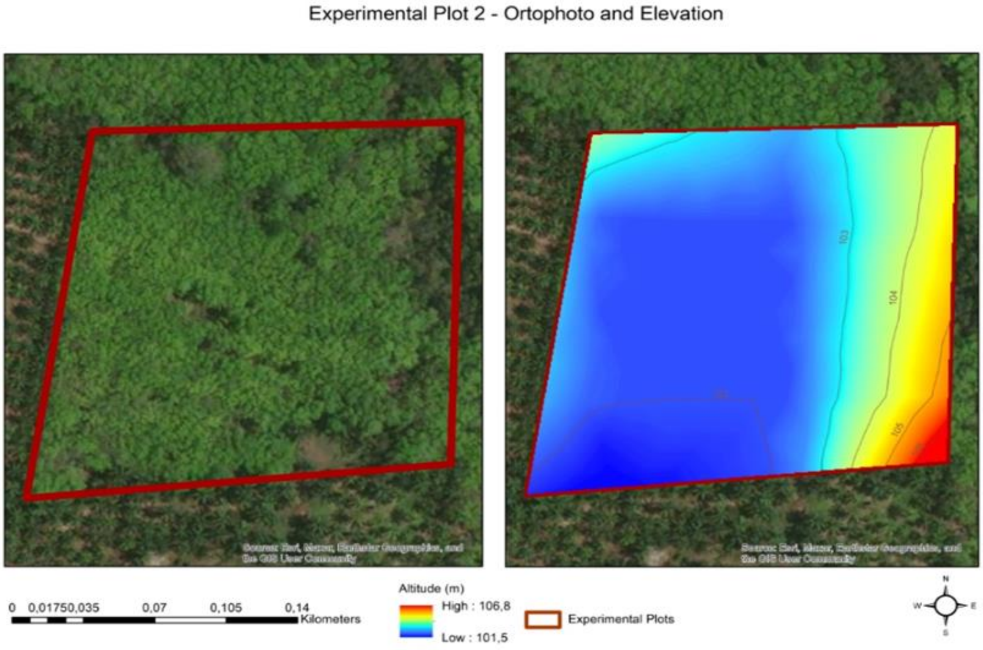

Figure 5.13: Experiment plot 2 with the terrain features (ArcMap 10.6.1).

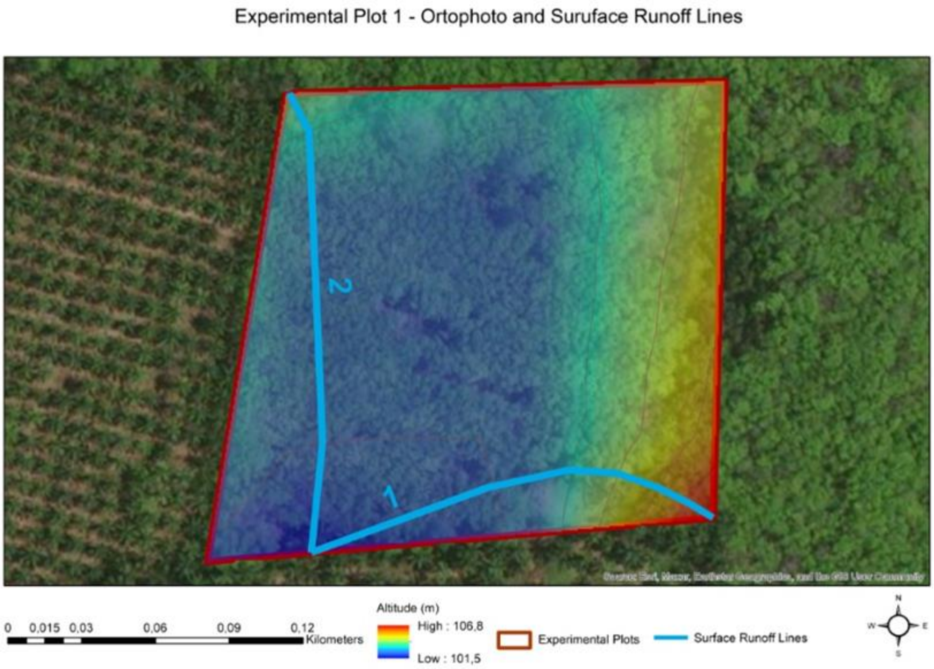

Figure 5.14: Experiment plot 2 with the terrain features and runoff lines (ArcMap 10.6.1).

