UNIVERSITY OF LIFE SCIENCES PRAGUE
FACULTY OF ENVIRONMENTAL SCIENCES
DEPARTMENT OF APPLIED ECOLOGY


# MONITORING CHANGES IN THE DEVELOPMENT OF NON--FOREST WOODY VEGETATION AT THE LANDSCAPE LEVEL

DIPLOMA THESIS

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# ČESKÁ ZEMĚDĚLSKÁ UNIVERZITA V PRAZE

Fakulta životního prostředí

# ZADÁNÍ DIPLOMOVÉ PRÁCE

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Zemědělská specializace
Krajinné a pozemkové úpravy

Název práce

**Sledování změny ve vývoji mimolesních dřevěných porostu na úrovní krajiny**

Název anglicky

**Monitoring changes in the development of non-forest stands at the landscape level**

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**Cíle práce**

Hlavním cílem práce je analýza a hodnocení změn mimolesních dřevěných porostu na úrovní krajiny na základě porovnání leteckých snímku z 50. letech a současné ortofoto mapy ČR.

**Metodika**

Území: bývalé historické Pardubické panství, vymezeno hranicemi povodí.

Podklady: historické letecké snímky z 50. letech 20. století, současná ortofoto mapa ČR.

Provedené analýzy: Analýza a hodnocení budou zpracovávání v program ArcMap a Excel.

**Doporučený rozsah práce**

cca 40-50 stran plus přílohy

**Klíčová slova**

mimolesní dřeviny, Pardubické panství, GIS, ortofoto, historické letecké snímky, ArcMap

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**Doporučené zdroje informací**


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doc. Ing. Jan Skaloš, Ph.D.

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Elektronicky schváleno dne 29. 3. 2022

**prof. RNDr. Vladimír Bejček, CSc.**

Děkan

V Praze dne 30. 03. 2022

**Declaration**

I declare that I have worked on my diploma thesis "*Monitoring changes in the development of non-forest stands at the landscape level*" by myself with a help of my supervisor doc. Ing. Jan Skaloš, Ph.D. and I have used only the sources mentioned at the end of the thesis, and that the thesis does not break copyrights of any their person.

I also declare that the printed version completely matches with the version assigned in University Information System (UIS).

In Prague, 08.12.2021 _____

**Acknowledgment**

I would like to thank my supervisor doc. Ing. Jan Skaloš, Ph.D. for the best leading of diploma thesis, professional advising, and patience when it was needed the most. Then to Ing. Vít Toman for his helpfulness, willingness, providing essential information and comments in the processing of this work and to Ing. Aleš Pachman, for leading me to the idea of the topic and giving me a guideline to the easiest path for its writing.

The last, but not the least, my parents for always believing in me, and my friends for not letting me give up in the hardest moments.

# Monitoring changes in the development of the non-forest stands at the landscape level


## Abstract

Thesis is dealing with issues of Land Use changes on the landscape level which are concept of the changes, connotation, protection, and renewal of the landscape. The focus is on non-forest woody vegetation, its significance, historical development, and changes during development.

Chosen territory is localized in the Northern-Eastern part of Czech Republic, Pardubice, and Hradec Králové region.

All the changes in Land Use development were analyzed and compared in the geographical information system (GIS) application ArcMap based on stabile cadaster maps (Franciscan cadaster), aerial photographs from 1953, and orthophoto maps from 2020.



**Keywords**: non-forest woody vegetation, historical aerial photography, ArcMap

# Sledování změny ve vývoji mimolesních dřevěných porostu na úrovní krajiny


## Abstrakt

Diplomová práce se zabývá problematikou využiti území na úrovní krajinný, včetně její změny, konotaci, ochrany a obnovy. Hlavní fokus je na mimolesní dřeviny, význam, historický rozvoj a změny během rozvoje.

Zájmové území se nachází v severovýchodní části České republiky, v Pardubickém v Královehradeckém kraji.

Analýzy všech změn v krajině byly zpracovávaný v softwaru geografických informačnách systému (GIS) ArcMap na zakladě map stabilního katastru (františkovský katastr), leteckých snímků z 1953 roku, a současny ortofoto mapy z roku 2020.



**Klíčová slova:** mimolesní dřeviny, historické letecké mapy, ArcMap

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# List of the abbreviations used in the thesis

CENIA – Česká informační agentura životního prostředí
ČSÚ – Český statistický úřad
ČÚZK – Český úřad zeměměřický a katastrální
DIBAVOD – Digitální báze vodohospodářských dat
ELC – The European Landscape Convention
GIS – Geographical informational systém
ÚSES – Územní systém ekologické stability
VÚMOP – Výzkumný ústav meliorací a ochrany půdy, v.v.i
VÚV TGM - Výzkumný ústav vodohospodářský T. G. Masaryka
WMS – Web Map Services

# 1 Introduction

The current state of forests is the result of cultural, economic, and political developments. Forest management no longer originated in the environment of natural forests, but in an area long influenced by logging and animal grazing (Vacek, 2006). Forest management is based on the complex aspect of the forest as a multipurpose function. Forest is not just a source of wood. It fulfills several other important functions for human society, such as climatic, soil protection, hydric, water management, recreational, health, hygienic, aesthetic, and other functions (Mráček and Krečmer, 1975).

The current This study is part of the research of forest development in the Czech Republic based on which it focuses on obtaining information on detailed trajectories of changes and non-forest wood vegetation at the landscape level. With a help of geographical informational system (GIS), monitor changes and evaluate their consequences and impact on the landscape.

# 2 Aims of the Thesis

The aim of thesis is to analyze changes and development of non-forest woody vegetation in different period, starting from 1843 with stabile cadaster maps, continuing with aerial photographs from 1950s and ending with current orthophoto maps from 2020 in Pardubice and Hradec Králové region.

During the development are followed basic parameters of the landscape as an area of the non-forest woody vegetation, also as a decrease, maintaining and increase of new stands represented in percent (%).

All the results are represented in form of described maps and tables.

# 3 Literature Review

## 3.1 Landscape

With several definitions and different oriented concepts of the landscape, it opens many approaches of defining it as much precisely as possible. The most popular are based on the legal, geographical, demographical, historical, ecological as much as artistic and emotional (Sklenička, 2003). It is a heterogeneous area of the Earth's surface made of unity of many similar interacting ecosystems repeating (Forman et al. 1986), „*overall area character*" (von Humboldt, 1805), therefore, none of the approaches or observations can't be final and exhaustive (Kupka 2010).

The most important and common point from all definitions is that the landscape is a part of the certain Earth's surface, and it is characterized by external observation with many different components of flora and fauna, and socio-economical elements. Together they create mutual relations and their unity (Kríštek et al. 2002).

From the legal side, landscape is defined by §3, paragraph 1, part k) from the Act number 114/1992 Coll., Czech national council act about nature and landscape protection where landscape is a part of the Earth's surface with relief characteristics made of unity of ecosystems and elements of demography.

### 3.1.1 Landscape changes

With an interaction between nature and man's action, landscape has always been changing. From nowadays, these changes are more chaotic as humanity is trying to control it with planned actions. In most cases, these actions don't end up as planned because nature's factor is rarely considered (Antrop, 2008).

