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DIPLOMA THESIS

Analysis of significant attributes of preserved field patterns - Ústecký Region

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Thesis supervisor: doc. Ing. Kristina Janečková, Ph.D.

Author: Monisha Madhuswini

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DIPLOMA THESIS ASSIGNMENT

Bc. arch. Monisha Madhuswini

Landscape Engineering
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Analysis of significant attributes of preserved field patterns – Ústecký Region

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Objectives of thesis

The aims of this diploma thesis are to identify the surviving remnants of the historical pluzina field patterns in a selected area and to classify these patterns and to determine their relevant attributes.

Methodology

The author will identify the surviving remnants of pluzina field patterns within Ústecký Region, classify these patterns and determine their relevant attributes, using a methodology following the scope of a broader research project carried out at the Department of Land use and Improvement. Using ArcGIS, she will analyze the relevant attributes of the pattern (e.g. length and width of hedgerows, area of preserved remnant, land use, etc.). In the final part of the thesis, the author will discuss the contribution of her findings to future use and protection of these patterns.

The proposed extent of the thesis

40 pages of text, graphic outputs

Keywords

pluzina, hedgerow, historic landscape pattern

Recommended information sources

BARR, C.J., GILLESPIE, M.K., 2000. Estimating hedgerow length and pattern characteristics in Great Britain using Countryside Survey data. J. Environ. Manage. 60, 23–32.

PLIENINGER, T., HÖCHTL, F.S.T., 2006. Traditional land-use and nature conservation in European rural landscapes. Environ. Sci. Policy 9, 317–321.

SKLENICKA, P., KOTTOVÁ, B., SALEK, M., 2017: Success in preserving historic rural landscapes under various policy measures: Incentives, restrictions or planning? Environmental Science and Policy, 75: 1-9.

SKLENICKA, P., MOLNAROVA, K., BRABEC, E., A., KUMBLE, P., A., PITTNEROVÁ, B., PIXOVA, K., SALEK, M., 2009: Remnants of medieval field patterns: driving forces behind their disappearance, the role of hedgerows, principles of conservation and restoration. Agriculture, Ecosystems & Environment, 129: 465-473.

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The Diploma Thesis Supervisor

doc. Ing. Kristina Janečková, Ph.D.

Supervising department

Department of Landscape and Urban Planning

Electronic approval: 27. 1. 2021

prof. Ing. Petr Sklenička, CSc.

Head of department

Electronic approval: 27. 1. 2021

prof. RNDr. Vladimír Bejček, CSc.

Dean

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DIPLOMA THESIS AUTHOR'S DECLARATION:

I hereby declare that I am the sole author of the thesis entitled "Analysis of significant attributes of preserved field patterns – Ústecký Region" under the supervision of doc. Kristina Janečková. All the literature cited has been mentioned in the references section.

Prague, 29.03.2021

Monisha Madhuswini

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Abstract

In the Czech Republic, pluzinas belong to the medieval time during the period of great colonization of the 13th century. Today the word pluzina is used for the remnants of these medieval field structures in the Czech Republic. Due to increasing production demand, modern mechanization, and collectivization of farmland, many pluzinas have disappeared. Identifying the remnants of pluzinas is a crucial step to proceed with their protection. This study focuses on identifying and analysing the morphological characteristics of pluzinas and their physical environment in the Ústecký region.

The pluzinas in the Ústecký region have shown properties similar to the ones found in other researches. The location of the Ústecký region matches all the characteristics favourable for the remnants of pluzinas to be found in an agricultural landscape. This study confirms that there is a lot of potential in the remnants of pluzinas to be protected as they have high aesthetic, cultural, historical, and ecological value.

Key words: pluzina, hedgerow, historic landscape pattern, land use

Abstrakt

V České republice se řadí plužiny do středověkého období velké kolonizace 13. století. Dnes se slovo plužina používá pro zbytky těchto středověkých polních struktur. Mnoho plužin zmizelo z důvodu rostoucí poptávky po výrobě, moderní mechanizaci a kolektivizaci zemědělské půdy. Identifikace zbytků plužin je rozhodujícím krokem k jejich ochraně. Tato studie se zaměřuje na identifikaci a analýzu morfologických charakteristik plužin a jejich fyzikální vlastnosti v Ústeckém kraji.

Plužiny v Ústeckém kraji vykazují podobné vlastnosti jako plužiny nalezené v jiných výzkumech. Poloha Ústeckého kraje odpovídá všem charakteristikám zbytků plužin, které mohou být nalezeny v zemědělských krajinách. Tato studie potvrzuje, že ve zbytcích plužin je velký potenciál a je potřeba je chránit, protože mají vysoké estetické, kulturní, historické a ekologické hodnoty.

Klíčová slova: pluzina, živý plot, historický krajinný ráz, využívání půdy

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1. Introduction

Hedgerows are historical landscape features visible all over the world (Deckers et al., 2005). It is found in the Mediterranean regions as terraced landscapes(Agnoletti & Rotherham, 2015), Bocage landscapes in the U.K. and Western Europe (Oreszczyn & Lane, 2000; Thenail & Baudry, 2004), and many other continents (Palang & Fry, 2003). In the Czech Republic and many other Central European countries, such hedgerows appear as historical rural landscape features (Mojses & Petrovič, 2013). In the Czech Republic during medieval times, the word pluzina signified one village's farmland (Molnárová, 2008). These pluzinas are comparable to the hedgerows found in the historic rural landscapes of Central Europe. Some of these have their original structures intact, as they used to border agricultural plots (Sklenicka et al., 2017). Today in the Czech Republic, the word pluzina is used for these medieval field structures' remnants. Hedgerows emerged from agriculture practices and always have coexisted with them. However, hedgerows visible in a landscape can be either planted, spontaneous, or remnant (R. Forman & Baudry, 1984).

Figure 1: Pluzina near Valštejn village (RIEZNER, 2008)

Apart from their ecological and cultural value, hedgerows provide high aesthetic value to the rural landscapes (Groot et al., 2010; Sklenicka et al., 2017). However, their functions have purely changed from providing shelter, source of firewood, and other food sources, into providing ecological benefits and biodiversity conservation (Baudry et al., 2000; Molnárová, 2008). Even though hedgerows have lost their previous functions, they are still dynamic structures that would benefit the environment and fit modern agriculture needs. Hedgerows worldwide have disappeared in the last few decades to enlarge arable lands (Lotfi et al., 2010) and, in some cases, just because of lack of management (Oreszczyn & Lane, 2000). However, awareness of their loss has brought a lot of attention to preserving these landscape features in many parts worldwide. Many studies have been carried out related to the disappearance of hedgerows and have come up with solutions to protect and manage hedgerows efficiently.

In the Czech Republic, pluzinas belong to the medieval time during the period of great colonization of the 13th century (Černý, 1976). Most of the pluzinas in the Czech Republic disappeared during the second half of the 20th century. Increasing production demand, modern mechanization, and political decisions such as collective farming caused the disappearance of pluzinas. Thankfully, many parts of the Czech Republic still possess these medieval landscape elements, especially the border with higher altitudes. Documenting each remaining pluzina structure and imposing new laws for their protection, and providing subsidies to do so would help in preserving the remaining pluzinas in the Czech Republic (Sklenicka et al., 2017). However, proper hedgerow management techniques are equally crucial (Baudry et al., 2000).

Historical landscape features are fragile and susceptible to social, political, and environmental conditions. Apart from that, they are dynamic and growing, and constantly changing shapes. Pluzinas are the skeleton of the medieval hedgerow pattern. They continuously keep growing and extending in different directions. Many pluzinas have merged into each other and have turned into a forest. Pluzinas are deeply connected to Czech Republic's political and social history. After WWII, the empty borderland after expelling German settlements made the region prone to materialistic revolution focusing mainly on production and economic growth. With the vast empty landscape and plenty of opportunities to grow towards industrialization, settlement planners regarded the northern borderlands as a laboratory for experimenting for the state- socialist order (Harris, 2016).

The study of historical and cultural landscapes is not a new thing in European landscape research. The availability of old maps, aerial photographs, and GIS makes the analysis even easier to study the landscape changes. However, identifying the historical landscape structures and identifying the values of those structures is crucial to proceed with the protection of landscape heritage (Šantrůčková et al., 2016). The traditional historical character of the Czech agricultural landscape with small scale field mosaics and country roads lined with fruit trees admired by painters and photographers lasted till the second half of the 20th century (Lipsky, 1995). Hence it is crucial to document the remaining fractions of pluzina structures visible in the Czech landscape using aerial photographs, old cadastre maps, and GIS.

2. Purpose and aims of the study

The second part will be to identify and study the characteristics of the remnants of pluzinas visible in the Ústecký Region of the Czech Republic with the help of GIS and old cadastre maps. Their relation to their environment they are found in will be analysed. Subsequently, the results will be compared with the previous studies, and ways to efficiently conserve pluzinas shall be discussed.

3. Literature review

The literature review aims to discuss the existing studies and researches carried out on hedgerows. By evaluating the historical landscape changes that have taken place in the Czech Republic, the origin of pluzinas is analysed. Their roles in agricultural landscapes shall be thoroughly discussed.

3.1 History of land use in the Czech Republic

Bohemia's first settlements are dated back to the palaeolithic era (2.5 million – 7,50,000 BCE)(Berend et al., 2013). These settlements were developed along the watercourses as it was easier to commute through waterways. The Czech Republic's physiography consists of mountain ranges at the borders and rivers and streams in the low-lying areas (Jirán et al., 2013). However, the human-nature interaction shaped the present-day appearance of the Czech landscape. It results from the transition from hunters/gatherers to intensive agricultural land use (Bičík et al., 2015). Land policies imposed by different ruling bodies also influenced the shape of the landscape in the later period. However, the changes in the Czech Republic during the 19th century took place mainly due to political factors, unlike other parts of the world where industrialization was the leading cause (Kušková 2012).

3.1.1 Stone Age

The Neolithic revolution marks a remarkable change in the history of human transition in Europe. During this period, in some parts of Europe, hunters and gatherers stopped wandering and started to colonize and domesticate animals. In other regions, farmers from the different areas migrated with their livestock and settled. (Bogucki, 1996). The neolithic era in the Czech Republic was between 6000/5000 – 4000 BCE. In this period, the first farmers started to clear forests and grow crops and were responsible for changing the landscape (Pánek et al., 2018). According to a study, the communities in the rocky terrains of Northern Bohemia used to herd cattle and gather wood from the wooded sandstone areas (Ptáková et al., 2020). The prehistoric settlement patterns in Bohemia showed East and southeast facing slopes inclined below 4 degrees and were not beyond 500 meters from a stream (Neustupný, 1991).

In the Neolithic period, the slash and burn system was used in agriculture, where land was cultivated after burning the forest for 3 – 4 years without ploughing and then was left fallow for 5 to 7 years. After the soil lost its fertility, another part of the forest was cleared for agriculture. The settlements eventually moved to different locations after all the land around the settlement area was no longer fertile (Molnárová, 2008). The changes in the Neolithic era were significant in Czech history as the pattern of settlement and economy continued to exist in the later period (Pánek et al., 2018).

3.1.2 Bronze Age

Following the Neolithic came the Bronze Age around the 3rd millennia. At the onset of this age, the invention of metals helped in tilling, which improved agriculture. The farmers tilled small plots that provided them with enough food (Pánek et al., 2018). The slash and burn method still prevailed and was intensified by ploughing, and communities started to form fixed settlements (Molnárová, 2008). The settlements in the Czech Republic preferred black earth that was associated with underlying loess. The preferred altitude for settlement was about 200-300 meters above sea level except for Southern Bohemia which was between 650-800 meters (Jirán et al., 2013).

3.1.3 Iron Age

The Celtic tribe called the Boii took over Bohemia during the iron age (Nathan & Scobell, 2012) (Pánek et al., 2018). The Boii were technologically advanced in ironwork and craft such as iron ploughshare, pottery wheel, etc. Blacksmiths, potters, and jewellers encouraged trade and exchange (Nathan & Scobell, 2012). With the introduction of iron ploughs, the two field system was introduced, and the village's overall production increased to 50-70 percent (Molnárová, 2008). However, according to a study, frequent forest fires in Bohemian Switzerland increased during the iron age, which could also be linked to the slash and burn method of farming still prevalent in the iron age (Ptáková et al., 2020). The Celts established the first pluzina (ploughland) boundaries with the help of stones picked from the fields and placed at the field boundaries (Molnárová, 2008). However, the area of farmed land was restricted during this period, and it became more prevalent only in the early medieval period around 900 AD (Kozáková & Danielisová, 2020).

3.1.4 Medieval

The Celtic culture represented five centuries of the highest stage of prehistoric development in Bohemia and was finally replaced by primitive Germans called the Marcomanni. The invasion (outer colonization) of the primitive Germans from the west took back the level of technological advancement reached by the Celts to a pre-Celtic level (Nathan & Scobell, 2012). On the other hand, the 4th century Slavs that colonized (inner colonization) Bohemia brought the burning field system from Eastern Europe before adopting the bush fallow system (Molnárová, 2008). During the 8th and 9th centuries, the settlements started to grow beyond 400 meters above sea level. The medieval saw an increase in population and settlements, and forested areas were cleared for agriculture and pastures (Hardt, 2019).

In the 11th and 12th centuries, agriculture was intensified by introducing heavy plough, thereby encouraging population growth (Molnárová, 2008). In the 12th century, the Slavic settlements were living in small villages with blocks of fields and moved to a different location once the soil lost its fertility. There was no clear demarcation of plots. Plots were organized only in the 13th century (Hardt, 2019)(Berend, 2017). The bush fallow system was replaced by three field system around the 12th and 13th centuries in which one or two fields remained fallow for a year and were used for pastures while the rest were cultivated (J.Kláptště, 2011)(Bičík et al., 2015). Three field system was practiced in the strip or radial forest plots in newly established settlements (Hardt, 2019). The regional landscape comprised of towns, villages, and noble properties (castles, forts, etc.) and was surrounded by enclosed fields and small broadleaf forests between them (Pánek et al., 2018).

During the 14th century, the development of the towns was mainly due to German immigrants, although the indigenous Czechs were also moving to the urban areas (Hardt, 2019). The Slavic (Czech) settlements increased along with the outer German colonization side by side. (Berend, 2017). Most of these German settlers were agriculturalists that cleared forests to make space for settlement. Soon villages with German populations started to shape the rural landscape of Bohemia and Moravia (Scales, 1999). Landscape character changed with the diminishing of the border between fields and forests (Berend, 2017). Between the 12th - 14th centuries, the cultural landscape was shaped by a mosaic of ploughlands, grasslands, and forests on an uneven relief (Lipský, 2000).

3.2 Plužina

The heavy ploughing involved in the three-field system gave rise to Plužinas during the high middle ages. They often originated from a farmstead and were connected to the village greens (Kučera et al., 2015). The three-field system significantly increased the yield of a pluzina (ploughland). The three equally divided parts were alternatingly used as a winter crop, spring crop, and the third that remained fallow was used for animal grazing (Molnárová, 2008). The boundaries between plots of land (different land-use) were not distinct. The fields, headland, fallow, pasture, clearing, and forest had no clear borders between them. The necessity of clear boundaries resulted in using trees, grassy field margin, large boulders, hedgerows, roads, and fences to demarcate borders (Sádlo et al., 2005).