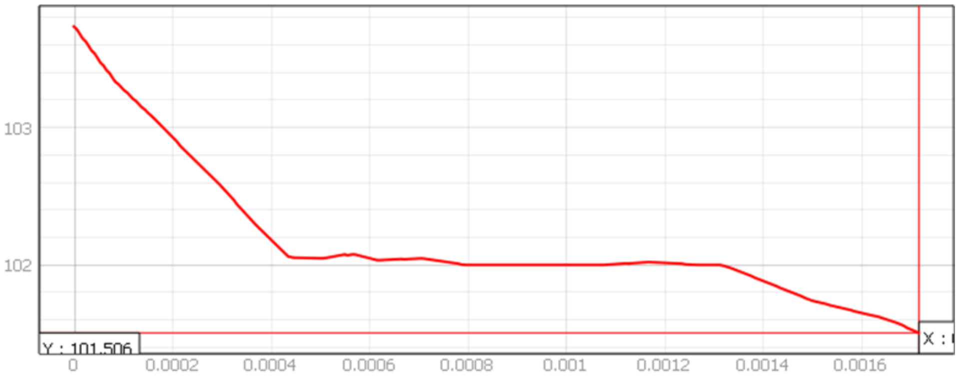

Figure 5.15: Runoff line 1 – plot 2 (QGIS 3.36).

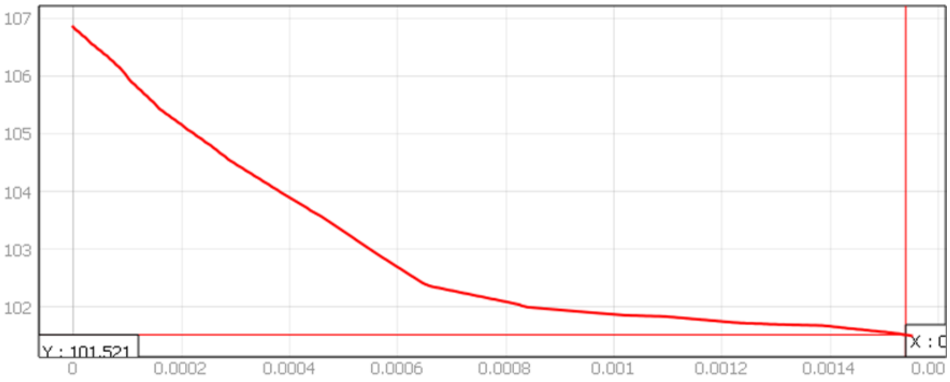

Figure 5.16: Runoff line 2 – plot 2 (QGIS 3.36).

Table 5.15: Calculation of L factor and S factor for divided experimental plot 2.

Runoff line	Length (m)	Slope (°)	Slope (%)	Factor L	Factor S
RF 1	172	0.76	1.33	1.84	0.28
RF 2	188	1.58	2.76	1.90	0.55

Table 5.16: Calculation of total soil loss for experimental plot 2.

Runoff line	Rainfall Factor	Soil Erodibility	Slope Lenght	Slope Gradient	Cropping Management*		Erosion Control Practice	Total soil loss (t/year/ha)
	R	K	L	S	C		P	A
RF 1	46	0.25	1.84	0.28	1	Bare soil	1	5.92
					0.2	Rubber		1.18
					0.3	Coffee		1.78
RF 2	46	0.25	1.90	0.55	1	Bare soil	1	12.02
					0.2	Rubber		2.40
					0.15	Eucalyptus		1.80

*C-factor values were taken from Watanasak (1978).

Table 5.16 meticulously evaluates the total soil loss for experimental plot 2, considering a multitude of influential factors ranging from rainfall intensity and soil erodibility to slope characteristics, cropping management strategies, and erosion control practices. Across the two distinct runoff lines, RF1 and RF2, varying levels of soil loss are observed. Notably, bare soil areas within these lines experience soil loss rates ranging from 5.92 to 1.78 tons per hectare per year, indicating a mild threat of erosion that remains below the established threshold of 9 tons per hectare per year.