Like globally, also in the Czech Republic Land Use and land cover structure have been changing and still changes a lot, especially after the territory of the whole country was surveyed for the first time in period from 1825-1842 period, totaling approximately 13000 cadastral units (Bičík et al. 2015). New forms of land management and spatial planning on the beginning of 90s of the 20$^{th}$ century had a big impact on landscape development, and accelerated infrastructure and industrial development brought more negative impacts on the landscape (Sklenička, 2003).

Based on what Vráblíková (2014) said, the biggest impact on the landscape quality and structure is market economy, which has significant impact on state parcels privatization and property restitution.

With the first villas in the suburb on the beginning of the 20th century, Czechoslovakia started with a trend of suburbanization, as many socialistic countries around the Europe (Perlín, 2002). Today, suburbanization has significant environmental impacts as continuously use of agricultural land, landscape fragmentation and consummation and enormous amount of energy needed to build new infrastructure (Ouředníček, 2013). With a new infrastructure, animal movements and plants spreading is being reduced, which leads to biodiversity decreasing. Hydrological conditions are also being changed as floods and droughts are more frequent than ever, and big cities become „*urban heat islands*" (Štych et al., 2016).

Landscape changes are not common just for suburb, but also for the countryside. After the collectivization under the communist regime, traditional mosaiced land structures were experiencing complete change and have been merged into large blocks. Like that, agricultural land has been exploited and used for industrial-agricultural type of production on the highest possible level. As a result, ecological stability and biological diversity has been endangered and water outflow was faster than ever. Human activity in rural areas were decreasing, most of them have been abandonment and followed with controlled or spontaneous afforestation (Štych et al., 2016).

Ecological picture was slightly changing from 1990 and experiencing a big transition in 2000s in a term of awareness of the importance of the environmental politics. The whole system done a turnover, and a lot of money has been invested in recultivation, grasslands restoration, as well as agricultural rural areas. The percentage of area of arable land in the whole country was now decreasing, and percentage of the grasslands and forests area were increasing (Štych et al., 2016).

### 3.1.2 Landscape protection

Act number 114/1992 Sb. about nature and landscape protection defines it as a „*Special care of state and individuals for the flora and fauna and their communities, minerals, rocks, paleontological findings, geological units, care about ecological systems and landscape units, as well as care about the appearance and accessibility*

*of the landscape.*", and shows us that nature and landscape species protraction is impossible without habitats protection, more precisely environment, as much as nature protection is impossible without protecting a landscape (Lipský, 2003).

Modern landscape protection wouldn't be possible without landscape values, divided in three categories. The most important is the traditional landscape and nature protection values in reservations and national parks, as well as protected landscape areas and biosphere reserves. For landscape with a strong aesthetical values protection, nature protection authority established nature parks which protects a different type of cultural landscape (Lipský, 2003).

Landscape protection on the European Union level is defined by The European Landscape Convention (ELC), and the landscape in Europe is considered as valuable part of natural, historical, and cultural heritage. ELC also defines landscape politics, landscape care and landscape planning, but not fully embedded in legislation of the Czech Republic. Upon signing this convention, countries who signed it (Czech Republic included from 30.10.2002), are obligated to insure and realize measures for cultural landscape protection (Lipský, 2003).

## 3.2 Woody vegetation

Woody vegetation are perennial plants, whose woody steam has secondary thickening ability. Its vegetation period lasts at least two years, in most of the cases tens to thousands of years (Špinlerová, 2014). According to the appearance, woody vegetation is divided into trees, shrubs, small shrubs, subshrubs, cushion-shaped and carpet-shaped woody vegetation, and also woody vines. (Musil, 2003).

### 3.2.1 Forest woody vegetation

Based on the official documents as an Act number 289/1995 Coll., §2, about forest and about some law's changes (Forest Act) as amended, forest is defined as a forest stands withing forest environment and a territory determined to fill full forest functionality, while forest stands stand for a trees and shrubs of the forest woods, which are fill fulling forest functionality with exact conditions. Territory determined to fill full forest functionality are defined by §3, Forest Act:

*„a) parcels with forest stands and areas, where forest stands were removed for the restoration reason, forest intersections and unconsolidated forest paths, with a*

*condition to not being wider than 4m, and areas where forest stands were temporary removed based on the decision of state forest administration.*

*b) consolidated forest paths, small water areas, other land areas, areas above the upper limit of woody vegetation, built-up areas with arrival communications, forest pastures for wild animals, unless they are a part of an agricultural land fund and if they are related or serves to forest industry purpose.".*

When it comes to forest definition from scientific angle, forests are valued and defined differently depends on the eye of the beholder. It can be seen as a source, ecosystem unity or as a home for indigenous people. We can also assume term forest from a Land Use and land cover perspective. Land Uses are considered as a landholding that are designed as a forest, despite its current vegetation. On the other hand, land cover is observed as an ecosystem or unique groups of plants and animals (Chazdon et al., 2016).

### 3.2.2 Forest development through history

It is known that forests are present in Europe several thousand years. The very first information about forests in the Czech Republic are wood and charcoal finds from Paleolithic period (Early Stone Age), with glaciers as far as the northern border mountains (Nožička, 1957). During the Mesolithic period, 8000 years ago, the Czech Republic territory was present primeval forest (Vašíček and Oliva, 2017), and forests are consisted mostly of willow, pine, and birch (Nožička, 1957). Oaks, lindens, elms, hazelnuts, and maples started began to appear a bit later (6800-5500 BC) (Uhlířová et al., 2004). Post-glacial period also represents period of forest development and the first human influence on the forests with slow migrations (Nožička, 1957). Early Stone Age, Neolith, is remembered as period when agriculture started to develop, areas of pasture grown, but forests in populated areas began to reduce. Forests were mostly composed of beech and fir and expanded fast in a period from Neolith to the Iron Age. With beginning of the Iron Age, the population was fast increasing, and a need for wood has been bigger than ever (Nožička, 1957). Need for woods increased even more after migration of Celts to Europe on the beginning on new millennium. It was mostly used for building up purposes (Němec et al., 2009). In Roman Empire when migrations were enormously big, steppe took place instead of forests, and forests were present just on the borders. With a German colonization, deforestation has been continued, and

that leaded to further deforestation (Hrabák and Poruba, 2005). With a fast development and wars, mass forest consummation was continued. In the end of the 17th century forest were practically destroyed. With a bad threatening of the forest came soil degradation and everything was leading to the ecological catastrophe (Nožička, 1957).

### 3.2.3 Forest development from 18th century to the present

On the beginning of the 18th century, right before the beginning of the First Industrial Revolution, Hapsburg Monarchy began to show a lack of wood needed as for the construction, also as a fuel for the development of metallurgical, glass and other industrial branch and development of handicrafts (Rakušan, 2017). Another big pressure on the forest was in the second half of 18th century with a population increase, and forest transformation into fields and meadows (Lenoch, 2004). For that reason, the government with an order of the emperor Maria Theresa, issued forest regulations for Bohemia, Moravia and Silesia, 5th of May 1754. These regulations have been issued to prevent deforestation and destruction of forest and to contribute to better management of forest. The owner of certain forest area was also obligated to take care of reforestation in case of deforestation. This year in the history of the Czech forests is marked as the important one, as the state stated to pursue its interest in the forest management (Nožička, 1972). By the end of the 18th century, the range of the forest was the lowest in history. For that reason, from 1798 the government began to prepare the reform of forest regulations. The first Forest Act No. 250/1852 Coll. was declared the 3rd of December 1852, and it was valid on the territory on the entire monarchy. In Czech Republic was valid until 1960 (Nožička, 1972).