A hedgerow-defined pluzina is made of an open space (ploughland) and the hedgerows (the field margins) that define its boundaries (Molnárová, 2008). The term "pluzina" (ploughland) is similar to the term "hide," which is the way of dividing a land tenure among family members and then among all the inhabitants of a village (Kučera et al., 2015). According to (Gojda, 2004), the pluzina was the land used for production in a medieval landscape such as fields, meadows, and pastures, interconnected by a system of field roads. Today, it refers to the remnants of medieval field patterns. They were used for boundaries, shelters, and sources of wood in the past, whereas nowadays, they are considered for their cultural and ecological value (Molnárová, 2008).

The nature of a pluzina landscape is in many ways similar to the hedged field (bocage) landscapes that are common in some parts of Europe, e.g., Belgium (Flanders), England, Scotland, Wales, France (Brittany and Normandy), or the Irish highlands (Sklenicka et al., 2009). Bocages or hedgerow network landscapes might be described as checkered grasslands and plough fields with boundaries made up of interconnected hedgerows that might be then connected to other uncultivated areas such as heathland or woodland (Taylor & Burel, 2010). On the other hand, pluzinas found in the Czech Republic have long parallel plots emerging from individual farmsteads of the village, with fewer shorter, transversal hedgerows (Sklenicka et al., 2009).

According to (Baudry et al., 2000), although any row of woody vegetation can act like a corridor or a boundary, it may not be called a 'hedgerow' if it is not maintained. A naturally occurring hedgerow or a planted one is controlled and managed to prevent growing into adjacent fields. In England, apart from being a ploughland feature or a medium for biodiversity conservation, hedgerows are an essential part of the historic landscape character of lowland England that has been shaped by centuries of human activity (Oreszczyn & Lane, 2000). Even though it is believed that hedgerows are typical to Western Europe, mainly to Great Britain and France, they are also found in many other parts of the world. They usually function as windbreaks or shelterbelts. In eastern North America, woody fencerows are used as field boundaries that are either remnant of a forest or a result of dispersal by birds. In African villages, hedgerows are planted for medicinal, religious and protection purposes (Taylor & Burel, 2010).

3.2.1 Use in the past and current benefits

There is not much documentation on the origin of hedgerows before the seventeenth century (Burel & Baudry, 1995). However, there are three predominant types of hedgerow origins: planted, spontaneous, and remnant. Planted hedgerows usually are made up of a single species and are not rich in biodiversity. Spontaneous hedgerows grow from seed dispersed by wind and animals along fences, ditches, and walls, and remnant hedgerows are trees left along a property border while clearing the forests. (R. T. T. Forman & Baudry, 1984).

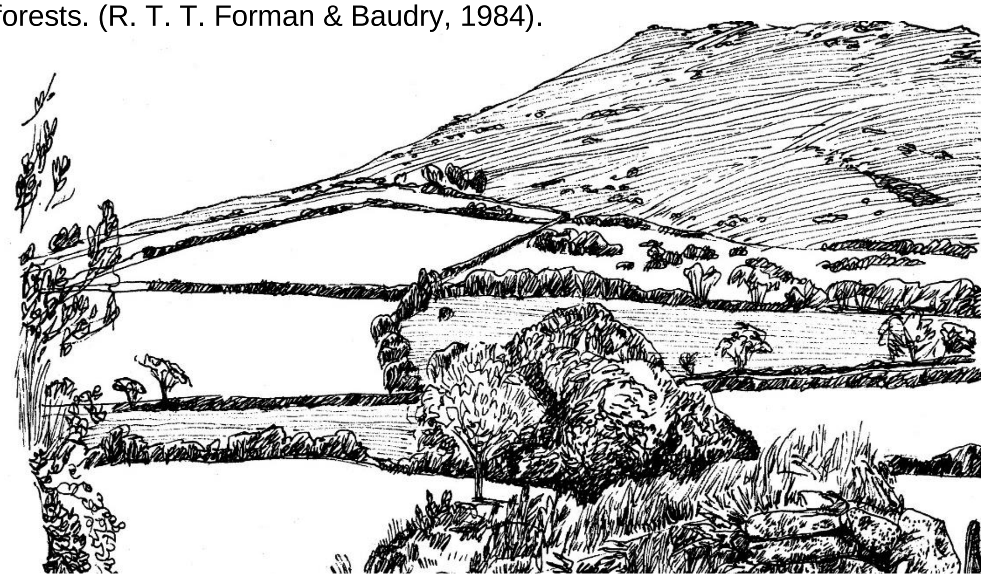


Figure 2: Sketch of British hedgerow landscape (Olin, 1981)

Figure 3: Pyrenean bocage in the Biros valley (Ariège)(J.P Métailié & Paegelow, 2004)

Hedgerows or other rows of woody vegetation are distinctive features around the world. They have a different purpose from the perspectives of the people who planted them or managed the naturally occurring hedgerows. However, nowadays, the primary function of hedgerows are considered to be their ecological and cultural values, for example, as recognised by the Hedgerows Regulation 1997 legislation in the U.K. (Baudry et al., 2000). One of the essential functions of hedgerows was to provide wood (e.g., firewood, timber, fence posts) on farms due to inaccessibility and unavailability of forests to peasants due to private ownership of woodlands (Baudry et al., 2000; Burel & Baudry, 1995). Peasants needed wood for cooking and heating in traditional rural societies, and therefore hedgerows were a source for firewood. Hedgerows were also used as fences to avoid cattle mixing (Baudry et al., 2000). The recurrence of ditches in hedgerows also indicates that they have been functioning as drainage systems apart from being a resource for fodder and small fruits (Burel & Baudry, 1995). Hedgerows and their elements (ditches and earth banks) were used to control water irrigation and soil erosion (Baudry et al., 2000). Well-managed stone-walled terraced field boundaries and hedgerows promote long-term soil conservation, improve topsoil retention, and reduce surface runoff and intense erosion (Houfková et al., 2015). Hedgerows act as habitats, refuges, corridors, or barriers and manage biodiversity. These environments favour many plants and animals to exist in agricultural landscapes (Baudry et al., 2000). Hedgerows are rich in biodiversity in rural landscapes. The plants and animals, which take advantage of the microhabitat heterogeneity of the hedgerows and its ditches and soil bank (Taylor & Burel, 2010).

3.2.2 Types/patterns

The type of pluzinas was directly related to the type of settlement (Kučera et al., 2015). Pluzinas cannot be studied separately without its village type. The original plan of a village is always related to its pluzina structure (Šitnerová et al., 2020). From the 13th century A.D., the long narrow parallel field structures were a result of single-direction tillage technology (Houfková et al., 2015). Apart from that, there are three types of field margins: a mound, a step, or a terrace. Mounds and steps functioned as a border between different land owners. Mounds (about 0.3–2.0 m in height and 2–4 m in width) made from piling up field stones are found in shallow slopes. Steps (1.0–1.5 m in height and 1.5–3.0 m in width) were a result of long-term farming and are found in hilly terrains. Horizontal terraces (1.0–2.5 m in height) were found on steep slopes owned by a single owner(Kovár, Vaššová, & Hrabalíková, 2011).

3.2.3 Village types and their pluzinas

Agglomerated Road Village: Compact settlement where houses are arranged near the street that forms the village's axis. The village is surrounded by an orchard that separates it from the farmland. Agglomerated road villages are primarily associated with pseudo sectional pluzina or sectional pluzina (Kučera et al., 2015).

Cluster village: Cluster village consists of an irregular group of small houses and is typical for early medieval settlements (Molnárová, 2008). Orchards separate these settlements from an open, undeveloped landscape. Cluster villages are not strongly associated with a specific type of ploughland. However, pseudo-longlands are more often seen as a part of the plot. (Kučera et al., 2015).

Green-village: Green-village can be described as a compact village having a central public space and surrounded by homesteads. A periphery of orchards separates the village from the open undeveloped farmland (Kučera et al., 2015). Village greens are typically connected with sectional or pseudo-sectional pluzina and found in old settlement area mostly belonging to the high middle ages (Kučera et al., 2015; Molnárová, 2008)

Street-village: Street-village has a street that acts like the central axis and one or two rows of houses surrounding it. They are often established on wolds near wide rivers

(Molnárová, 2008). They are mostly connected to sectional or leneic pluzina (Kučera et al., 2015).

Street-green-village: Street-green-village is a combination of the street village and the green village (Molnárová, 2008). The houses have elongated plots, and the village is surrounded by trees separating from the undeveloped farmland (Kučera et al., 2015). These are typically connected to sectional pluzina or pseudo sectional pluzina (Molnárová, 2008).

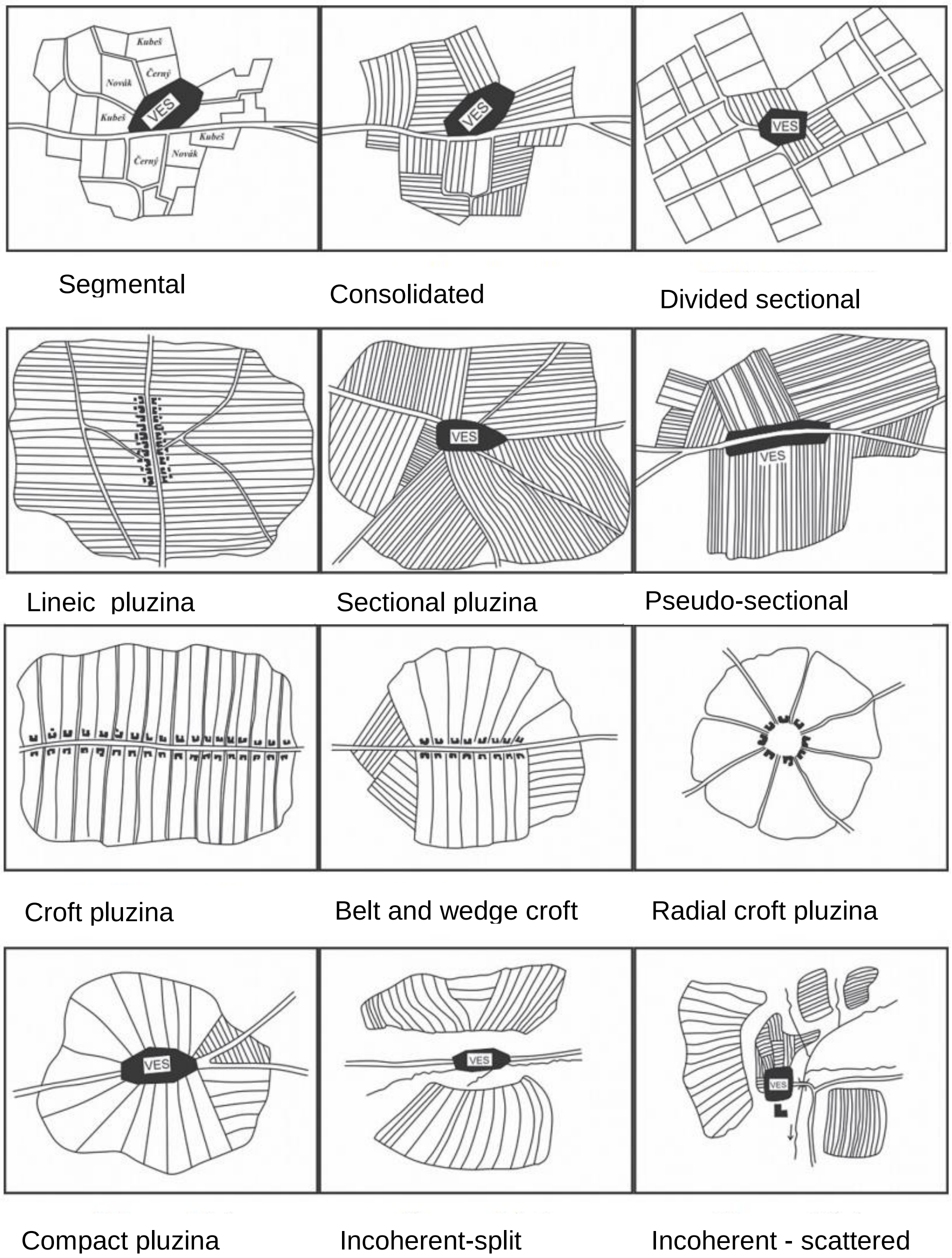


Figure 4: Pluzina types (Šitnerová et al., 2020)

Forest-hide-village: The main feature of a forest-hide-village is its linear form. These settlements were mainly established during the colonization in the Late Middle Ages (Kučera et al., 2015). Forest-hide-villages are associated with croft pluzina (Molnárová, 2008).

Figure 5: A well preserved croft pluzina structure (Sklenicka et al., 2017)

By the middle of the 13th century, settlements inhabited all areas good for agriculture in the Czech Republic. The second phase of settlements that moved to higher altitudes mainly took the shape of linear forest rope villages. These villages had croft pluzinas adjacent to the village (Šitnerová et al., 2020). These croft pluzinas were usually located in flat areas, usually have double rows and originate from the homesteads, and distributed along the long axis of the village (Černý, 1976). These ploughlands were not accessible from the roads and were only accessed through their individual homesteads (Vermouzek, 1979). These pluzinas were the most commonly found in the Czech landscape until the end of the 1940s (Machov & Elznicov, 2002)

3.2.4 Disappearance of pluzinas

The change and the loss of past functions of hedgerows are the primary reasons for the threat and disappearance of hedgerows (Baudry et al., 2000). In the 18th century England, the enclosure movement divided the common land into private plots, which were bordered by hedgerows. France made it compulsory according to the Civil Code of the Napoleonic period to divide property among the heirs. This led to the demarcation of new property limits with hedgerows. These new fragmented properties were unsuitable for modern agriculture, which led to new planning. Hence agriculture intensification and conversion of grassland to farmland and use of modern machines resulted in the enlargement of fields and removal of hedgerows (Burel & Baudry, 1995). In Western Europe, land consolidation is used as a way to tackle land fragmentation and other issues related to agricultural lands, such as an increase in farm sizes and adjusting to modern farm machinery. However, during the last thirty years, the purpose of land consolidation in many countries of Western Europe has shifted towards nature conservation and environmental protection (Hartvigsen, 2014). Since the 1950s, countries such as the Netherlands, France, and Germany, for example, have consolidated large areas of land to tackle fragmentation of land (van Dijk, 2007). These countries compensate farmers with cash for the land lost due to consolidation that helps them to sustain and increase their production. Western Europe has different procedures for land consolidation (Hartvigsen, 2014).

3.2.4.1 Historical causes

The Renaissance period (1500 - 1620 in the Czech lands) saw an expansion of agricultural land following the pattern of the Middle Ages (Molnárová, 2008). Mining of high-grade ores in the mountainous areas and decrease and disappearance of the broad-leaved forest started to take place (Pánek et al., 2018). This was balanced by the introduction of a diverse range of crops and the construction of fish ponds and artificial lakes. The Thirty Years' War (1620-1648) brought a 43% decrease in population that resulted in the village and farmland abandonment and consequently an increase in the forest area. In the middle age, the established settlements divided the farmland into three parts, where one was permanently used to grow crops, the other for pasture, and the third was used as needed, alternating between crop land and pasture land. Pluzinas were fully developed, according to their origin and historical development. Field margins, roads, ditches developed in established settlements. The landscape lacked shrubs due to the presence of cattle (Molnárová, 2008). In Bohemia, during the 17th and 18th century 80 % of the population was into agriculture and lived in the countryside (Brenner, 2014).