Transitioning to coffee cultivation or implementing mixed cropping methods could economically benefit this experimental plot. Coffee cultivation, particularly, shows promising results with low soil loss rates, while eucalyptus cultivation also performs well. These findings highlight the significance of crop selection in soil conservation efforts and emphasize the importance of tailored cropping strategies and erosion control practices. Integrating alternative crops offers an opportunity to enhance sustainability and productivity in agricultural lands. With these insights, land managers can make informed decisions to mitigate soil erosion and promote economic viability and environmental stewardship.

6 Discussion

The comparison of experimental plots in the Czech Republic and Thailand offers valuable insights into the diverse landscapes and soil erosion dynamics present in these regions. In the Czech Republic, specifically in the South Bohemia region, the experimental plots exhibit varying degrees of slope and runoff characteristics, contributing to significant soil erosion rates. For instance, Land 770-1160 (1606/3) demonstrates an exceptionally high threat level of soil erosion, exceeding the allowable limits set by legislation. This finding underscores the urgency of implementing effective mitigation strategies to protect soil resources and sustain land productivity in the region. The analysis suggests that suitable crops need to be selected on slopes. Appropriate crop rotations are important.

Similarly, in Land 750-1140 (3502/3) and Land 760-1170 (9301/3), high soil erosion rates were observed, highlighting the widespread nature of the issue across different areas within the South Bohemia region. Despite variations in slope, runoff patterns, and land use practices, the commonality of elevated erosion rates emphasizes the need for tailored soil conservation measures to address specific challenges faced by each plot. The proposed division of land into sections and identification of suitable crop suggestions present promising avenues for reducing soil loss, particularly when considering factors such as slope gradient and soil erodibility.

In contrast, the experimental plots in Thailand, located in the Sadao district of the Songkhla province, exhibit distinct characteristics reflective of the tropical climate and agricultural practices prevalent in the region. Despite facing similar erosion challenges, the Thai plots demonstrate unique features such as slightly steeply undulating terrain and predominant land use for rubber and palm farming. The assessment of soil erosion rates in Plot 1 and Plot 2 reveals significant threats to soil resources, necessitating urgent interventions to mitigate erosion and preserve land productivity.

Overall, the comparison highlights the importance of understanding local environmental conditions, land use practices, and soil erosion processes to develop effective soil conservation strategies. By integrating site-specific data and recommendations, policymakers, land managers, and researchers can collaborate to implement targeted measures aimed at promoting sustainable land management practices and safeguarding soil resources. Continued monitoring and assessment efforts are essential to track the effectiveness of mitigation measures over time and ensure the long-term resilience of ecosystems and agricultural systems against the adverse impacts of soil erosion.

Limitations of the study and suggestions for future research

While this study provides valuable insights into soil erosion dynamics and management strategies in both the Czech Republic and Thailand, it is not without limitations. Firstly, the study's scope is limited to selected slopes within specific regions of each country. Additionally, the assessment primarily focuses on the application of the USLE and may overlook other important factors contributing to soil erosion, such as land use changes, climate variability, and socioeconomic factors. Furthermore, the study does not consider the long-term impacts of soil conservation measures or the effectiveness of different erosion control practices over time.

In Thailand, future research needs to expand the areas studied for soil erosion to get a better idea of erosion patterns across the country. Using advanced methods like modeling and remote sensing can make our predictions about erosion more accurate and help us analyze it more effectively. We also need to keep track of erosion rates over time and see how well our efforts to control erosion are working. Understanding the social and economic impacts of soil erosion and involving people in decision-making can help us come up with strategies to conserve soil that fit Thailand's specific needs. Lastly, research that looks at soil erosion from different angles, like the environment, farming, geography, and economics, is necessary to deal with the problem effectively and promote sustainable land management practices in Thailand.

Conclusions

This thesis investigates soil erosion dynamics across five plots, three located in the Czech Republic and two in Thailand, utilizing the USLE to assess long-term soil loss and improve land management strategies. By GIS with the USLE model, various factors such as rainfall, soil characteristics, slope, crop management, and erosion control practices were analyzed to estimate annual soil erosion rates.

In the Czech Republic, the analysis revealed significant soil erosion potential across the experimental plots. Implementing crop recommendations and land division strategies showed promise in reducing soil loss, underscoring the importance of tailored approaches for effective erosion control. Conversely, in Thailand, where erosion legislation is less stringent, the study verified the feasibility of deforesting certain plots for arable use due to their flat terrain and minimal erosion threat.