After the first Forest Act was declared, forest authorities were set up which were independent from other government sectors. The owner of the forest parcel or forest had been obligated to employ permanent workers, which brought positive impact on quality improvement on forestry work quality. The biggest positive impact for forestry was rise in coal mining. Forestry could focus more on cultivation of construction wood and reforestation (Nožička, 1972), with a grown of coniferous forests, declining mixed and almost disappearing of deciduous forests (Lenoch, 2004). The era of reforestation didn't last long. Right after the end of The First World War, its demand is growing as the consequence of the war, which was one of the reasons for

government to declare an Act number 82/1918 about forest protection. Economic crisis has been stronger every day, which led to slowing down of forest industry and reproduction (Lenoch, 2004). With end of The Second World War and socialism expansion and creates the idea of joining agricultural land of individuals into the wholeness to fulfill the needs of the state well known as a collectivism. This type of the land restauration and complete change of agricultural system in was popular among all socialistic countries, with the biggest consequences in Czechoslovakia and almost destroyed soil fund. That brought a landscape to the destabilization (Lipský, 1999). Year 1989 was crucial for the forest industry as it came to the system change. From 1st of January 1992, started to exist state enterprise Forests of Czech Republic (Lesy České republiky), which was responsible for everything connected to the forests including restitution of private forest property and issuing property to municipalities and forest cooperatives (Salašová et al., 2014).

State agricultural politics against farming on national lever has been drastically changed. The main goal was to reduce arable and increase woody vegetation and grasslands and prevent additional land destruction. For that reason, agricultural grassing is still present in Czech agriculture in revitalization of abandoned and unused (Lipský, 2005).

### 3.2.4 Non-forest woody vegetation

Based on Nature and Landscape Protection Act number 114/1992 Coll., §3, non-forest woody vegetation refers to trees or shrubs growing in groups or individually in the open countryside and in settlements in the territory outside the forest. Elements of non-forest vegetation are often a part of the territorial system of ecological stability (Územní systém ekologické stability - ÚSES).

As a green element of the agricultural landscape, non-forest vegetation represents an important part of the landscape in the countryside, gives the effect of the better visual landscape quality and their character and structure (Tóth et al., 2016).
Also known as a scattered vegetation, represents woody vegetation without having a forest vegetation function (Sklenička, 2003). There are three ways of its forming. First of them is the retreat of forest, when scattered vegetation are remnants of the woody vegetation. The second way is spontaneous spread of forest vegetation outside of forest

areas, and the last one is conscious human vegetation spread by planting or sowing (Sklenička, 2003).

Scattered vegetation can be divided into linear, planar, and solitary elements, depending on the shape. The linear shape is characterized by dominant length over width. (Sklenička, 2003). The most important linear elements are alleys, usually made of formed from domestic deciduous trees as a linden, maple, oak, also as beech, birch and sorbus (Semorádová, 1998). Planar elements are not linear, the upper limit for their width is 3 ha, and have low production potential. Solitary elements are usually individual trees, or small isolated group of trees (Sklenička, 2003).

### 3.2.5 Non-forest woody vegetation development through history

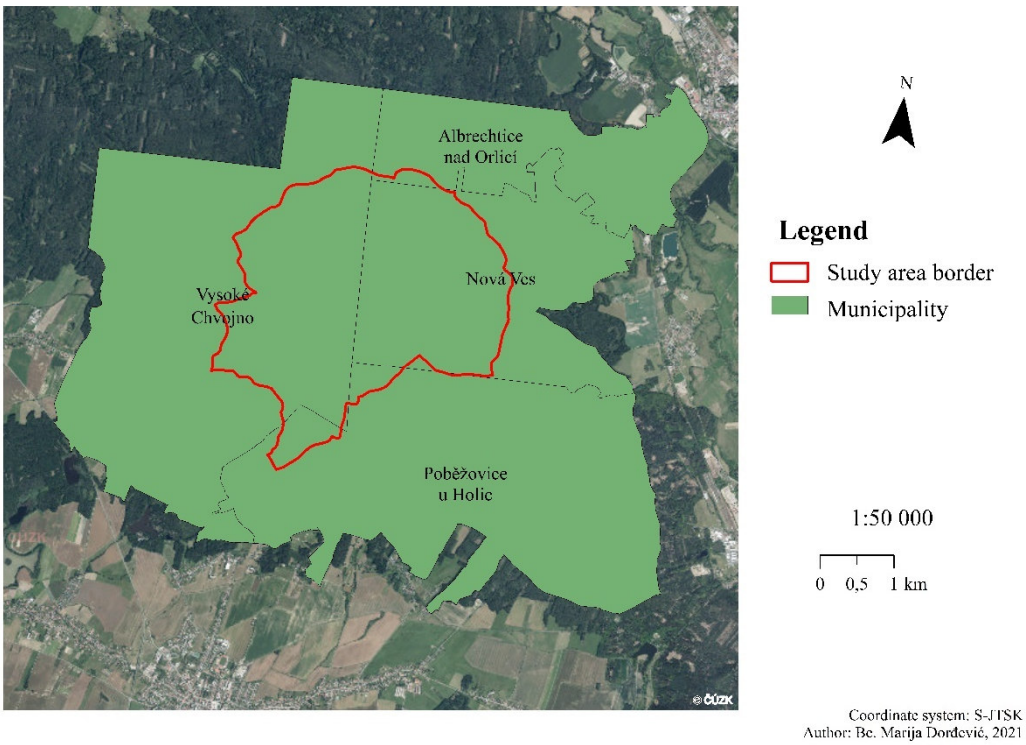
The really first notes about non-forest vegetation, mainly by the roads, originate from the Middle Ages when the nobility moved from their strategically located castles to more comfortable castles environment. During the Renaissance, with the castle building, began to appear gardens as a part of the castle (Šulcová, 2013). In the Baroque period, during the Maria Theresa's rule, was supported the development of scattered greenery, by whom in 1752 was issued an order to plant trees along all new roads. The reason was economical, aesthetic and safety. Later, her son Joseph II made as obligation to plant trees at schools and major imperial roads, today known as alleys (Vysloužil, 2007). Alley's expansion lasts until first half of the 20$^{th}$ century, when in 1950s slowly start to disappear due to collectivization. In 1970s comes to remove of thousands of hectares of non-woody vegetation to increase the acreage of land, to experience a total collapse in the late 1980s and be nearly destroyed (Šulcová, 2013). The situation changes drastically after the fall of communism, so it can be said, that today there is more non-woody vegetation, than before collectivization (Kyselka, 2001).

# 4 Natural characteristics of chosen area

Chosen area is localized in the North-Eastern part of Czech Republic, approximately 20 km south-east from Pardubice, and 20 km north-east from Hradec Králové (ČÚZK, 2020), in valley of stream Novoveský, a tributary of Orlice and Elbe rivers (VÚV TGM, 2020).

## 4.1 Chosen area localization

It is divided in two regions, Pardubice, and Hradec Králové, and four municipalities, Albrechtice nad Orlicí, Nová Ves u Albrechtic, Poběžovice u Holic and Vysoké Chvojno (Picture no. 1) (ČÚZK, 2020). Total area of the chosen territory is 1018 ha, and it represents one of the drain basins of the 4$^{th}$ level in Czech Republic (DIBAVOD, 2021).