3.2.4.2 Causes of 18th, 19th, and the 20th century

At the end of the 18th century, ponds started to disappear due to the growing demand for agricultural land for cereal farming and pasture. The percentage of arable land increased by 20% (Pánek et al., 2018). The demand for labour increased, which often resulted in peasants not tilling their land. After a disastrous famine in 1771, feudalism in agriculture seemed unsuitable. In 1777, 105 estates belonging to nobles and church were divided among peasants upon the orders of Empress Maria Theresa. The injustice towards the lead up to the revolution of 1848 (Davis, 1900). In 1848 the serfdom and Unfree Labour was abolished by Francis Joseph I, which authorized peasants to have complete ownership, inheritance, and even sell their lands. The peasants had to pay their new taxes over a period of forty years. Some of them prospered by taking advantage of the new market-oriented production, while the small land owners could not profit from the new system and lost their land. Subsequently, there was an increase in labour migration to manufacturing areas and speculation of rural land (Albrecht, 2004). Despite the abolishment of serfdom at the end of the 19th century, the feudal system was still reflected in the land ownership patterns. While 30% of huge estates covering 1000 ha were owned by 0.05% of the population in size, the rest 70% of the farms were less than 5 ha of land, which were highly fragmented. Land consolidation was implemented between 1883 and 1914 in 104 villages in Moravia. However, in Bohemia, not many villages took part in this project (SkaloŠ et al., 2012). There was a 50 % increase in usable arable lands during the 19th century, whereas permanent grasslands decreased (Lipský, 2000) (Molnárová, 2008).

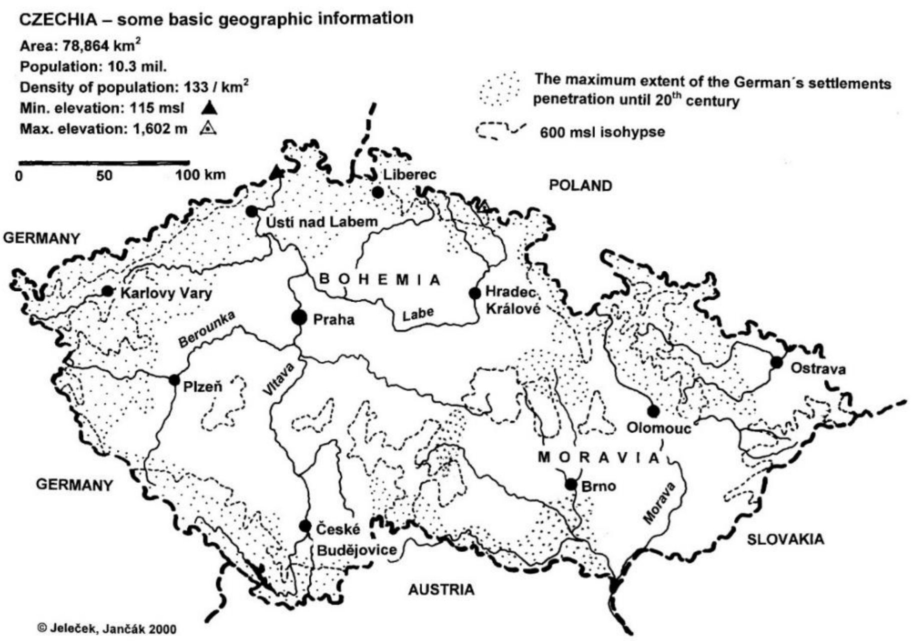


Figure 6: Extent of German settlements until 20th century (Bičík et al., 2001)

Most of the population before the industrialization lived in the rural areas as farmers. Industrialization brought a significant difference in the urban population. After the war, when the Germans left, most of the villages were abandoned. The Ústecký region was one of the many areas that suffered from abandonment (Bičík et al., 2015). This abandonment led to the loss of lands of 2 to 3 million Germans whose farmlands gradually turned into forests (Grešlova Kuškova, 2013). The expelling of 3 million Germans resulted in the discontinuity of agricultural and demographic development in their dwelling areas (Molnárová, 2008). More than 1000 settlements disappeared, and so did their economic functions. This left the borderland uncultivated and eventually reforested (Kuskova, Gingrich, & Krausmann, 2008). These borderlands were not fit for large-scale agricultural production. These led to fields converting into pastures and meadows, which had a positive effect on the environment. But in some parts of Northern Bohemia, under the Ore Mountains, large fertile areas were converted to open-pit coal mining industries (Bičík, Jeleček, & Štěpánek, 2001). Therefore Czech agriculture underwent changes not just due to industrialization but because of shifts from the capitalist method of production to centrally owned large-scale fields (Grešlova Kuškova, 2013).

Collectivization was implemented between 1950 and 1980 (Kuskova et al., 2008). Agricultural properties were confiscated from the farmers, and they were forced to join agricultural co-ops. Field borders were ploughed to make them unrecognizable to the farmers (Molnárová, 2008). The farm land owned by co-operatives and state increased to more than 80%. In the Czech Republic, cultural farming landscape character like the field mosaics and country roads lined with fruit trees were visible till the second half of the 20th century.

The 19th and 20th centuries ' political and social developments, especially the socialist government, influenced land ownership in the Czech Republic. The period between 1948 and 1989 had the most impact by interrupting the long-term bond between the land and farmers. Additionally, this period negatively impacted the ecological and aesthetic values of the landscape (Sklenicka, 2006) (Thomas, 2006). There were significant changes seen in the Czech landscape during the 20th century in the function and field patterns of agricultural landscapes. The first land reform was in the so-called "First Republic" (1918-1934) in which noble properties were seized and sold to small farmers (Molnárová, 2008). In 1919, all farm land greater than 150 ha and all other lands greater than 250 ha were redistributed to 500,000 farmers of small parcels. As the country moved towards large-scale socialist production, farmland was only seen as an area for production. It was modified to suit heavy mechanization with the removal of stabilizing elements which in turn increased the size of farmland increased to 50 fold (Lipský, 2000).

After 1950 collective farming led to the simplification of the landscape (Lipsky, 1995). There was a significant decline in the area of pluzina landscapes during the second half of the 20th century (Sklenicka et al., 2017). In 1980 the average size of a co-operative was 2500 ha, and the size of a state farm was 6800 ha (Kuskova et al., 2008). These expansive state farms did not care for the previous form and functions of the landscape. The most striking changes visible in the landscape were enormous fields and the extinction of scattered greenery. This involved the removal of small biotopes (woodlots, ditches, hedges, field margins including pluzinas, road verges, etc.) that resulted in a decrease in biodiversity and aesthetic characteristics of the landscape, extensive soil erosion, and degradation of landscape organization (Sklenicka, 2006) (Molnárová, 2008). Many previously controlled areas, strips of meadows and pastures along with forests, pathways, creeks, grassy balks, and old orchards on slopes, were abandoned. Natural succession of trees and shrubs took over these areas, which became a refuge for plants and animals pushed out of the enormous agricultural landscape (Lipský, 2000). After the re-imposition of democracy in 1989, new trends have been responsible for shaping the landscape. Speculations are made regarding the recent trends such as restitution and privatization of land, land consolidation, and urbanization, might impose a threat to the conservation of the remaining pluzinas (Molnárová, 2008).

3.2.4.3 Current

Like Central Europe, most of the farming landscape in Western Europe has shown extreme changes in hedgerow networks in the last few decades. Scattered greenery has been removed to encourage agriculture. These changes caused many environmental problems such as sheet and wind erosion (Taylor & Burel, 2010). In France, the removal of hedgerows comes along with plot reallocation programmes. Removal of woody elements from the fields is decided based on the soil's agronomic characteristics, impact on the environment, and property borders. The aesthetic value of the hedgerows are not evaluated (Burel & Baudry, 1995)

Around the 1980s, the privatization of the land led to the agricultural transition in Central and Eastern European countries. Following this was the restitution of the properties to its previous owners (Lerman, 2001). The consequence was faced by many rural areas that had significant problems that were caused by the unsuitable structure and extremely fragmented ownership of the agricultural land (van Dijk, 2003). This, in turn, resulted in a decline in agricultural production because it prevented individual farms from growing properly by depriving them of substantial investment (Pašakarnis & Maliene, 2010).

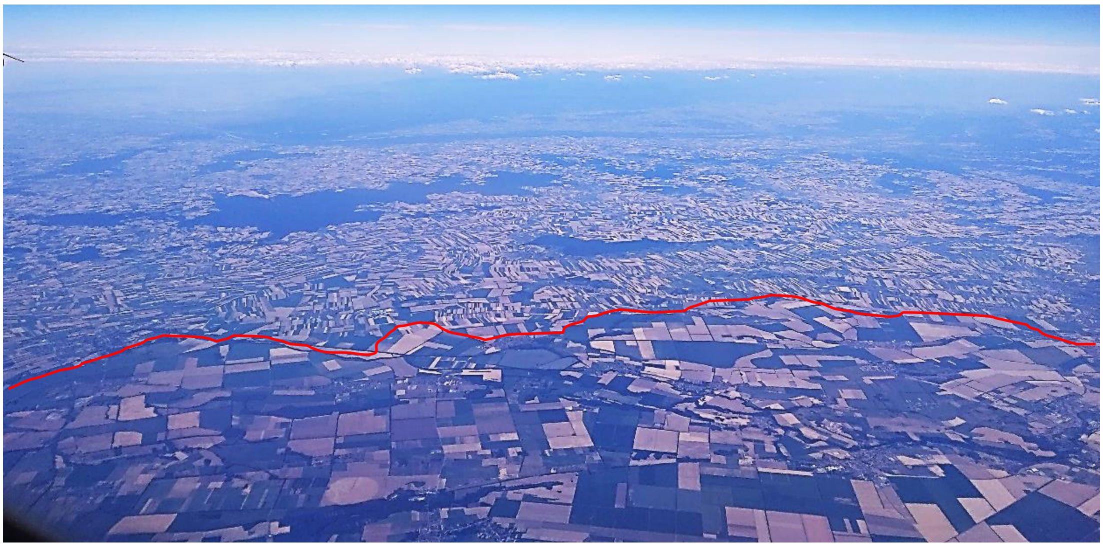


Figure 7: Aerial photograph showing differences in field sizes between Austria and Czech Republic 2018

In the Czech Republic, the most important post-1990 changes that took place which impacted the land-use pattern involved the restitution of private property, the partial privatization of state property, enforcement of environmental laws and awareness, respecting legal rights of land owners in agricultural co-operatives, borders opened for economic activities, and the restitution of land market (Bičík et al., 2001)(van Dijk, 2007). From the year 2000 to 2008 Czech Republic saw an increase in grasslands and a decrease in arable lands to tackle agriculture intensification and its negative environmental impacts. The borders which have high altitudes and colder climate saw a 50 percent decrease in arable land (Lorencová et al., 2013).

Agricultural ecosystems provide ecosystem services that include soil retention, food production, and aesthetics (Lorencová et al., 2013). In the Czech Republic, water retention and soil erosion have been the main problem, particularly after 1998. The large fields without any natural vegetation and extreme soil compression due to heavy machinery are still visible in Czech agriculture. However, due to the reduction in the use of fertilizers and pesticides, biodiversity has shown a slight improvement (Bañski & Bednarek, 2008).

Land-use changes are responsible for a substantial contribution to the global CO_2 concentrations in the long-term (Lorencová et al., 2013) (Krkoška lorencová, Harmáčková, Landová, Pártl, & Vačkář, 2016). Czech agriculture has 6% of UAA (utilised agriculture area) practicing ecological farming. However, most of the area following the ecological practices is only used on livestock production on grassland, whereas only 8% is used for food production (Bañski & Bednarek, 2008).

The difference between the land-use change of 2000 and 2010 at a national level is insignificant as it makes only 1% of share in the case of arable land category and less than 1% in the other two land-use categories (Lorencová et al., 2013).

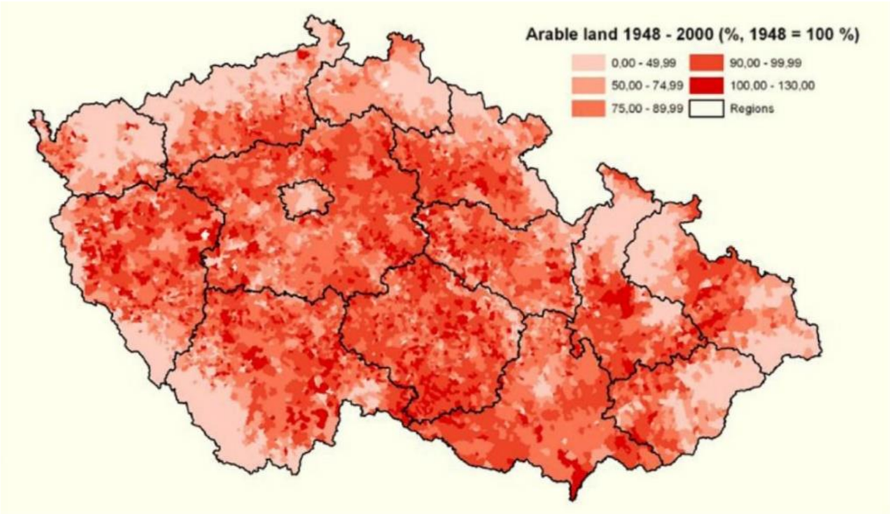


Figure 8: Relative change in share of arable land from 1948 to 2000, the Czech Republic (Czech LUCC Database).(Lorencová et al., 2013)

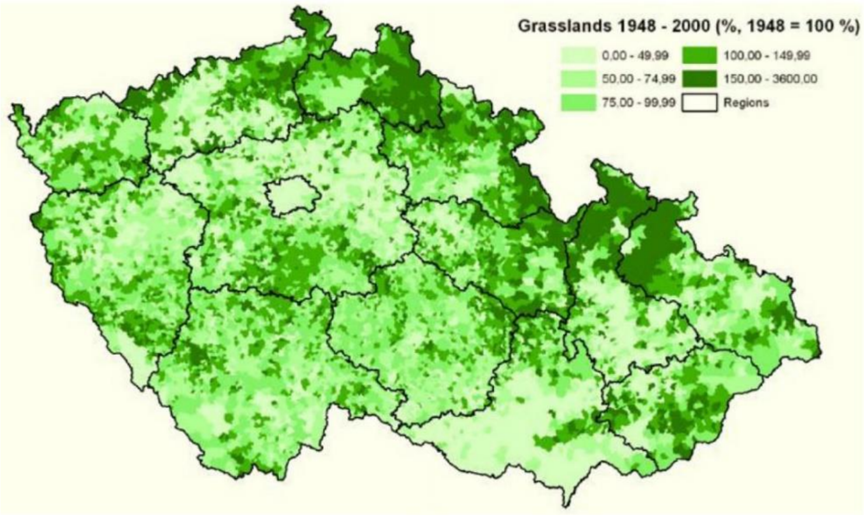


Figure 9: Relative change in share of grasslands from 1948 to 2000, the Czech Republic (Czech LUCC Database). (Lorencová et al., 2013)

4. Methodology

4.1 Site description, characteristics

Ústí nad Labem Region or Ústecký kraj was selected as the study area. It has an area of 5,335 square kilometres. It is located in the North-Western part of Bohemia. This region consists of 354 municipalities, of which 53 are towns. It consists of 7 districts (Chomutov, Děčín, Litoměřice, Louny, Most, Teplice, Ústí nad Labem), Ústí nad Labem being the largest of all. Ústecký Kraj falls on the region of the black triangle (an area of heavy industrialization and environmental damage in the borders of Poland, Germany, and the Czech Republic). Heavy industrial production is concentrated in the foothills of the Ore Mountains (the Chomutov, Most, and Teplice Districts, and part of the Ústí nad Labem District). There has been extensive damage to the landscape in this region, mainly due to mining activities. There have been many displacements of villages in this region due to political and industrialization factors.