Overall, the findings highlight the importance of appropriate land management practices in minimizing soil erosion and maintaining soil health. They also stress the value of interdisciplinary approaches, integrating environmental science, agronomy, geography, and socio-economic perspectives to address complex erosion challenges and promote sustainable land management practices effectively. This research provides valuable insights into factors influencing soil erosion and offers practical recommendations for mitigating erosion risks and promoting sustainable land use practices in both the Czech Republic and Thailand.

In conclusion, the assessment of long-term soil loss in both countries underscores the urgent need for concerted efforts to mitigate soil erosion and promote sustainable land management practices globally. Soil erosion poses a significant threat to food security, environmental sustainability, and socio-economic development, necessitating immediate action to address its root causes. Prioritizing soil conservation and implementing evidence-based strategies can safeguard soil resources for future generations and ensure the resilience and productivity of agricultural systems. Collaboration among governments, researchers, farmers, and local communities is essential in addressing this global issue and ensuring a resilient and sustainable future for all.

References

Arna'eza, J., Larreab, V., & Ortigosa, L. (2004). Surface runoff and soil erosion on unpaved forest roads from rainfall simulation tests in northeastern Spain. Catena, 57, 1-14.

Beutler, J.F., Bertol, I., Veiga, M., et al. (2003). Water erosion caused by natural rainfall in a clayey Hapludox with different cropland tillage systems. Rev Brasileira De Cienc Do Solo, 27(3), 509–517.

Brady, N.C., & Weil, R.R. (2005). The Nature and Properties of Soils (13th ed.). Macmillan Publishing Company.

Bryan, R. B. (2000). Soil erodibility and processes of water erosion on hillslope. Geomorphology, 32(3-4), 385-415.

Bünemann, E. K., Bongiorno, G., Bai, Z., Creamer, R. E., De Deyn, G., De Goede, R., & Brussaard, L. (2018). Soil quality–A critical review. Soil biology and biochemistry, 120, 105-125.

Cogo, N.P., Levien, R., Schwarz, R.A. (2003). Soil and water losses by rainfall erosion influenced by tillage methods, slope-steepness classes, and soil fertility levels. Rev Brasileira De Cienc Do Solo, 27(4), 743–753.

Conrad, O., Kruger, J.P., Bock, M., et al. (2006). Soil degradation risk assessment integrating terrain analysis and soil spatial prediction methods. In Proceedings of International Conference Soil and Desertification Integrated Research for the Sustainable Management of Soils in Drylands, Hamburg, Germany.

Deng, C., Zhang, G., Liu, Y., Nie, X., Li, Z., Liu, J., & Zhu, D. (2021). Advantages and disadvantages of terracing: A comprehensive review. International Soil and Water Conservation Research, 9(3), 344-359.

Dostál, T., Janecek, M., Kliment, Z., Krása, J., Langhammer, J., Váška, J. and Vrana, K. (2006). Czech Republic. In Soil Erosion in Europe (eds J. Boardman and J. Poesen). https://doi.org/10.1002/0470859202.ch10

Dridiger, V.K., Ivanov, A.L., Belobrov, V.P., et al. (2020). Rehabilitation of Soil Properties by Using Direct Seeding Technology. Eurasian Soil Sc., 53, 1293–1301. https://doi.org/10.1134/S1064229320090033

Duniway, M. C., Pfennigwerth, A. A., Fick, S. E., Nauman, T. W., Belnap, J., & Barger, N. N. (2019). Wind erosion and dust from US drylands: a review of causes, consequences, and solutions in a changing world. Ecosphere, 10(3), e02650.

Esmaeilzadeh, J., & Ahangar, A. G. (2014). Influence of soil organic matter content on soil physical, chemical, and biological properties. International Journal of Plant, Animal and Environmental Sciences, 4(4), 244-252.

Eurostat. (2022, May 30). Farms and Farmland in the European Union Statistics. Retrieved from https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Farms_and_farmland_in_the_European_Union_-_statistics

F.A.O. (n.d.). Wischmeier and Smith's Empirical Soil Loss Model (USLE).