*Picture no. 1: Localization of a study area in Czech Republic (source: ČÚZK, 2020).*

### 4.1.1 Historical development of the chosen area

The first mention of Pardubice region comes from about 6000-7000 years ago with Celts as the very first settled nation. After a long break in the settlement, came Slavs in the 7$^{th}$ to 8$^{th}$ century. Ancestors left many valuable traces in the region in the form of the remains of Celtic oppida, as well as numerous temples and fortresses. The

most known historical architectural monuments are in the north part of Pardubice region, and they are related to Moravian family of lords from Pernštejn, castle Litice nad Orlicí from the 13th century and Kunětická hora from the second half of the 14th century (Místopisný průvodce po České Republice, 2021). Pardubice region today is one of the most developed parts of the Czech Republic and yet it has managed to preserve its natural beauty and wealth (Místopisný průvodce po České Republice, 2021).

The same as Pardubice region, Hradec Králové region has been an important settlement area since prehistoric times, in which members of various prehistoric cultures gradually took turns. Settlements were concentrated in the Elbe basin and other rivers. From 10th region starts to be important part of Czech history as it officially began to exist as a region. The region developed fast, so in 15th century it has been an important center of the Hussite revolution from 1423 – 1424. Hradec Králové region existed as an administrative until the end of the regional establishment in 1860 – 1862. The capital of the region is Hradec Králové from early 16th century, and it became the second most important city after Prague between 18th and 19th century. After the renewal of the regional establishment in 2000, Hradec changes name to Hradec Králové region and holds it until today (Mapový portál Královéhradeckého kraje, 2021).

### 4.1.2 Chosen are today

Beside the chosen is situated between two regions mentioned in the chapter 4.1.1, it is also covered with area of four municipalities (ČÚZK, 2020). Albrechtice nad Orlicí is located at the confluence of the rivers Tichá Orlice a Divoké Orlice, and together form river Orlice (VÚV TGM, 2020). The total cadastral area of the village is 523 ha big, and by 1.1.2020 counts 978 inhabitants (ČSÚ, 2021). Nová Ves u Albrechtic is municipality which occupies the east side of the chosen area with 842 ha in total (ČÚZK, 2020). As the least inhabited from four municipalities, it counts 215 inhabitants (ČSÚ, 2021). South part of the chosen occupies Poběžovice u Holic, as the biggest municipality with 1342 ha (ČÚZK, 2020), and counts 271 inhabitants (ČSÚ, 2021). At the present, the municipality of Vysoké Chvojno has 424 inhabitants as of 1 January 2020 (ČSÚ, 2021). It is situated on west part of the chosen are with 1703 ha in total (ČÚZK, 2020).

## 4.2 Natural conditions

### 4.2.1 Pedology

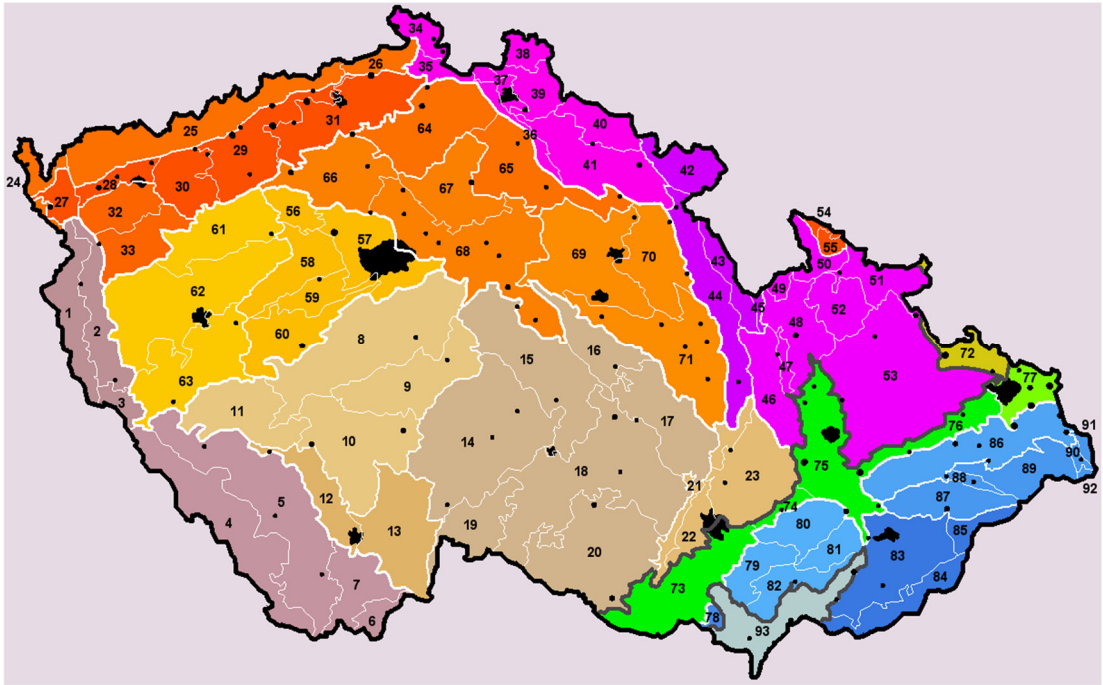
From pedological side, based on CENIA (2020), the most present soils are cambisols (kambizem), gleysols (glej) and regosols (regozem) (VÚMOP, 2021). Cambisol is the most widespread soil type in the Czech Republic. Because of its brown color, formerly was called brown (forest) soil. It has medium and fine texture, derived from the wide range of rocks. As it makes good agricultural land, intensity of use in agriculture is big. As the second most present soil type, gleysols is mostly present in wetlands, due long-term action of groundwaters situated not deep under the surface and surface water coming from springs from the slope. The last type of soil that occurs more significantly in the area is regosol. As a poor developed soil, is formed by humification is mineral-poor unconsolidated sediment composed from sand (Němeček et al. 2001).

### 4.2.2 Geology

From the geological side, the whole studied area is localized in sedimental region. Sediments are the most widespread rock on the earth. However, they contribute minimally to the construction of the earth's surface. Sediments in this area are composed from calcareous claystone and marlstone. As both of included sediments are calcareous origin, it means both are mostly or partly composed of calcium carbonate, to be precise lime or chalk. Claystone contains between 5-25 % $CaCO_3$ (Hruška, 1998).

### 4.2.3 Geomorphology

While Europe is divided in five geomorphological areas, Czech Republic is a part of two: Alpine-Himalayan and Hercynian region, as the geomorphological units of the European first order and first level of the geomorphological system in Czech Republic. Geomorphological system of the second level is subdivision into lower geomorphological units, and Czech Republic counts four: Hercynian Forest, European Plain, Pannonian Plain and Carpathian Plain. In total, Czech Republic has seven sub-division levels (Picture no. 2) (Czudek et al.kol., 1972).



*Picture no. 2: Czech Republic geomorphological division map of 3rd division level colored and 4th division level numbered (source: Wikipedia https://cs.wikipedia.org/wiki/Seznam_geomorfologick%C3%BDch_celk%C5%AF_v_%C4%8Cesku, 2021)*

The most important area of the subdivision of the 4th level for the studied is Orlická plate, where study is situated.