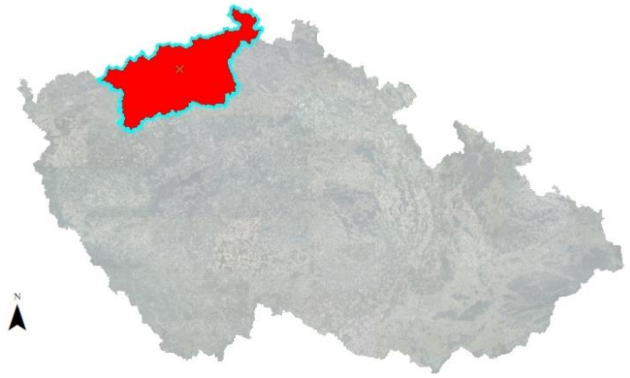


Figure 10: Location of Ústecký region(study area) in the Czech Republic

The total area of the Ústecký region is 5,335 kilometres square. The German borders of Ústecký Kraj are lined up with the ore mountains, Lužice Mountains, and Labe sandstone rocks. The south-eastern part of this region contains the Bohemian central upland. The ore mountains are rich in brown coal. The largest watercourse in the region is the river Elbe. The Bohemian Switzerland National Park is the most important protected area in this region, which also includes part of the Elbe Sandstones.

4.2 Data collection

4.2.1 Research considerations

GIS has been used to map and analyze hedgerows in many parts around the world, for example (Lotfi et al., 2010), (Thenail & Baudry, 2004) and (Groot et al., 2010). These data are then used to study the effect of hedgerow management on hedgerows. This study is a part of a landscape ecology project called the "identification and preservation of historic landscapes," which is being carried out by the Department of Landscape Planning, Faculty of Environmental Sciences of Czech University of Life Sciences in Prague. The database for the mapping of pluzinas(hedgerows) for the Ústecký region was provided, and the mapped pluzinas were used for analysis.

4.2.2 Part 1: Morphological features of pluzinas

For the mapping and analysis of data (overlay of maps), ArcGIS 10.6.1 was used. The Czech national coordinate system (EPSG: 5221 - S- JTSK (Ferro)/ Krovak East North) was used for the Czech Republic. Each remaining hedgerows were digitized using ArcGIS. Visual identification was done using an updated orthophoto map and then compared with Lidar layer and stable cadastre map (1840 – 1860). GIS can be used as a spatially referenced database, a visualization, and an analytic tool (Gregory, 2005). Geographical Information Systems help in the integration and analysis of large amounts of data sets (Draper et al., 2003). The following steps were followed for the vectorization of pluzinas:

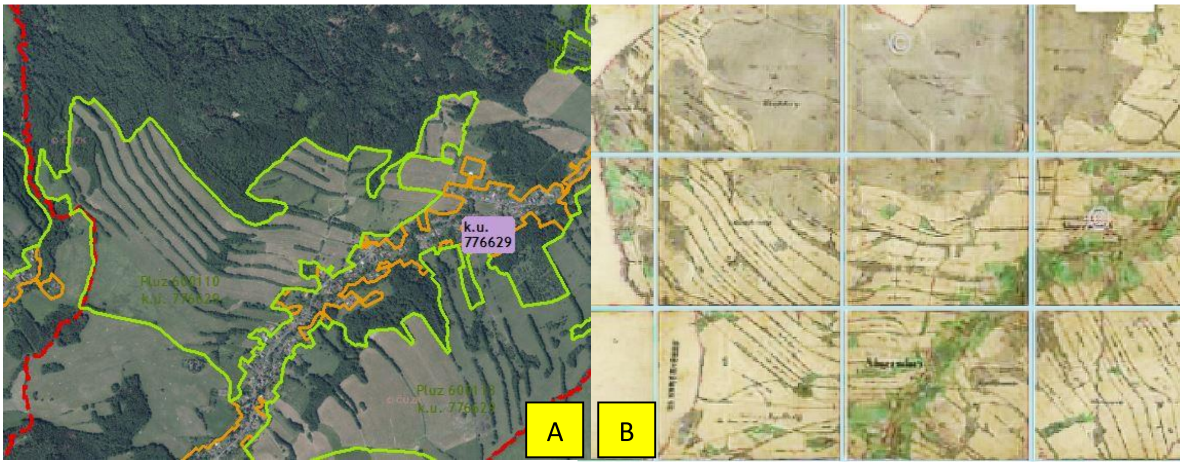
- Pluzinas were identified by their long, narrow, and parallel ploughlands belonging to one village.

- Vectorisation was considered only if there were a set of at least three consecutive linear strips.

- Using a stable cadastre map (1840 – 1860) and Lidar layer, the authenticity of its historical origin was checked.

- Hedgerows that consisted of more than 10% of the forest were not included due to the rules of this project.

- After vectorization, characteristics such as the land cover, rhythm, integrity, and merging of hedgerows were analyzed.



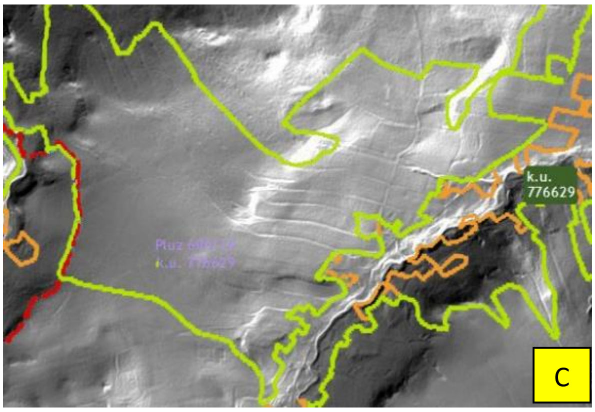


Figure 11: Pluzina vectorization

A: Vectorisation of pluzina and built-up areas using orthophoto map in GIS.

B: Confirmation of its historical origin using stable cadastre map. Source: https://ags.cuzk.cz/archiv/

C: Confirmation of its historical origin using Lidar layer in GIS.

Layers used for Physical properties analysis:

BPEJ_2019 – Shapefile for qualitative analysis for soil, climate, and slope. The BPEJ system represents the primary qualitative basis for the differentiation of soil and climatic conditions of agricultural land in the Czech Republic.

AOPK_CHU – Shapefile with different categories of protected areas Agency of nature and landscape conservation Czech Republic.

DIST_POP100k_5km – Shapefile with 5 kilometres buffers up to 80 kilometres from major cities.

DIST_POP10k_5km – Shapefile with 5 kilometres buffers up to 30 kilometres from small cities.

DMR_po100m – Raster file having 10 values for altitude.

Attributes of pluzinas	Classification
Pluzina number	I.D.
Cadastre number	ID (Hranice katastr.uzemi layer)
Land use	1 - grassland 2- 75% grassland, max 25% arable land 3- 50% grassland, max 50% arable land 4- 25% grassland max 75% arable land 5- arable land
Rhythm	1- fully preserved 2- very well preserved 3- well preserved 4- badly preserved 5- barely visible
Integrity	1- unbroken 2- Occasional interruptions (90%) 3- Significantly interrupted (up to 60%) 4- Only fractions left (up to 40%) 5- Barely visible (up to 20%)
Merging hedgerows	1- No overlap 2- Overlap of small sections (< 10%) 3- Overlap of large sections (< 40%) 4- Overlapping most of the structure (< 60 % 5- Linear structures barely visible
Layers used	
Pluziny	Digitized pluzinas
zastavěné území (současné)	Digitized built up areas
Hranice katastr.uzemi (souc)	Boundaries of cadastral lands and ID of cadastre
ZABAGED	To digitize the built-up areas
dmr5g	LIDAR layer to check the historical origin of hedgerows
ortofoto	Orthophoto to digitize visible pluzinas
Pluzina s lidarem	To digitize parts of pluzinas only visible in LIDAR but have disappeared or merged with forest in orthophoto.

Table 1: Attributes of pluzina and layers used in vectorization of pluzinas

4.2.3 Part 2: Physical features of the study area and pluzinas

Physical properties	Range and categories
Climate Layer: BPEJ_2019 Value field: KOD_KLIM1	0-9
Altitude Layer: DMR_po100m	0-11
Soil productivity Layer: BPEJ_2019 Value field: Vynos	0-10
Slope and aspect Layer: BPEJ_2019 Value field: KOD4_TEREN	0-9
Distance to major cities (100,000 inhabitants) Layer: DIST_POP100k_5km	The maximum distance of 5KM buffer is 80KM
Distance to small cities (10,000 inhabitants) Layer: DIST_POP10k_5km	The maximum distance of 5KM buffer is 30KM
Protected areas Layer: AOPK_CHU	PR – Nature reserves NPR – National nature reserves P.P. – natural monuments NPP – National natural monuments CHKO – Protected landscape areas N.P. – National parks O.P. – Other protected areas

Table 2: Categories of physical properties for analysis

Along with the morphological characteristics of individual pluzinas, the physical attributes of pluzinas and Ústecký region were also compared. Intersect, and clipping tools were used to overlap the maps to compare the soil fertility, climate, slope and aspect, altitude, number of pluzinas in protected areas, and their distance from big and small cities. These analyses were represented as graphs and maps to find possible relations to the preservation of the remaining pluzinas. ArcMap 10.7.1 was used for digitizing the pluzinas and overlapping the layers for analysis, and graphs were made using excel.

4.2.3.1 Tables used for the analysis of physical properties

Productivity range	Description	GIS code
6 – 11	Insignificant	1
11 – 28.2	Productivity of low importance	2
28.2 – 43.7	Extremely low productivity	3
43.7 – 58.4	Very low productivity	4
58.4 – 65.3	Low productivity	5
65.3 – 73.1	Medium productivity	6
73.1 – 81.0	Productive	7
81.0 – 89.0	Medium productive	8
89.0 – 97.0	Highly productive	9
97.0 – 100	Highly productive with stabilized yields	10

Table 3: Soil productivity

Code	Depth category	Slope in degrees	Definition	Exposure category	Exposure	Exposure characteristics
0	0 - 1	0 – 3	Plane	0	Plane (0-1°)	Omni-directional
1	2	3 – 7	Slight inclination	0		
2				1	South	SW-SE
3				3	North	NW-NE
4	3	7 – 12	Medium slope	1	South	SW-SE
5				3	North	NW-NE
6	4	12 – 17	Significant slope	1	South	SW-SE
7				3	North	NW-NE
8	5 - 6	17 – 25	Steep slope	1	South	SW-SE
9				3	North	NW-NE

Table 4: Slope and aspect value

Region code	Description	Annual total precipitation (mm)
0	very warm, dry	500-600
1	warm, dry	under 500
2	warm, slightly dry	500-600
3	warm, slightly moist	550-700
4	slightly warm, dry	450-550
5	slightly warm, slightly humid	550-700
6	slightly warm, moist, lowland	700-900
7	slightly warm, humid	650-750
8	slightly cold, humid	700-800
9	cold, moist	over 800

Table 5: Climate type and precipitation

Values	Meters above sea level
1	Below 100
2	100-200
3	200-300
4	300-400
5	400-500
6	500-600
7	600-700
8	700-800
9	800-900
10	900-1000
11	Above 1000