Food and Agriculture Organization of the United Nations. (1995). Agricultural Diversification/Restructuring of Agricultural Production Systems in Thailand. Paper prepared for the Food and Agriculture Organization of the United Nations.

Fiener, P., & Auerswald, K. (2003). Effectiveness of grassed waterways in reducing runoff and sediment delivery from agricultural watersheds. Journal of Environmental Quality, 32(3), 927-936.

Foster, G. R., Young, R. A., Römkens, M. J. M., & Onstad, C. A. (1985). Processes of soil erosion by water. Soil erosion and crop productivity, 137-162.

Foster, G.R. (1990). Process-based modelling of soil erosion by water on agricultural land. In J. Boardman (Ed.), BGRG Symposia Series: Soil Erosion on Agricultural Land. Chichester: Wiley.

Foth, H.D. (1978). Fundamentals of Soil Science (6th ed.). John Wiley & Sons, Inc.

Gao, H., Sabo, J. L., Chen, X., Liu, Z., Yang, Z., Ren, Z., & Liu, M. (2018). Landscape heterogeneity and hydrological processes: a review of landscape-based hydrological models. Landscape ecology, 33, 1461-1480.

Ghulam M. Hashim, et. al., 1995. Soil erosion process in sloping land in the east coast of Peninsular Malaysia. Soil Technology. 1995, 8: 215-233.

Golman S.J., Jackson K., Bursztynsky T.A. (1986): Erosion and Sediment Control Handbook. McGraw Hill Book Co., New York.

Gomiero, T. (2013). Alternative land management strategies and their impact on soil conservation. Agriculture, 3(3), 464-483.

Greenwood, K. L., & McKenzie, B. M. (2001). Grazing effects on soil physical properties and the consequences for pastures: a review. Australian Journal of Experimental Agriculture, 41(8), 1231-1250.

Herlina Hartanto, et al., 2003. Factors affecting runoff and soil erosion: plot-level soil loss monitoring for assessing sustainability of forest management. Forest Ecology and Management. 2003, 180: 361-374.

Hillel, D. (2003). Soil Physics and Soil Physical Characteristics. In Introduction to Environmental Soil Physics (pp. 3-17). Academic Press. https://doi.org/10.1016/B978-012348655-4/50002-2

Hillel, D. (2012). Soil and Water: Physical Principles and Processes. Elsevier.

Issaka, S., & Ashraf, M. A. (2017). Impact of soil erosion and degradation on water quality: a review. Geology, Ecology, and Landscapes, 1(1), 1-11.

Janeček, M., Dostál, T., Kozlovsky-Dufková, J., Dumbrovský, M., Hůla, J., Kadlec, V., Kovář, P., Krása, T., Kubátová, E., Kobzová, D., Kudrnáčová, M., Novotný, I., Podhrázská, J., Pražan, J., Procházková, E., Středová, I., Toman, F., Vopravil, J., & Vlasák, J. (2012). Erosion Control in the Czech Republic - Handbook. Prague, Czech University of Life Sciences.

Janeček, M., Květoň, V., Kubátová, E., Kobzová, D., Vošmerová, M., Chlupsová, J. (2013). Values of rainfall erosivity factor for the Czech Republic. J. Hydrol. Hydromech., 61, 97–102. https://doi.org/10.2478/johh-2013-0013

Karlen, D. L., & Cambardella, C. A. (2020). Conservation strategies for improving soil quality and organic matter storage. Structure and organic matter storage in agricultural soils, 395-420.

Kinnell, P. I. A. (2000). The effect of slope length on sediment concentrations associated with side-slope erosion. Soil Science Society of America Journal, 64(3), 1004-1008.

Knapen, A., Poesen, J., Govers, G., Gyssels, G., & Nachtergaele, J. (2007). Resistance of soils to concentrated flow erosion: A review. Earth-Science Reviews, 80(1-2), 75-109.

Knápek, J., Vávrová, K., Králík, T., & Outrata, D. (2020). Biomass potential—Theory and practice: Case example of the Czech Republic region. Energy Reports, 6, 292–297. https://doi.org/10.1016/j.egyr.2020.11.146

Lal, R. (2001). Soil degradation by erosion. Land Degradation & Development, 12, 519-539. http://dx.doi.org/10.1002/ldr.472

Lal, R. (2009). Challenges and opportunities in soil organic matter research. European Journal of Soil Science, 60(2), 158-169.