#### 4.2.3.1 Hercynian or Variscan orogenic belt

The west part of geomorphological unit of Czech Republic is under the Variscan orogeny (Hercynian) belt, as the result of the crush of Africa with Baltic with microplates in between in early Paleozoic time (Franke, 1989). It extends in western Europe for more than 3000 km from Portugal, Ireland, and England in the west through Spain, France (Brittany, Massif Central, Vosges and Corsica), and Germany (Black Forest, Harz) to the Czech Republic in the Bohemian Massif (Franke et al., 2020). Contains many rocks and structures that indicate that its formation was a result of seafloor spreading, subduction of oceanic crust, and plate collision (Britannica, 2016). It has a sinuous outcrop caused by collisional indentation of one block into another (Selley, 2005).

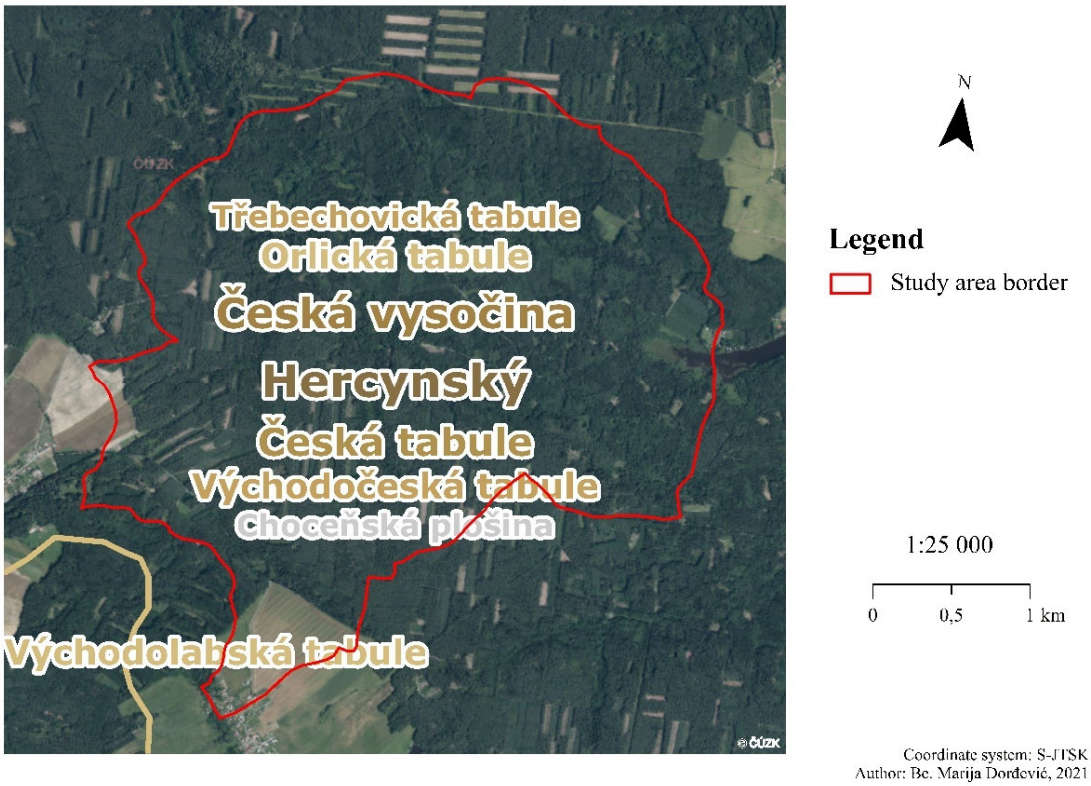
#### 4.2.3.2 Alpine-Himalayan orogenic belt

Other geomorphological area of Czech Republic is reserved for Alpine-Himalayan orogenic belt, young orogen (Lister, 2002), stretching over a distance more than 16000 km across Eurasia from the western Mediterranean to the western Pacific, specifically from Spain to New Zealand (Sharkov, et al., 2015).

#### 4.2.3.3 Orlická plate

By Demek (2006), Orlická plate is geomorphological unit lying on the siltstones, claystones and spongilites of the upper cretaceous, with Pleistocene River and aeolian (wind) sediments. There is a weakly subdivided accumulation, erosion accumulation and erosion denudation surface of Pleistocene River terraces and valley floodplains.

By division, Orlická plate is the fifth subdivision unit, preceded by region East-Czech plate, sub province Czech plate province Bohemian Massif and Hercynian system as the final and the first subdivision unit by the order (Picture no. 3) (Demek et al., 2006).




*Picture no. 3: Geomorphological division map of study area (source: ČÚZK, 2020).*

### 4.2.4 Hydrology

Despite the study area is a part of Elba's drainage basin, the only watercourse flows on this territory is stream Novoveský (waterbody index number 1-02-03-020). Novoveský stream is a tributary of Orlice river, which is formed from Divoká Orlice and Tichá Orlice. (DIBAVOD, 2021).

### 4.2.5 Climate conditions

Quitt (1971) categorizes three areas in the Czech Republic (warm, moderately warm, and cold) with 13 units. According to him, the most dominant climate unit in studied area is warm climate unit, precisely T2 (Table no. 1). In this climate area spring is relative short, warm to mildly warm, with average temperature 8-9 °C, followed by long, dry, and warm summer with average temperature is 18-19 °C. Average temperature in autumn is 7-9 °C. Winters are short, dry to very dry with average temperature is -2 to -3 °C (Quitt, 1971).

| Climatic characteristics of the warm area | T2 |
|---|---|
| Number of summer days | 50-60 |
| Number of days with approx. temp. +10 °C | 160-170 |
| Number of days with frost | 100-110 |
| Number of ice-days | 30-40 |
| Avg. temp. in January | -2 to -3 °C |
| Avg. temp. in April | 8-9 °C |
| Avg. temp. in July | 18-19 °C |
| Avg. temp. in October | 7-9 °C |
| Avg. number of days with precipitation of +1 mm | 90-100 mm |
| Sum of precipitation in the growing season | 350-400 mm |
| Sum of precipitation in winter | 200-300 mm |
| Sum of precipitation in total | 550-700 mm |
| Number of days with snow cover | 40-50 |
| Number of cloudy days | 120-140 |
| Number of clear days | 40-50 |

*Table no. 1: T2 climate unit by Quitt (1971).*

### 4.2.6 Phytogeography and vegetation zones

As the whole area is situated in Hradec Králové and Pardubice region, it's also divided in two phytogeographical regions: Thermobohemicum – Pardubice Polabí, and Mesophyticum Massivi bohemici - Chvojenská plateau (Skalický, 1988). Thermobohemicum is a well-known region by the warm moist summers and cool winters, where dominant are temperate broad-leaf forests - trees that lose their leaves each year. Different from that, Mesophyticum Massivi bohemici includes the class

Quercetea pubescentis deciduous forest formations in upper Mediterranean vegetation zone (Skalický, 1988).

### 4.2.7 Nature protection

#### 4.2.7.1 ÚSES

Areal system of ecological stability (ÚSES) is irregular site, by § 3, a) law number 114/1992, about nature and landscape protection, interconnected system of natural and changed ecosystems, which are close to natural ecosystems, and aims to maintain natural balance. The main goal of ÚSES is to strengthen stability of the landscape with preservation or renewal stabile ecosystems and their correlations.