Table 6: Altitude

5. Results

5.1 Morphological analysis of pluzinas

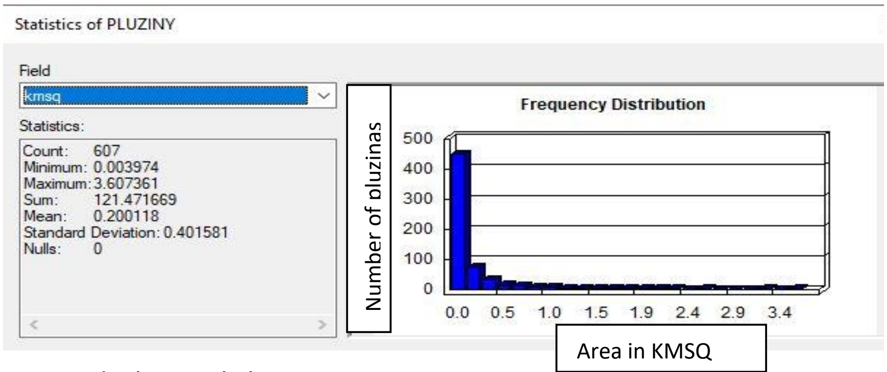


Figure 12: Pluzina statistics

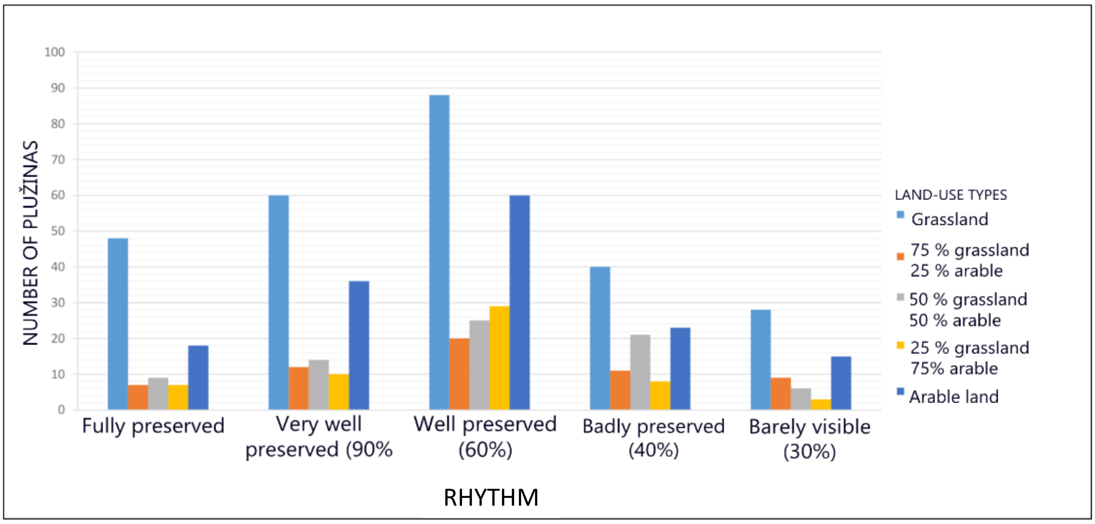


Figure 13: Graph of rhythm in relation to land-use in pluzinas

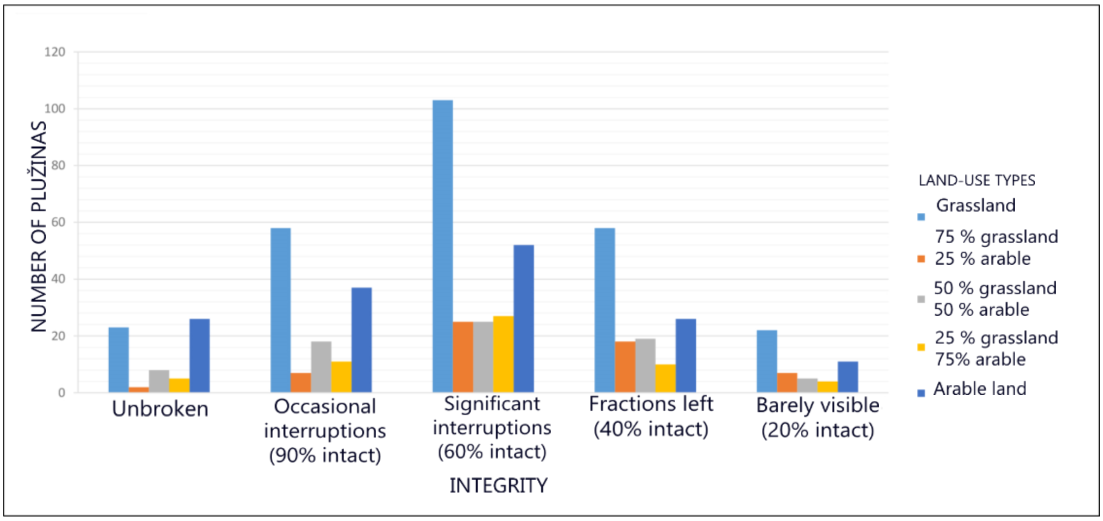


Figure 14: Graph of integrity in relation land-use in pluzinas

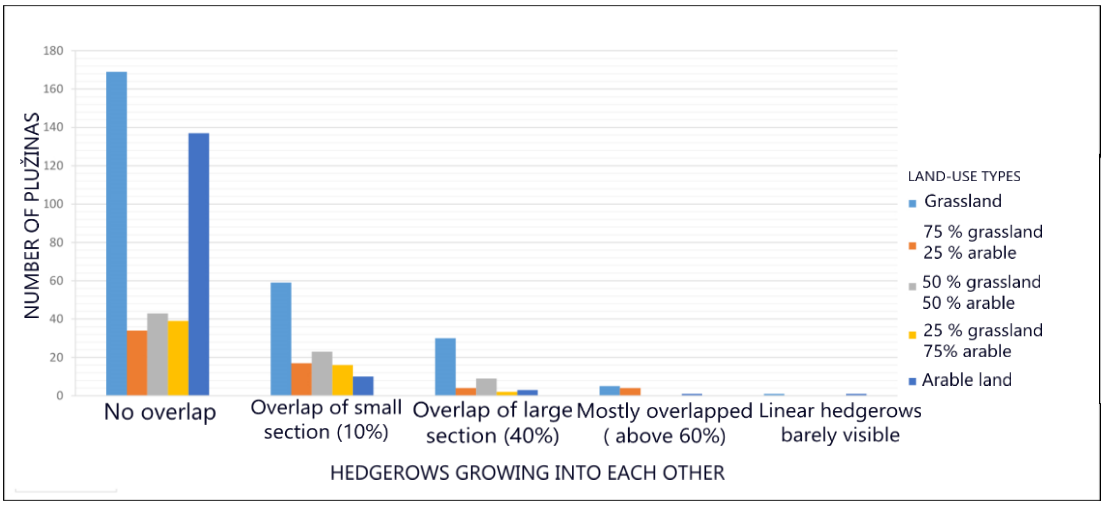


Figure 15: Graph of merging hedgerows in relation to land-use in pluzinas

A total of 607 pluzinas were digitized in the Ústecký region belonging to 338 municipalities out of 1059 municipalities included in the Hranice katastr.uzemi (souc) layer of GIS. The total pluzina area digitized is 121.5 square kilometres. Each hedgerow's historical origin was checked in cadastre maps and LIDAR layer. Their rhythm, integration, and discreteness were analysed. Out of 607 pluzinas digitized, 89 had perfect rhythm, 64 had intact integrity, 422 were discrete without merging into each other, and 264 were found in total grassland.

The majority of pluzinas were found in grassland, having well-preserved rhythm, significant interruptions in their integrity, and no overlapping. The rhythm and integrity were the primary factors considered in deciding the best-preserved pluzinas. Secondly, the area and the merging of hedgerows were taken into account to find the best-preserved pluzinas. The pluzina in the Oblik hill situated between the village Chraberce and Raná in the district of Louny and many pluzinas in and around the village Valkeřice in the district of Děčín were found to be the best-preserved ones in Ústecký region. This result is further supported by (Riezner, 2011) where four pluzinas, including the ones at Oblik and Valkeřice, were selected based on their well-preserved pluzinas to analyze their characteristics. The pattern that appears in the stable cadastre maps of 1840 – 1860 is clearly visible in these pluzinas.

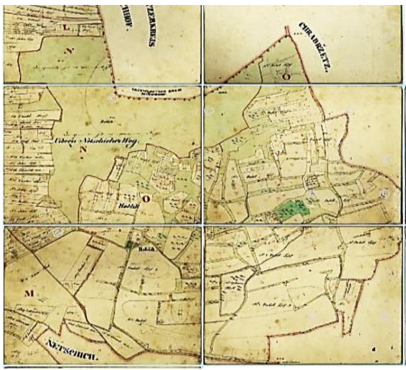


Figure 16: Right - vectorization of the best preserved pluzina in Oblik hill in the district of Louny. Left – old cadastre map confirming its historical origin

The pluzina in the Oblik is a segmental pluzina (Riezner, 2011). The segmental pluzinas are separated from the village and have irregular square or rectangular-shaped plots (Kučera et al., 2015). The pluzina in Oblik shows the exact attributes. The pluzina stretches from the North-East slope to the Southern slope of the Oblík hill. This hill is a part of the Central Bohemian Uplands and is an NPR (National Natural Monuments) protected area. The area of the pluzinas digitized in Oblik is 1.26 square kilometres.

Figure 17: Pluzina on Oblik hill (Riezner, 2011).

Figure 18: Pluzina on Oblik hill (Purkyn, 2011)

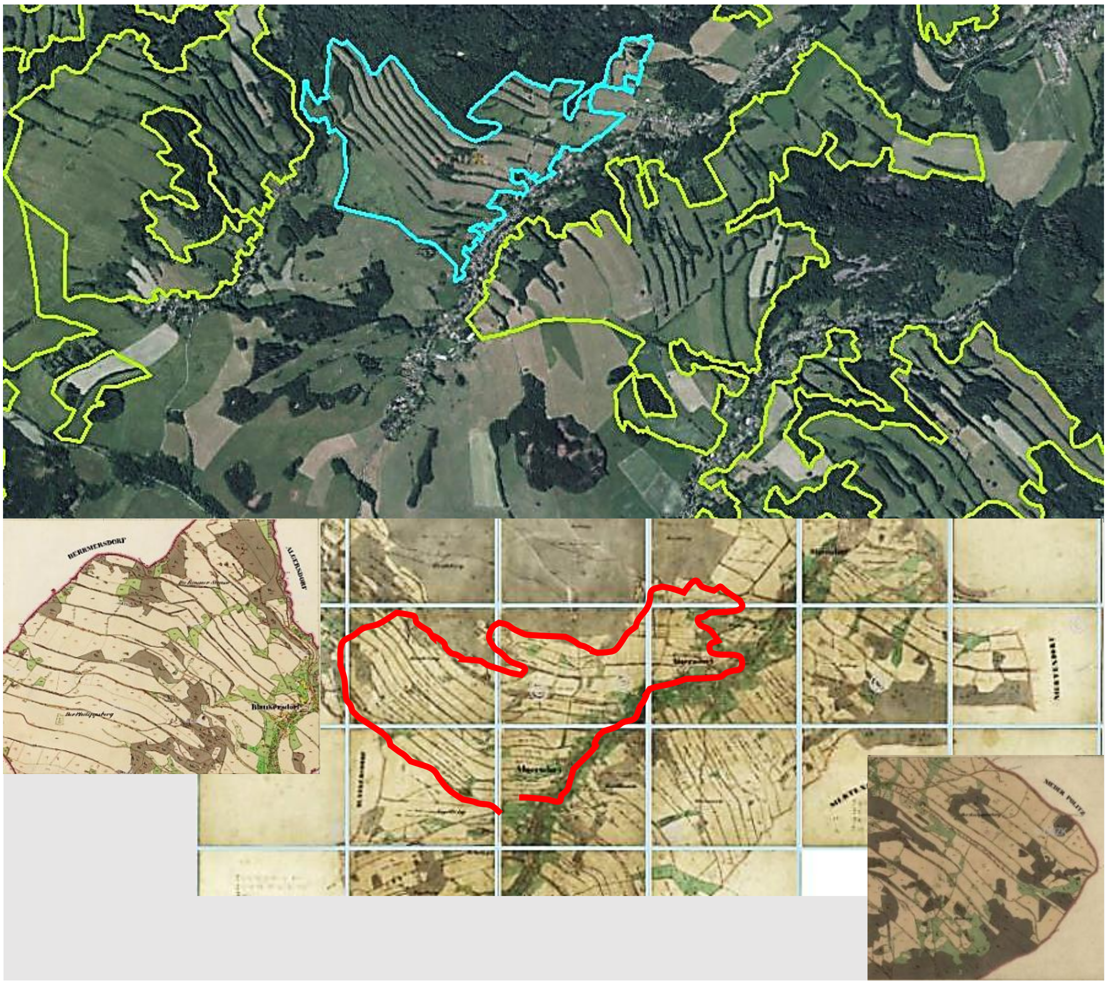


Figure 19: Croft pluzinas of Valkeřice village compared to stable cadastre image 1843

Figure 20: Valkeřice, Pluzina hedgerows(Left) and stone embankments in a hedgerow(Right)

Valkeřice is a forest rope village having well-preserved croft pluzinas. The pluzinas are located on the southern slope of Kohout hill (Riezner, 2011). Croft pluzinas are common on hilly terrain and are the most common type of pluzinas found in the Czech landscapes (Molnárová, 2008). The area of the best-preserved pluzinas digitized in Valkeřice is 1.42 square kilometres.

5.2 Analysis of the physical properties of the pluzinas

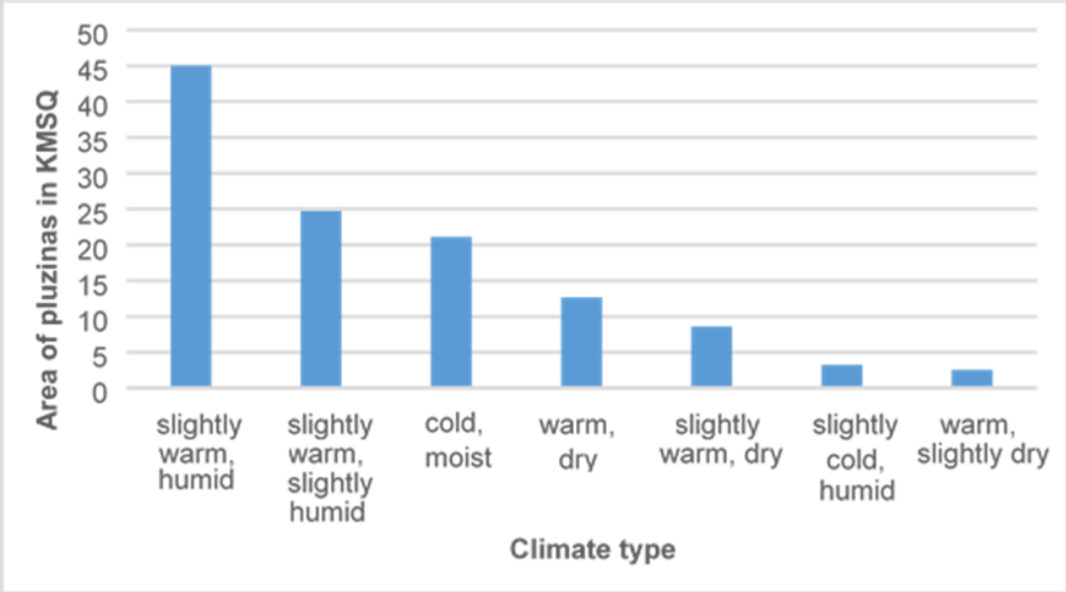


Figure 21: Graph of pluzina area in relation to climate type

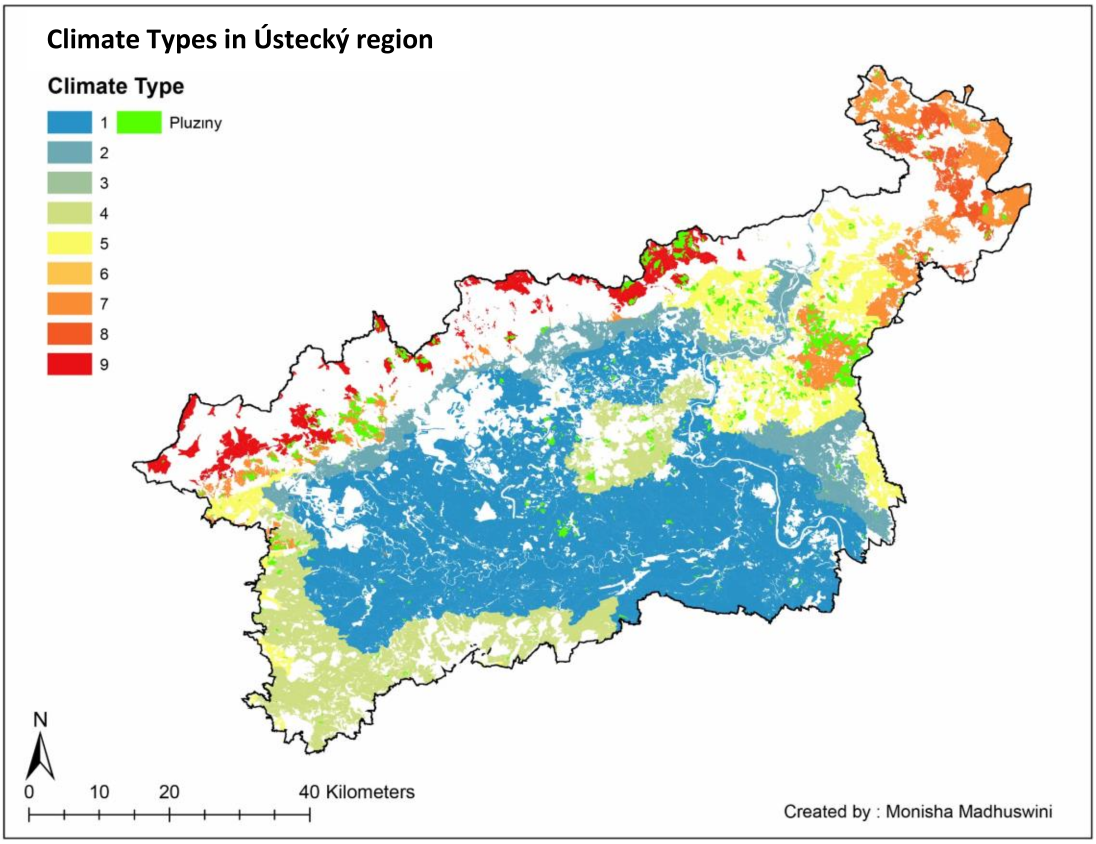


Figure 22: Map of climate of Ústecký region. Refer to table 5 for codes.