Larson, W. E., & Clapp, C. E. (1984). Effects of organic matter on soil physical properties. Organic matter and rice, 363.

Maetens, W., Poesen, J., & Vanmaercke, M. (2012). How effective are soil conservation techniques in reducing plot runoff and soil loss in Europe and the Mediterranean? Earth-Science Reviews, 115(1-2), 21-36.

McKell, D. (1993, February). Assessing the economic benefits of implementing conservation practices. In Soils and Crops Workshop.

Midmore, D. J., Jansen, H. G. P., & Dumsday, R. G. (1996). Soil erosion and environmental impact of vegetable production in the Cameron Highlands, Malaysia. Agriculture, Ecosystems & Environment, 60, 29-46.

Mihi, A., Tarai, N., Chenchouni, H. (2019). Can palm date plantations and ossification be used as a proxy to fight sustainably against desertification and sand encroachment in hot dry lands? Ecol Indic, 105, 365–375. https://doi.org/10.1016/j.ecolind.2017.11.027

Mills A.W., Thomas G.W. (1985). Rainfed retention probabilities computed for different cropping-tillage system. Agricultural Water Management, 15: 61-71.

Mitchell J.K., Bubenzer G.D. (1980). Soil loss estimation. In: Kirkby M.J., Morgan R.P.C. (eds): Soil erosion. John Wiley and Sons Ltd., London, 17-62.

Monte R. O'Neal, M.A. Nearing, Roel C. Vining, Jane Southworth, Rebecca A. Pfeifer (2005). Climate change impacts on soil erosion in Midwest United States with changes in crop management. CATENA, 61(2–3), 165-184. https://doi.org/10.1016/j.catena.2005.03.003

Morgan, R. P. C. (2009). Soil Erosion and Conservation (3rd ed.). Blackwell Publishing.

Nearing, M. A., Xie, Y., Liu, B., & Ye, Y. (2017). Natural and anthropogenic rates of soil erosion. International Soil and Water Conservation Research, 5(2), 77-84.

Norton, D., Shainberg, I., Cihacek, L., & Edwards, J. H. (2018). Erosion and soil chemical properties. Soil quality and soil erosion, 39-56.

Novotny, Chesters G. (1981). Handbook of Non-Point Pollution: Sources and Management. Van Nostrand Reinhold, New York.

Novotný, I., Žížala, D., Kapiˇcka, J., et al. (2016). Adjusting the CPmax factor in the Universal Soil Loss Equation (USLE): Areas in need of soil erosion protection in the Czech Republic. J. Maps, 12, 58–62. http://doi.org/10.1080/17445647.2016.1157834

Pal, S. (2016). Identification of soil erosion vulnerable areas in Chandrabhaga river basin: a multicriteria decision approach. Modeling Earth Sys Environ, 2(1), 5 https://doi.org/10.1007/s40808-015-0052-z

Phongpaichit, P., & Baker, C. (1997). Power in Transition: Thailand in the 1990s. In K. Hewison (Ed.), Political Change in Thailand. London.

Pla Sentis, I. (1997). A soil water balance model for monitoring soil erosion processes and effects on steep lands in the tropics. Soil Technology, 11, 17-30.

Panizza, M. (1996). Developments in earth surface processes 4, Environmental geomorphology (pp. 1-285). Amsterdam, The Netherlands: Elsevier Science Bv.

Pimentel, D. (2006). Soil erosion: A food and environmental threat. Environment, Development and Sustainability, 8(1), 119-137.

Rast, M., Johannessen, J., & Mauser, W. (2014). Review of understanding of Earth’s hydrological cycle: Observations, theory and modelling. Surveys in Geophysics, 35, 491-513.

Rieke-Zapp, D. H., & Nearing, M. A. (2005). Slope shape effects on erosion: a laboratory study. Soil Science Society of America Journal, 69(5), 1463-1471.

Rose, C. W., & Hairsine, P. B. (1988). Processes of water erosion. In Flow and Transport in the Natural Environment: Advances and Applications (pp. 312-326). Berlin, Heidelberg: Sprin-ger Berlin Heidelberg.

Senesi, N., & Loffredo, E. (2018). The chemistry of soil organic matter. In Soil physical chemistry (pp. 239-370). CRC press.