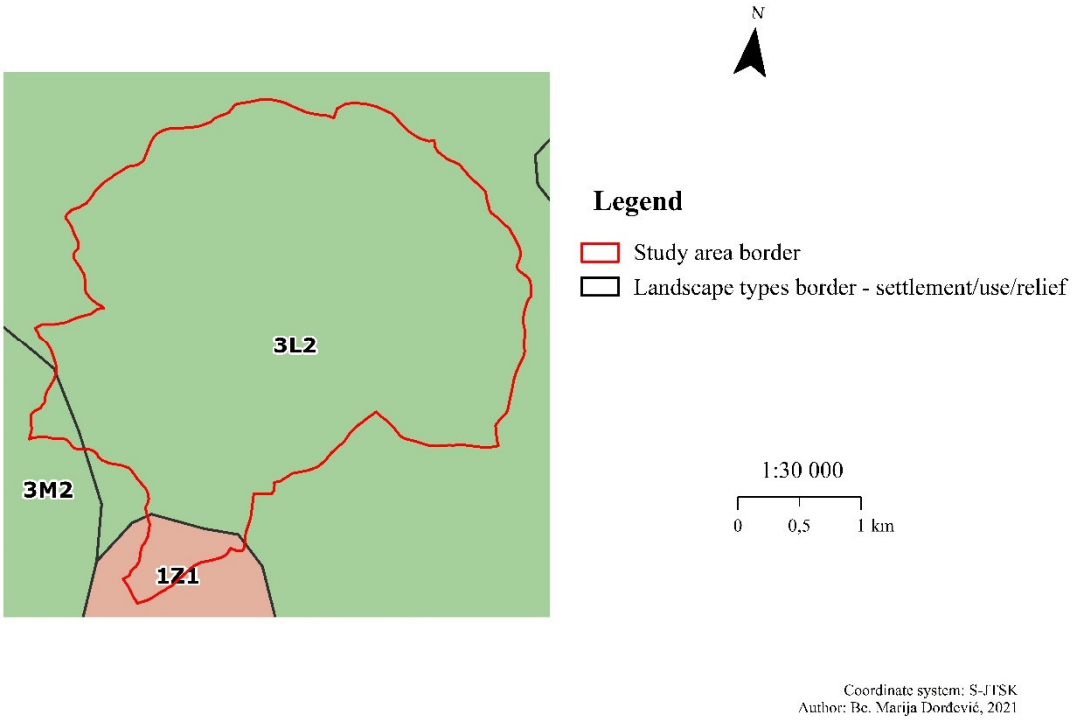
#### 4.2.7.2 Parts of ÚSES

Biocentre is a biotope or the biotope system of the landscape close to natural ecosystem, which allows permanent existence of natural or changed ecosystem with its own size and conditions (MZP, 2021). Bio corridor is an area, which aims a migration of the biocentre's habitants between biocentres and that way makes a network from divided sites. (MZP, 2021). Interactive elements are hierarchically on the lowest level, and they are not necessarily connected with the other ÚSES components; simply said, interactive elements are the landscape segments, which are balancing convenient interaction of basic ÚSES parts on the neighborhood fewer stabile parts. They usually allow permanent existence of certain species with less space requirements (MZP, 2021).

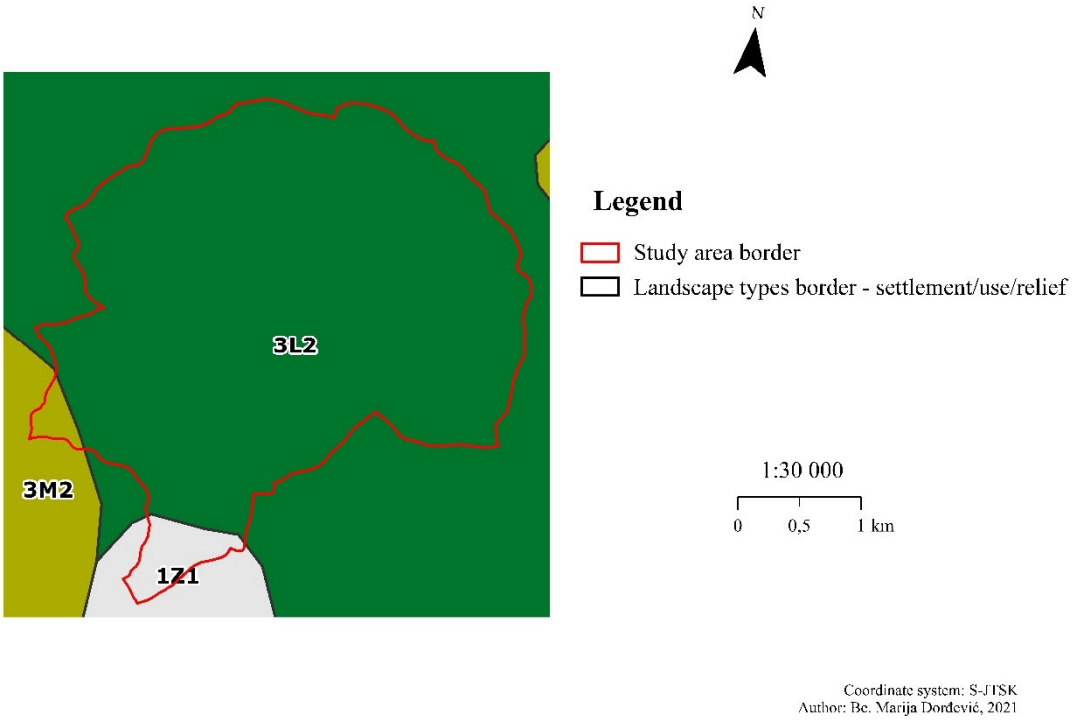
By the importance, all ÚSES are surpa-regional (minimal area 1000 ha), regional (area within 10-50 ha) and local (area not bigger than 10 ha). (MZP, 2021). In the studied area we can distinguish regional and surpa-regional biocentres, and surpa-regional bio corridor.