1 – Warm and dry

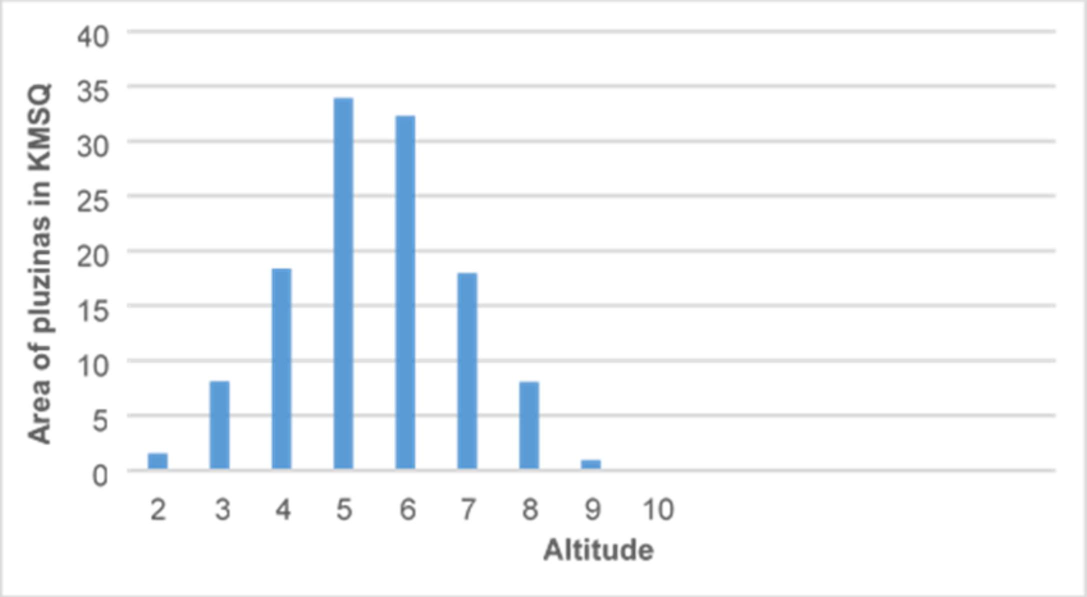


Figure 23: Graph of pluzina area in relation to Altitude

Altitude value	Category(metres a.s.l)
5	400-500
6	500-600

Table 7: Results of altitude graph

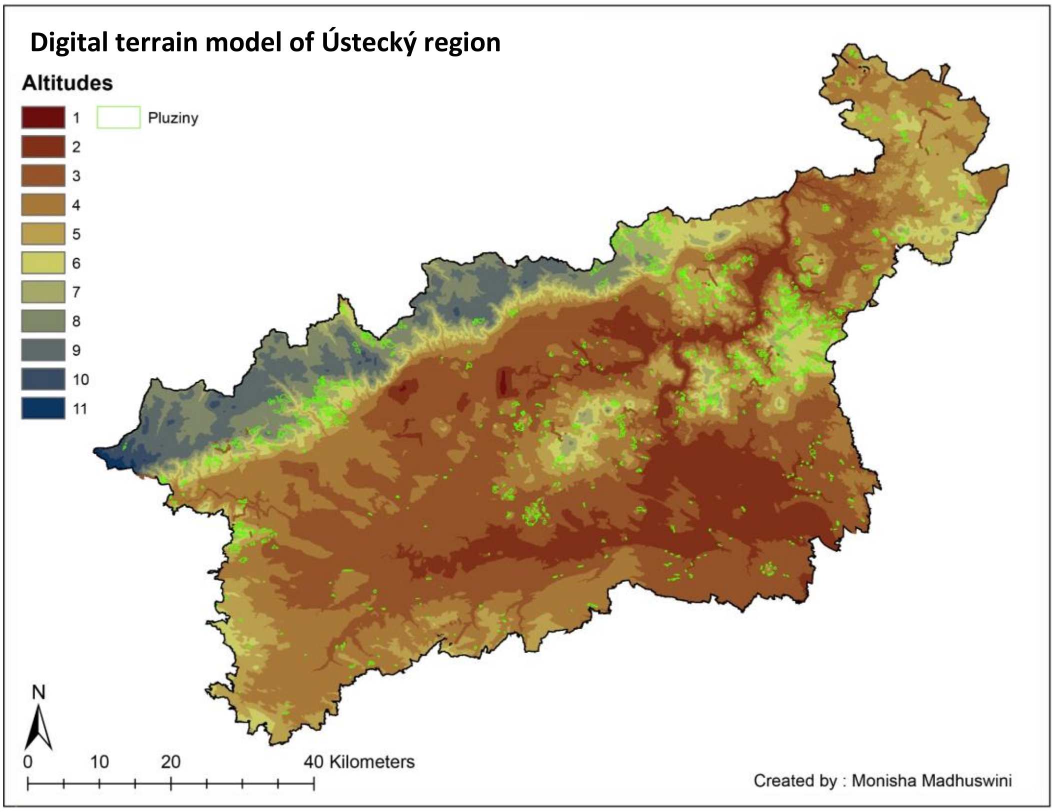


Figure 24: Digital terrain model of Ústecký region. Refer to table 6 for codes.

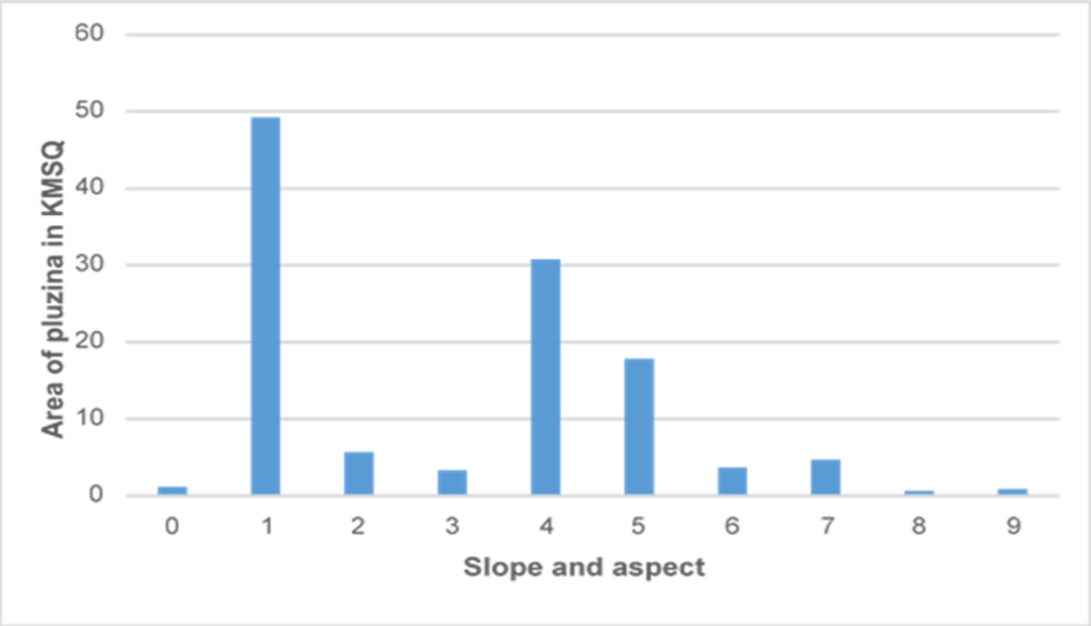


Figure 25: Graph showing area of pluzinas in relation to slope and aspect

Value	Slope	Exposure
1	3 – 7 ° Slight slope	Plane (0-1°) Omni directional

Table 10: Results of the slope and aspect graph and its description as mentioned in table 4.

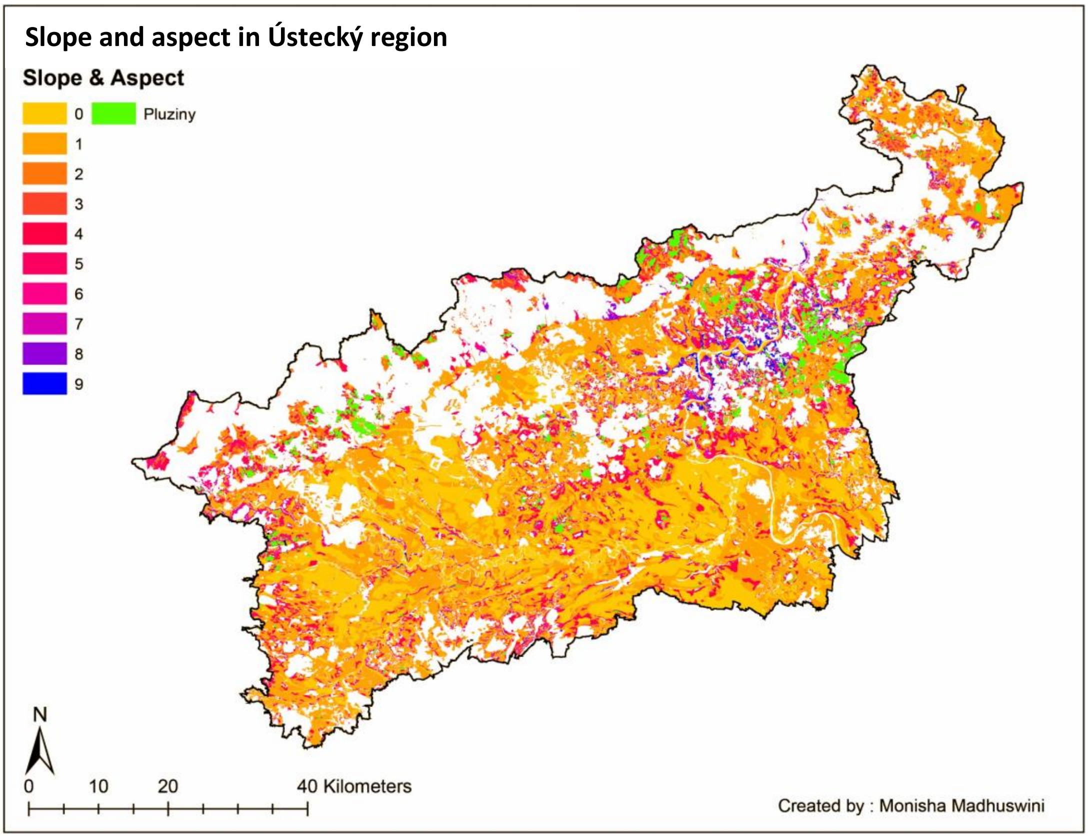


Figure 26: Slope and aspect of Ústecký region. Refer to table 4 for codes

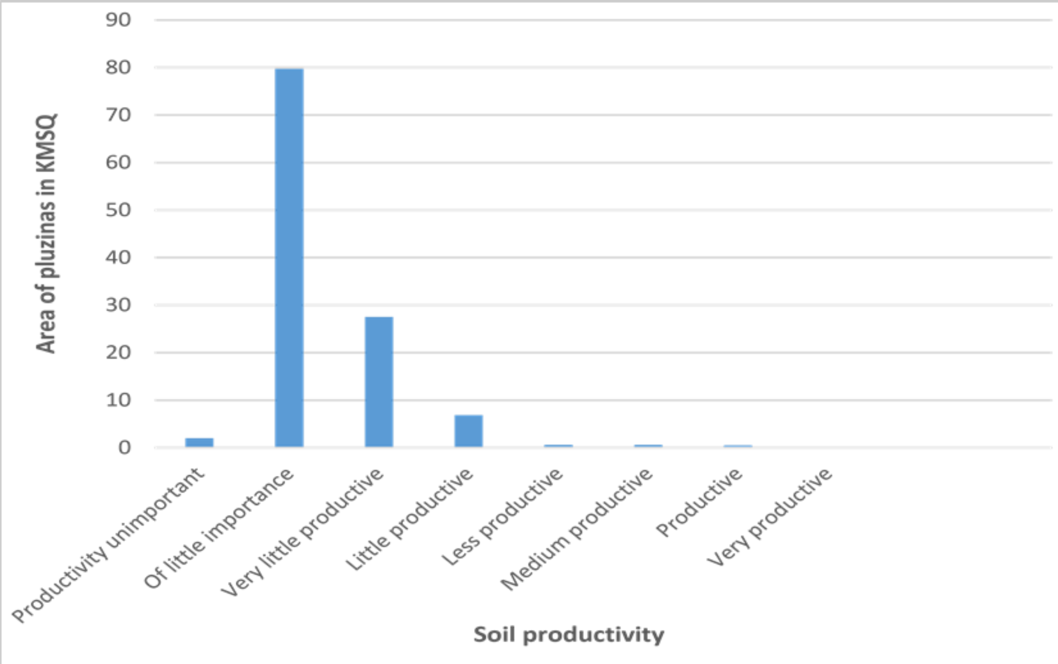


Figure 27: Graph showing area covered by pluzinas in relation to soil productivity

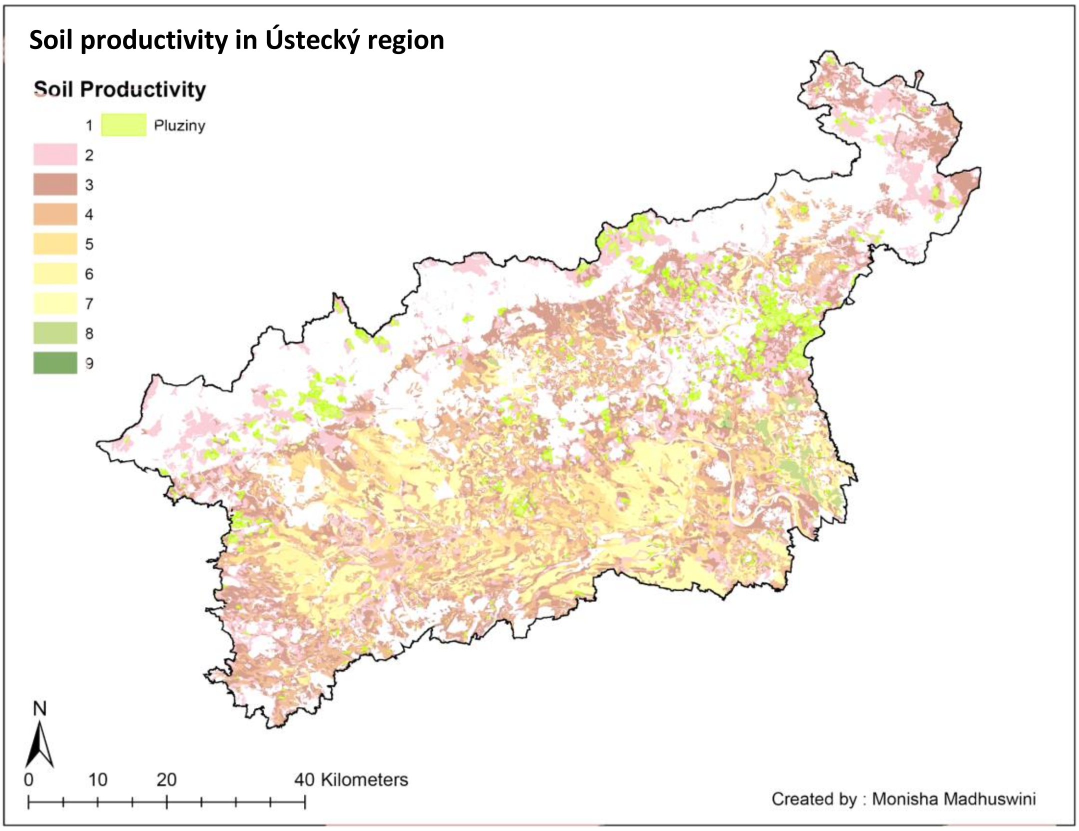


Figure 28: Soil productivity map of Ústecký region. Refer to table 3 for codes.