Shah, K. K., Modi, B., Pandey, H. P., Subedi, A., Aryal, G., Pandey, M., & Shrestha, J. (2021). Diversified crop rotation: an approach for sustainable agriculture production. Advances in Agriculture, 2021, 1-9.

Shanshan, W., Baoyang, S., Chaodong, L., Zhanbin, L., & Bo, M. (2018). Runoff and soil erosion on slope Cropland: A Review. Journal of Resources and Ecology, 9(5), 461-470.

Soane, B. D. (1990). The role of organic matter in soil compactibility: a review of some practical aspects. Soil and Tillage Research, 16(1-2), 179-201.

Srikhajon M. (1984). Soil Erosion in Thailand Land Development Department, Bangkok. (in Thai).

Sthiannopkao, S., Takizawa, S., & Wirojanagud, W. (2006). Effects of soil erosion on water quality and water uses in the Upper Phong Watershed. Water Science and Technology, 53(2).

Stephens, C. M., Lall, U., Johnson, F. M., & Marshall, L. A. (2021). Landscape changes and their hydrologic effects: Interactions and feedbacks across scales. Earth-Science Reviews, 212, 103466.

Tale, K. S., & Ingole, S. (2015). A review on the role of physicochemical properties in soil quality. Chemical Science Review and Letters, 4(13), 57-66.

Thomas, G. A., Titmarsh, G. W., Freebairn, D. M., & Radford, B. J. (2007). No-tillage and conservation farming practices in grain growing areas of Queensland–a review of 40 years of development. Australian Journal of Experimental Agriculture, 47(8), 887-898.

Terrence, J. T., George, R. F., Kenneth, G. R. (2002). Soil Erosion: Processes, Prediction, Measurement, and Control. John Wiley & Sons, Inc. ISBN-13: 978-1466593927

Toy, T. J., Foster, G. R., & Renard, K. G. (2002). Soil erosion: processes, prediction, measurement, and control. John Wiley & Sons.

Van Rompaey, A., Krasa, J., Dostal, T. (2007). Modelling the impact of land cover changes in the Czech Republic on sediment delivery. Land Use Policy, 24, 576–583. https://doi.org/10.1016/j.landusepol.2005.10.003

Verheijen, F.G.A., Jones, R.J.A., Rickson, R.J., Smith, C.J. (2009). Tolerable versus actual soil erosion rates in Europe. Earth-Science Reviews, 94(1–4), 23-38. https://doi.org/10.1016/j.earscirev.2009.02.003.

Wischmeier, W. H., & Smith, D. D. (1978). Predicting rainfall erosion losses: a guide to conservation planning (No. 537). Department of Agriculture, Science and Education Administration.

Wolka, K., Mulder, J., & Biazin, B. (2018). Effects of soil and water conservation techniques on crop yield, runoff and soil loss in Sub-Saharan Africa: A review. Agricultural water management, 207, 67-79.

Xiao, M., Cao, J., Wang, X., Zhang, C., Lv, J. (2021). Spatial characteristics of the human factors of soil erosion at the boundary of political divisions: A spatial approach. CATENA, 201, 105278. https://doi.org/10.1016/j.catena.2021.105278.

Xiong, M., Sun, R., & Chen, L. (2018). Effects of soil conservation techniques on water erosion control: A global analysis. Science of the Total Environment, 645, 753-760.

Zaw, N. W. (2013). Assessment of Soil Erosion and Sedimentation: A Case Study of Kalaw Chaung Sub-Watershed of Inle Lake in Myanmar. Thesis, School of Science Mae Fah Luang University. Retrieved from http://tdc.thailis.or.th/tdc/basic.php

Zhang, L., Huang, Y., Rong, L., Duan, X., Zhang, R., Li, Y., & Guan, J. (2021). Effect of soil erosion depth on crop yield based on topsoil removal method: a meta-analysis. Agronomy for Sustainable Development, 41, 1-13.

Zobeck, T. M., & Van Pelt, R. S. (2011). Wind erosion. Soil management: Building a stable base for agriculture, 209-227.

Zuazo, V. H. D., & Pleguezuelo, C. R. R. (2009). Soil erosion and runoff prevention by plant covers: a review. Sustainable agriculture, 785-811.

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