### 4.2.8 Vegetation current state

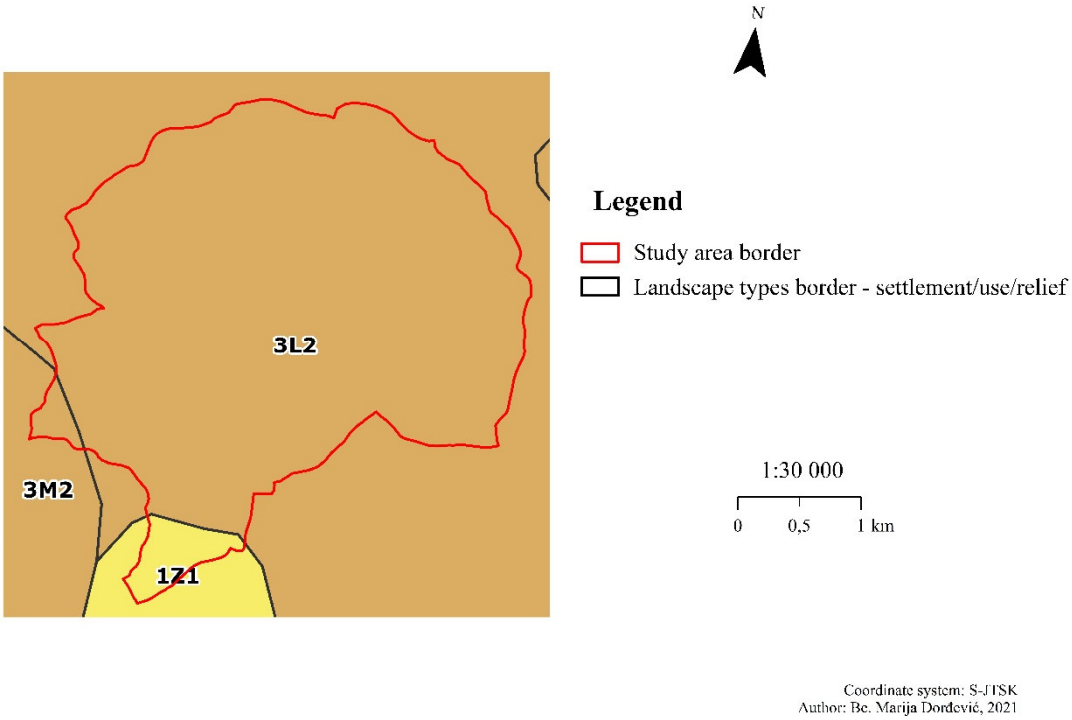
Vegetation current state is defined by three-placed code in the form number-letter-number. The first number represents the settlement (Picture no. 4), which indicates when this landscape has been settled. The following letter represents Land Use (Picture no. 5), and the second number (Picture no. 6) is a landscape divided by surface type (Lőw et al., 2006).




*Picture no. 4: Vegetation current state – settlement (source: CENIA, 2020).*




*Picture no. 5: Vegetation current state – Land Use (source: CENIA, 2020).*




*Picture no. 6: Vegetation current state – relief (source: CENIA, 2020).*

Vegetation current states present in study area (CENIA, 2020):

1Z1 - Old settlement landscape of Hercynica and Polonica / Agricultural landscape / Landscapes of plateaus and flat hills.

3M2 - Highly medieval settlement landscape of Hercynica / Forest agricultural-landscape / Landscapes of rugged hills and highlands Hercynica.

3L2 - Highly medieval settlement landscape of Hercynica / Forest landscpae / Landscapes of rugged hills and highlands Hercynica.

### 4.2.9 Potential natural vegetation

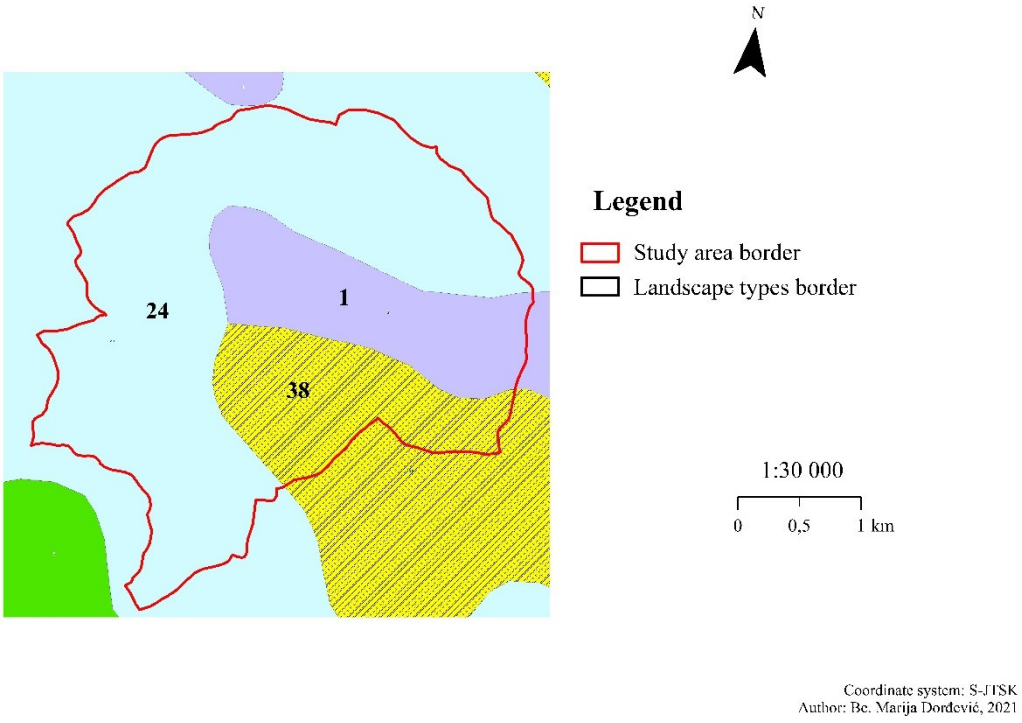
Balance between modern man, irreversibly changed environment and vegetation is defined as a potential natural vegetation (CENIA, 2020). Located in warm area unit T2, three dominant vegetation types starting from the most the least dominant are (Picture no. 7):

1- Pruno-Fraxinetum - a forest plant community that occurs on flat places along streams and small rivers, which are under the influence of seepage water or regularly flooded (CENIA, 2020),

Alnion glutinosae which develop in habitats with high groundwater levels, around ponds, streams, and rivers. They are a natural part of the successive development of wetland communities (CENIA, 2020).

24 - Luzulo-Fagetum - is a forest habitat with a predominance of beech, the most common species of beech. Many of them are legally protected as valuable stands (CENIA, 2020).

38 - Vaccinio vitis-idaeae-Quercetum - where the dominant is winter oak (Quercus petraea), sometimes summer oak (Quercus robur) and pine (Pinus sylvestris) form light stands that are close to natural (CENIA, 2020).




*Picture no. 7: Potential natural vegetation (source: CENIA, 2020).*

# 5 Methodology

Task of thesis is to evaluate changes in development of non-forest woody vegetation in chosen area between two times horizons. Evaluation of these changes is based on following the development of individual land covers, and their layout and areal representation (Lipský, 1999). The most important terms used for changes evaluation needed to be define are land cover and Land Use. Based on Sklenička (2003), Land Use is not simply a Land Use, but also landscape use. Many authors from Earth remote sensing background, like Lambin (2006), defines Land Use as a surface of the planet Earth with soils, topography, surface, biota, groundwater, and human structures included. He also defines land cover, as a purpose of Land Use. To simplify, land cover is dealing with visible aspects of the surface, unlike from Land Use, whose data are not always directly available. For analyzing purposes of this thesis, was used Land Use term with twelve categories defined. Data used for this purpose are graphical material – stabile cadaster maps from 1840s and aerial photographs from 1950s.

## 5.1 Definition of chosen area

The study area chosen for examination purposes is located on historical administrative unit Pardubice manor (org. Pardubické panství). The main reason for choosing exactly this area is possibility for collaboration with historians. Includes municipalities **V**ysoké Chvojno, Poběžovice u Holic, Nová Ves u Albrechtic and Albrechtice nad Orlicí and total surface area 1018 ha (ČÚZK, 2020). As border line was used 4$^{th}$ riverboard zone of the tributary of Orlice river (DIBAVOD, 2021).