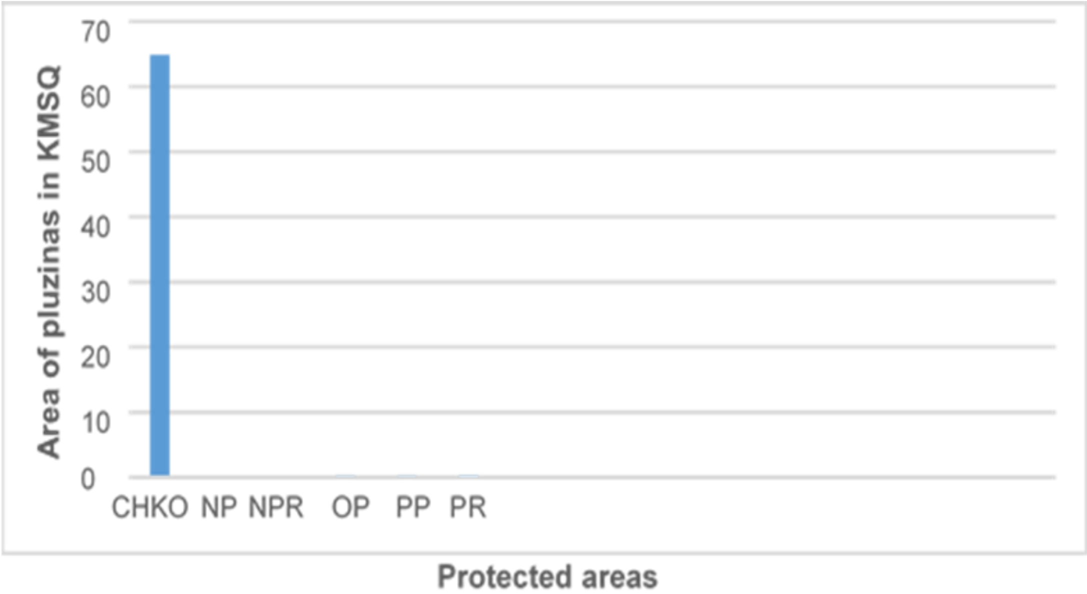


Figure 29: Graph showing area of pluzina in relation to protected areas (CHKO - protected landscape areas)

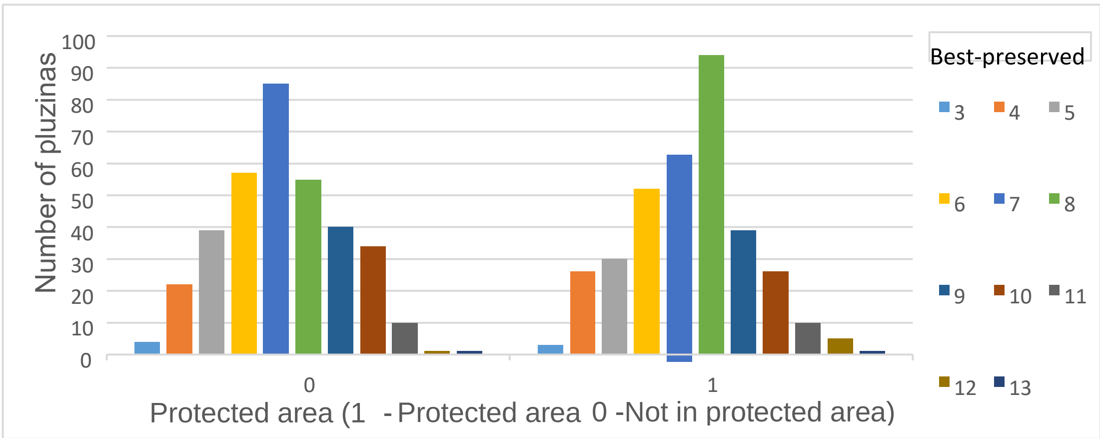


Figure 30: Graph showing the best protected pluzinas in relation to protected areas.

(3 – Best, 13 – Worst)

Note: Area factor has not been taken account specifically in this graph to determine best preserved.

These best-preserved pluzinas fall under the band of the high demand of protection after evaluating the landscape character of the Protected Landscape Area of České středohoří.

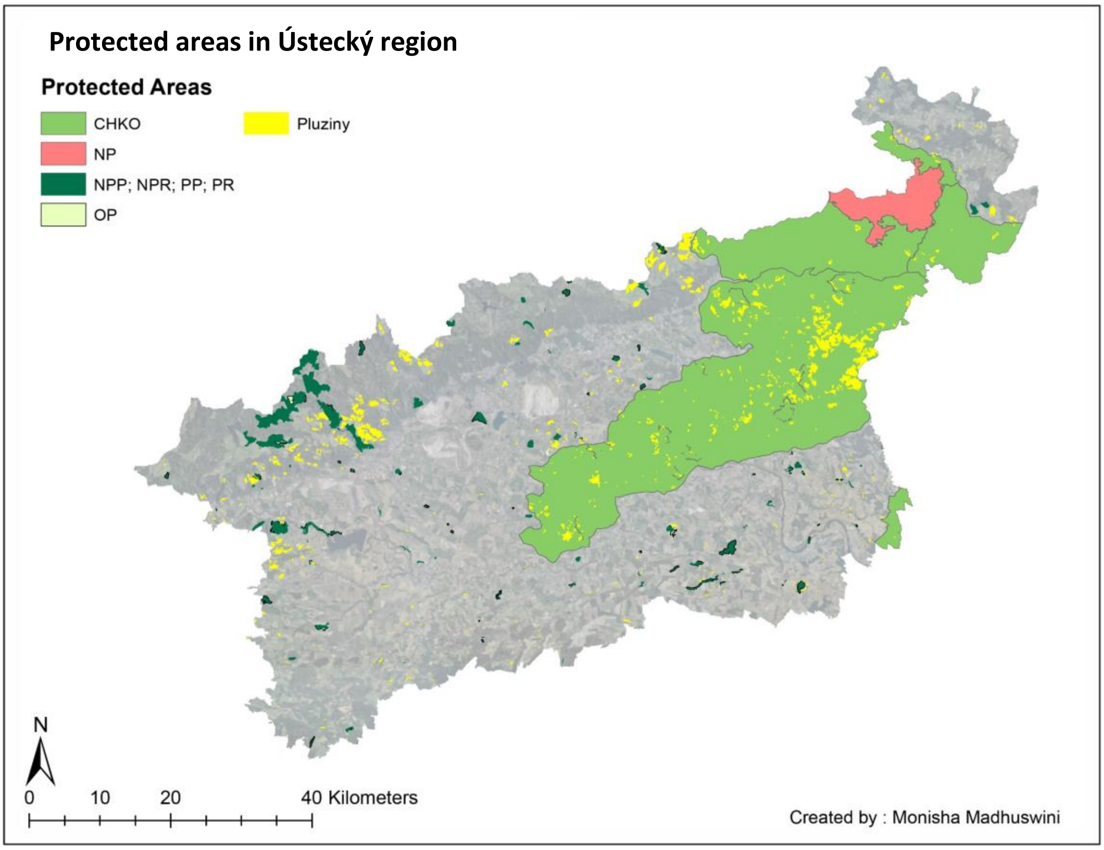


Figure 31: Protected areas in Ústecký region

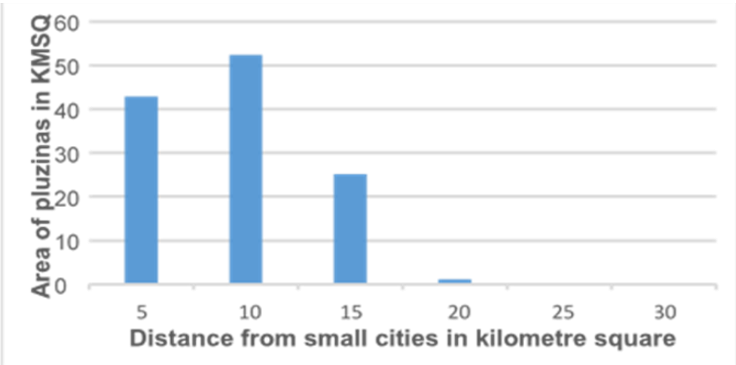


Figure 32: Graph of pluzina area in relation to distance from small cities

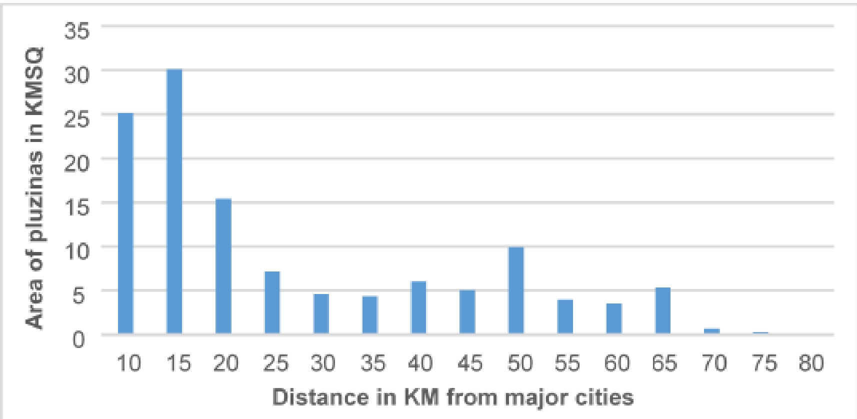


Figure 33: Graph of pluzina area in relation to distance from major cities

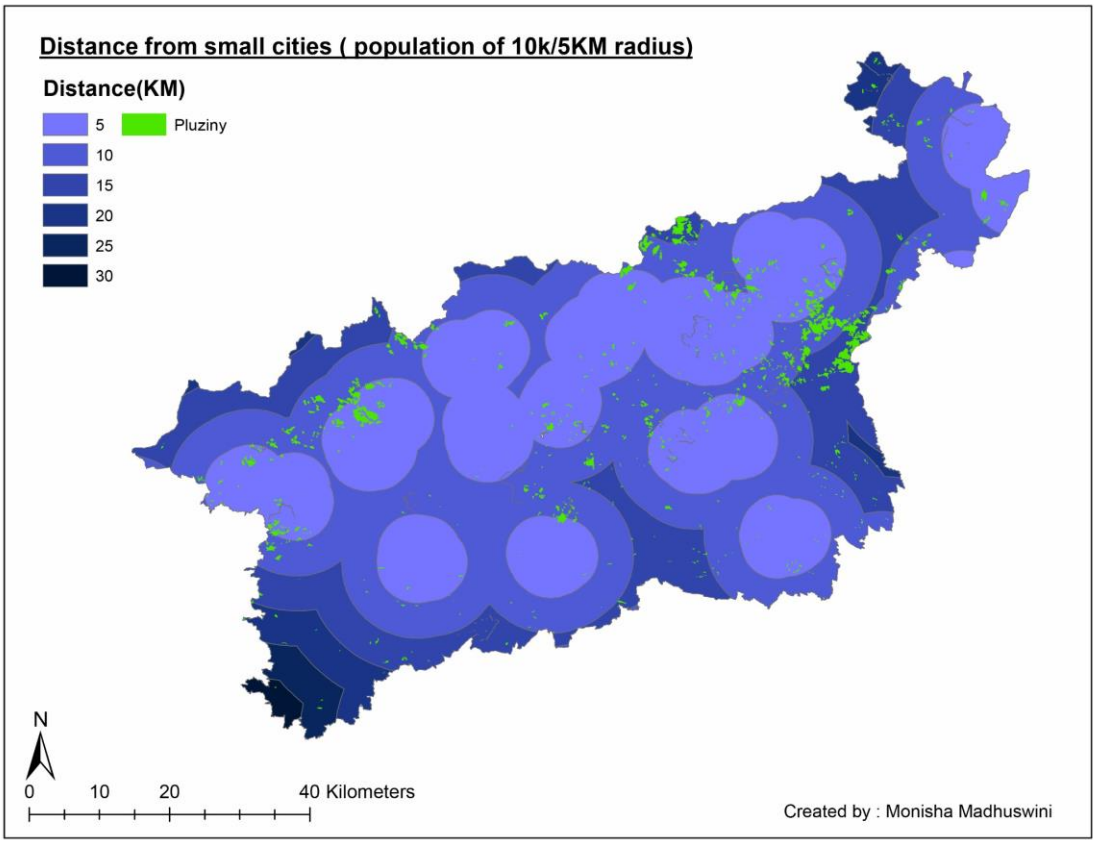


Figure 34: Location of small cities in Ústecký region with a buffer of 5km till 35km.

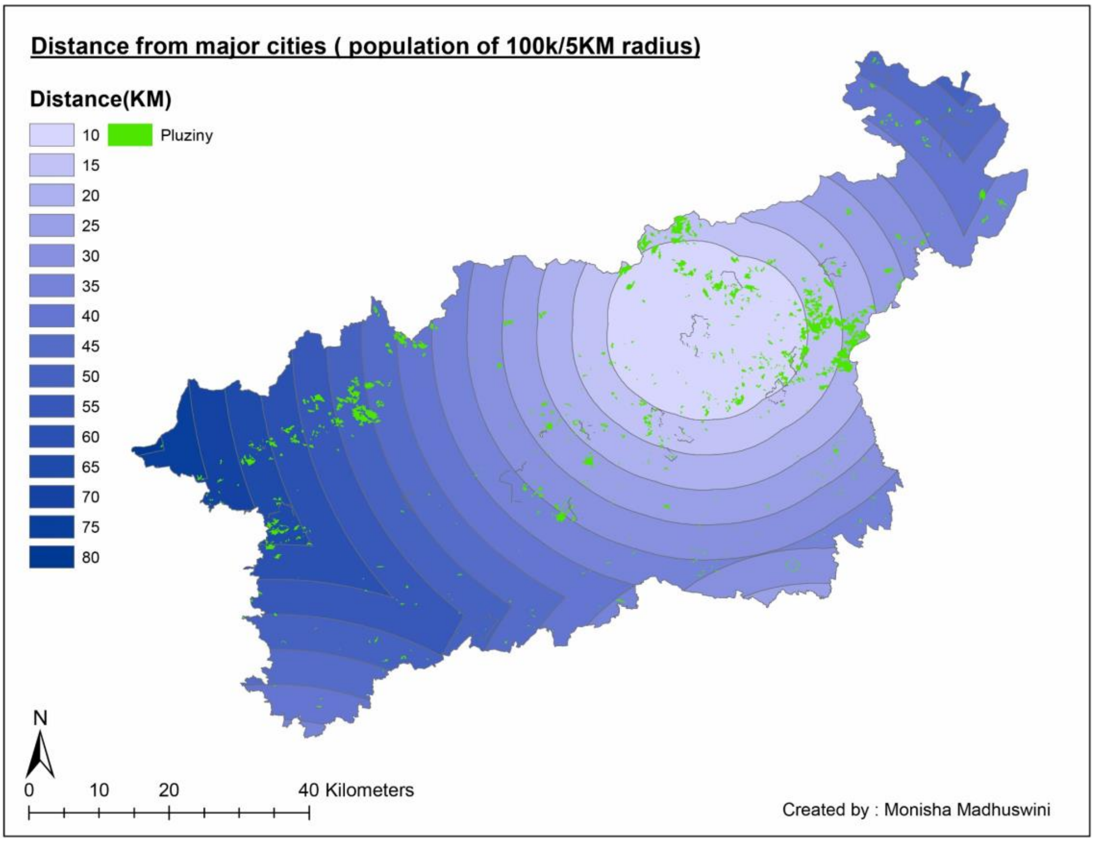


Figure 35: Location of major city Ústí nad Labem in Ústecký region with a buffer of 5km till 80km

6. Discussion

Previously many studies have been carried out on hedgerows around the Czech Republic. Along with their benefits, cultural and aesthetic values, methods to conserve them and maintain them have been analysed in many studies. However, this project takes the research on pluzinas a step further by digitizing all the visible hedgerows found in the Czech landscapes, which would help in further analysis of each individual hedgerows for future research. As local factors are essential in preserving pluzinas (Sklenicka et al., 2017), the data collected can be used to study the impact of the maintenance and preservation techniques, and the best locally suitable solution could be applied to preserve the pluzinas.

The historical origin of pluzinas was checked with the help of both cadastre maps and LIDAR images. The analysis of the physical properties of their environment further proved the medieval origin of these hedgerows. The altitude, soil conditions, slope, and location all pointed towards their medieval origin.

The results clearly show that land-use plays a significant role in the preservation of pluzinas, as described by (Sklenicka et al., 2009). The graph (Figures 12, 13, and 14) shows that majority of pluzinas are present in grasslands. During the second half of the 20th century, high demand for productivity led to the removal of hedgerows in arable land. This shows that the intensification of agriculture led to the disappearance of pluzinas. On the other hand, extensification led to the abandonment of farmlands, and that led to afforestation and gradual merging of hedgerows into the forest (Sklenicka et al., 2009). However, the two well-preserved pluzinas at Oblik and Valkeřice have only 25% grassland and 75% arable. This is visible in the graph (Figure 13 – unbroken), where integrity is the best in arable land.

The soil productivity graph (Figure 22) shows that the majority of pluzinas are located in extremely low productive soil. That means the majority of pluzinas are present in the soil that is less fertile where the physical environment is not good for farming. This matches the results of (Sklenicka et al., 2017) because tilling and removing hedgerows from an infertile land would be more expensive than removing hedges from a fertile soil that would have good crop return. (Holden et al., 2019) and (Sánchez et al., 2010) say that the soil under hedgerows can be very different from the neighbouring fields. The soils under hedgerows are beneficial for farmland for storing organic carbon, boost infiltration and preventing runoff and increasing earthworm diversity. (Sánchez et al., 2010) also mentions that hedgerows act as wind barriers, thereby decreasing the wind velocity and prevent soil erosion. Along with controlling wind erosion, hedgerows also prevent surface runoff, thereby also preventing soil erosion. Hence hedgerows play a vital role in soil conservation.

Land use and land cover impact microclimates such as soil and air temperatures. Therefore removal of hedgerows impacts the local climate. As mentioned earlier that they work as a wind barrier, which also affects the microclimate (Sánchez et al., 2010). This is proved in the results (Figure 20) where the majority of pluzinas fall under the climate category "slightly warm, humid," whereas the majority of Ústecký region falls under the climate category "warm, dry," refer to (Figure 21). This, of course, depends on the altitude and slope of the region as well.

The majority of hedgerows were found in the slight category slope (3°- 7°) and having an Omni-directional exposure (Figure 21). The second majority was found in the slope category medium slope (7°-12°) and exposure being SE-SW. The second result matches with the results of (Sklenicka et al., 2009), whereas previous studies have shown that hedgerows remained on steeper slopes and disappeared in mild to moderate slopes. The reason is that steeper slopes make it hard for the agriculture machines to move, so expansion of arable land by removal of hedgerows is of least interest (Sklenicka et al., 2009). The results also show that the majority of pluzinas are located at an altitude of 400-500 meters above sea level (Figure 19). As mentioned earlier, the settlements started to inhabit beyond 400 meters above sea level during the medieval era (Hardt, 2019).

The major city in Ústecký region is Ústí nad Labem with a population of 93000. The majority of pluzinas are located at a distance of 15 and 10 kilometres from Ústí nad Labem and at a distance of 10 kilometres from smaller cities (Figure 24 and 25). The graph shows that most pluzinas are located not that far from the cities. This is mainly because of the location of the cities. For example, Ústí nad Labem is located near the Czech-German border, where the altitudes are between 400-500 meters. This is where most pluzinas are found. Therefore the distance of pluzinas from the cities is not far. According to (Lieskovský et al., 2014) a case study in Slovakia showed that the remnants of pluzinas were found near to settlements but isolated from major cities. Therefore the connectivity of the major cities to the historical landscape plays an important role in this case.

The graph (Figure 23 and figure 24) shows that half of the pluzinas are located in a protected landscape. According to (Sklenicka et al., 2017), best-preserved pluzinas are located in protected areas. This statement is true for pluzinas in Oblik and

Valkeřice, but in (Figure 24) the graph shows that the majority of the best-preserved pluzinas are not in protected areas. However, the best-preserved is counted by adding rhythm, integrity, and hedgerows merging into each other, while the area factor has not been taken into account for the graph in this particular case. Many remaining small sections of former bigger pluzinas are well preserved even though just a fraction of the total structure remains.

Many factors are responsible for the conservation of pluzina, as mentioned above. All the factors are related to one another. The climate depends on altitude, and so does soil. Climate and soil also depend on slope and aspect, and so does the vegetation that impacts the soil. Apart from the quality of the natural conditions of a pluzina also depends on management practices, farming tools, and its historical period of emergence as that would determine its structure (Šitnerová et al., 2020). Apart from all these factors responsible for the conservation, it is highly important to understand that pluzina is not a fixed structure (Vermouzek, 1979). Unlike architectural heritage, the landscape is changing continuously, so are the hedgerows. Conserving the pluzina structures needs regular and proper maintenance. These are delicate structures that are extremely susceptible to disappearing.

6.1 Conservation of hedgerows

The ecological requirements related to hedgerow structure are strongly related to species that would benefit from it (Dondina et al., 2016). Because hedgerows act as corridors to different plant and animal species that would not exist otherwise in an agricultural landscape, a lot of focus has been given to hedgerow conservation worldwide. They are also natural artefacts (Baudry et al., 2000). However, preserving hedgerows needs a lot of effort from many bodies connected to the agricultural society. Unlike historical gardens that have a limited area to manage, cultural landscapes are widespread landscapes and are mostly changing rapidly. There is more than one owner of a landscape, and not everyone is interested in the conservation of some or the other cultural landscape feature (Baudry et al., 2000; Oreszczyn & Lane, 2000).

Nowadays, more interest is shown in the management of hedgerows. In the U.K., maintenance of hedgerows is supported by agri-environment programs and not by government bodies, for example, schemes like Environmentally Sensitive Area and countryside Stewardship. However, as the old functions of hedgerows decline, new functions take their place; it's important to be aware of the modern functions of hedgerows for the local bodies so that they can adequately manage hedgerows (Baudry et al., 2000). Hedges are an important feature in the British landscape. The significant loss since 1945 has spread awareness of their value. The total loss of British hedgerows between 1984 and 1993 was 158000 kilometre. However, this loss was due to negligence instead of the removal of hedges (McCollin, 2000).

According to (Baudry et al., 2000), Different managing bodies have different interests and different target species are taken as a priority to conserve. Hedgerow legislation of Britain states that the lengths of hedgerow that have more than 5 woody species in 30 metre length should be given priority. Many consider this as ignorance of other historical values of a hedgerow. Furthermore, pluzinas have to be analysed from a different perspective and cannot be taken as an isolated phenomenon. Their natural environment, historical significance, type of farming, types of mechanization used for agriculture should all be taken into consideration to conserving them (Vermouzek, 1979).

6.2 Role of hedgerows in soil Conservation

The word degradation is commonly used for many land conditions, for example, desertification, salinization, erosion, compaction, or invasion of foreign species (Gibbs & Salmon, 2015). Soil degradation is seen in more than a quarter to a half of the world's arable land (Bai et al., 2008). Soil degradation as a result of intensive cultivation, over ploughing with machines, livestock overgrazing, and compacting has led to the loss of soil organic carbon, reduced infiltration, and loss of soil water holding capacity. This, in turn, leads to an increase in nutrients and pesticides easily washed to groundwater and water bodies (Soane & van Ouwerkerk, 1995). These practices are also responsible for the loss of ecosystem engineers, such as earthworms and mycorrhizal fungi (Holden et al., 2019).

In the Czech Republic, the geological and soil conditions are irregular. There are a variety of geological formations and soil types, from fertile deposits in the lowlands to gravel soil in the mountains, loamy impervious soil, to sandy pervious soil (Morgan, 1933). Practicing prevention of surface runoff, erosion control, and conservation tillage are considered to be the most vital factors in decreasing the extreme effect of agriculture on the environment (Soane et al., 1995). Wind velocity increases at the top of the hedgerows, whereas it is lower at the bottom centre and completely reduced at the lower parts towards the ground facing the windward side. On the leeward side, there is absolutely no wind velocity unless for strong winds. Soil moisture is less in fields than in hedgerows; however, plant transpiration is greater in hedgerows because of the wind. Similarly, snow lasts longer in hedgerows, and hence spring soil moisture could be expected (R. Forman & Baudry, 1984).

There is more soil organic carbon in hedgerows soil than in adjacent fields. In addition to that, stones in hedgerows encourage habitat for species such as lichens and mice. Infiltration of rain water in slopes is higher in when there are hedgerows as surface runoff is reduced (R. Forman & Baudry, 1984).

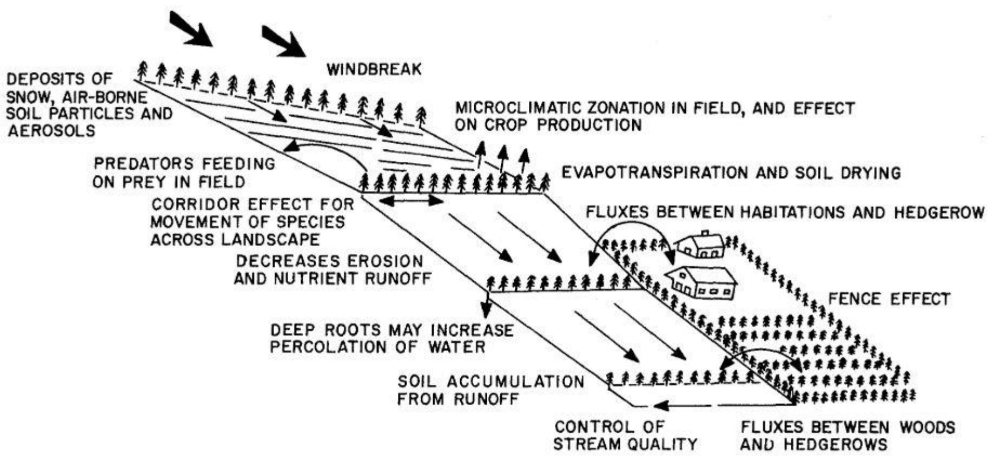


Figure 36: Summary of many major hedgerow functions. Arrows from upper left indicate predominant wind direction (R. Forman & Baudry, 1984)

6.3 Role of hedgerows in the conservation of biodiversity

Hedgerows modify the microclimate, thereby determining the species that would benefit from that environment. Hedgerows also allow habitat movement between fields and hedgerows; therefore, it, directly and indirectly, affects the organisms in the adjacent fields (R. Forman & Baudry, 1984). Land-use and climate change jointly impact the loss of biodiversity. Biodiversity is said to be a necessity for the operation of ecosystems and its services (Frélichová & Fanta, 2015). Although land- scape-scale studies are common, the single hedgerow approach works towards defining the best vegetation composition for different groups of species. However, this method has some flaws as no single hedgerow can accommodate all the local species of a particular group, e.g., plants, birds, or insects. Many authors believe that dense hedgerow are an efficient passage for forest species movement. Biodiversity, therefore, must be evaluated at the land-scape scale not only because of the diversity of hedgerows but also because of processes involved in the landscape- scale (Baudry et al., 2000). Open fields without hedgerows make it difficult for different species to cross from one forest to another. Patchy vegetation or fragmented forests encourage low species richness and are a threat to biodiversity loss. Hedgerows act as a corridor and connect the landscapes (Bailey et al., 2010). However, connectivity of pluzinas should not be considered a priority while conserving as they do not show a high level of connectivity. The connectivity is not extremely important, as in the case of English hedgerows. Similarly, it is not recommended for pluzinas to have greater width as that might end up merging two parallel hedgerows thereby losing the pattern of the original pluzina (Molnárová, 2008).

6.4 Aesthetic values of hedgerows

Finally, many perceive hedgerows as aesthetically pleasing features in the agricultural landscape. (R. T. T. Forman & Baudry, 1984). Agriculture supplies with these services as some farmers preserve field hedgerows or enhance the aesthetics of landscape by planting them (Sandhu et al., 2008). Hedgerows add rhythm to the landscape as they are equally spaced. They also provide texture and a sense of mystery to the landscape. The enclosed space formed by hedgerows creates a sense of refuge. These characteristics make pluzinas high in aesthetic value. (Molnárová, 2008). Apart from satisfying visionary sense, hedgerows with all the habitat species of flora and fauna also stimulate the sense of smell, taste, and hearing. All these senses and their memories could create an immense bond between the locals and the hedgerows as their cultural landscape.

7. Conclusion

The 607 pluzinas digitized with a total area of 121.5 square kilometres have shown properties similar to the ones found in other researches. Most of them are found in grassland. The location of the Ústecký region matches all the characteristics favourable for the remnants of pluzinas to be found in an agricultural landscape. Ústecký being on the border of the Czech Republic, has favourable altitude and soil conditions which have still protected the pluzinas from disappearing.

After comparing hedgerows from other parts of the world with pluzinas, it was clear that different patterns of hedgerows require a different form of management. Hedgerows, though, have many common benefits to provide, but some have different roles to play, and not all hedgerows can provide all of them. This doesn't make any hedgerows unfit for conservation. After all, hedgerows have many different roles in an agricultural landscape.

The digitization and analysis of each of the 607 hedgerows belonging to 338 municipalities of the Ústecký region have opened new opportunities for further research. As mentioned earlier, hedgerows act differently in different environments. Local research on each pluzina structure could benefit the locals, local plants, and animal species and benefit the environment. The economic benefits of the farmers should also be considered while making policies for hedgerow management.

With the help of GIS, many other different maps could be overlapped to the pluzina database to extract data about each pluzinas. This way, it could be easier to manage pluzinas locally by making individual management decisions and policies based on the physical and morphological properties of the pluzinas. Identifying historical and cultural landscape heritage is the first step in their conservation. Hence, it could be said that this database of pluzinas from 14 different regions is the first step of conservation that would prevent them from disappearing.

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