## 5.2 Materials

For analyzing a change in non-forest stands on a landscape level, three types of sources were used as material. Individual polygons of Land Use/land cover were determined directly in studied area by fieldwork.

### 5.2.1 Maps material

The goal of the thesis is to monitor non-forest woody vegetation and determine its changes and development, it was necessary to establish which time horizons for these purposes are the most representative for analysis. The first one chosen for these

purposes were stabile cadaster maps from 1841, representing maps of Bohemia. As the first modern cadaster, the stable cadaster became the basis for tax assessment in Bohemia in 1860 but work on it began as early as 1817. The most important part of the stable cadaster is the cadastral map, consisting of three parts: a valuation map with documents and protocols, which forms the basis for the actual valuation of land, a written map, where we find data on individual plots, and copies of original maps with mandatory imperial prints. A scale of original maps was 1:2880, but copies have been made in more precise 1:1440 scale, primarily due detailed presentation of towns (Bumba, 2007). Cadaster maps were provided by Czech Geodetic and Cadastral Office (ČÚZK) in .jpg format.

Aerial photographs from 1953 were next used map source for analyzing purposes and represent a landscape right before the beginning of collectivization and industrial era in socialism. Although represent the first aerial photographs of the Czech Republic territory, pictures are black and white (Lipský, 1999). Aerial photographs were provided by Department of Ecology on Faculty of Environmental Sciences in Prague in .jpg format.

For the current representation of the land cover and Land Use it was used orthophoto map of the Czech Republic from 2020. Orthophoto represents regular two-year update set of color photographs with a layout of the State maps sheets in 1:5000 scale. It is, also, the most accurate way of maps and like that can be used in monitoring changes in woody stands (ČÚZK, 2020). Map is available in a form of web map services (WMS), available from Geodetic and Cadastral Office (ČÚZK).

### 5.2.2 Geographical information system – GIS

GIS represents computer system which allows us to store, process and analyze spatial data. Roots of GIS dates to 1960s, when the first GIS was built in Canada to process information collected in the map, with the very simple math functions, when it all progressed to complex spatial analysis in 1970s and 1980s (Goodshild, 2000). With the computer price drop in late 1980s, GIS became affordable to the originations that could effectively use it (Goodshild, 2000). Today GIS represents an important landscape assessment technology. It offers resources to process analysis relating to the landscape (Malenová, 2008). Software used for this diploma thesis is ArcMap 10.7.1

from company ESRI. As a leader in this area, ArcMap provides tools for editing, analyses, and modeling on different level.

### 5.2.3 Excel

In an order to represent the results of the analyzed data precisely and clear, another application used for the purposes of writing this diploma thesis was Excel, version 16.58.

History of Microsoft Excel dates from 1985, when the application was launched as the spreadsheet system, by the company Microsoft. It deals with organization of columns and rows and manipulates them through formulas and allows a software to preform mathematical functions on the data (Dodge and Stinson, 2007). Another function of Microsoft Excel is possibility of graphic representation of processed data and its results in different chart forms (Microsoft, 2022).

## 5.3 Field research

For better meeting with a chosen area, it was necessary to get to know it directly by going on a filed. Beside meeting with the area, field research has been an important part of classification process by detailed following every predefined class, as a Land Use is not visible in every part of orthophoto map. Photos taken during the field research were used in this thesis (Attachment no. 5-14), for a better idea about the territory appearance.

## 5.4 Land Use classification

Sorting objects in into a predefined group is a process of classification, where group is defined as a category based on certain objects characteristic named classifier. (Kolář, 2003). After the field research and Landscape inventory methodology (Černý et al., 2009), all the categories have been defined together with a thesis supervisor, with small corrections.

For analyze purposes of this work, was defined new category 300, other agricultural land which includes all agricultural land categories except category without groups 100 and 200 included.

All the watercourses in the study area are small, from that reason was not possible to identify them and vectorize. Due that reason, watercourses were not classified and monitored.

| Land Use code | Land Use category |
|---|---|
| 100 | arable land |
| 200 | grassland |
| 300 | other agricultural land |
| 400 | water |
| 500 | urbanized land |
| 610 | mixed forest |
| 620 | deciduous forests |
| 630 | coniferous forests |
| 700 | solitaires |
| 710 | non-forest woody vegetation in the landscape |
| 720 | non-forest woody vegetation along the road |
| 730 | non-forest woody vegetation along the water |

*Table no. 2: Overview of the Land Use category.*

| Land Use code | Land Use details |
|---|---|
| 100 | arable land |
| 200 | pastures, perennial grassland, grassland |
| 300 | all agricultural except 100 and 200 |
| 400 | watercourses, water surfaces, ponds, lakes, dikes, wetlands, mosses |
| 500 | constructions, industrial areas, parking, roads (roads, railways) |
| 610 | area with mixed forests cover |
| 620 | area with deciduous forests cover |
| 630 | area with coniferous forests cover |
| 700 | solitary growing woody vegetation and shrubs |
| 810 | groups of woody vegetation and shrub in the landscape |
| 820 | groups of woody vegetation and shrub along the communications |
| 830 | groups of woody vegetation and shrub along the water |

*Table no. 3: Characteristics of the use of individual categories of Land Use.*

## 5.5 Vectorization and data processing

The very first step to be able to use stabile cadaster maps, was adapting them to GIS environment by cutting them based on the border of predefined area. Followed with georeferencing, cadaster maps were transformed to local coordinate system S-JTSK Krovak East North, using ground control points. Ground control points are representing points with a known location on the Earth's surface used as an orientation for transforming raster without predefined coordinate system. The same location needs to be identified on the transformed raster. As an identical points corners of the square, crossroads, corners of map sheets were used.This process had been used on stabile cadaster maps only, as aerial photos from 1953 and orthophotos already have S-JTSK Krovak East North as predefined coordinate system.

The next step in analyzing process was including two-time layers, aerial photos from 1953 and orthophotos. Vectorization is transfer of the information included in raster maps into vector. Analyzing had always took a place in each cadaster separately gradually at both time horizons marking the boundaries of every Land Use category. For precise result, Land Use categories for aerial maps were drawn with line boundaries, and transferred to polygons, while Land Use layer of orthophotos was drawn as polygon directly. After vectorization, all created polygons were marked in attribute table, by certain Land Use category from the chapter 5.4. Calculation of every polygon of the Land Use has been done with a software ArcMap 10.7.1. Woody vegetation, both forest and non-forest, based on (Skaloš et al. 2015) was divided into three categories representing different developments of Land Use categories in time and space.

| Land Use spatial horizon | Land Use time horizon |
|---|---|
| **continuous** | 1953 included, 2021 included |
| **extinct** | 1953 included, 2021 excluded |
| **new** | 1953 excluded, 2021 included |

*Table no. 4: Spatiotemporal dynamics of woody vegetation.*

Based on that the categorization from Table no. 4, every individual woody category has been analyzed and determined if Land Use of every category is continuous, extinct, or new.

To determine if whether continuous woody vegetation existed in analyzed area in 1841, was used visualization, where continuous polygon layer and of each woody vegetation was compared with georeferenced map of stable cadaster of each cadaster. The results and output of this analyze was estimated.

Whole process of vectorization has been time consuming, especially for orthophotos where details are easy noticeable and visible and therefore have more details, comparing to aerial photographs from 1953 where vectorization had been done based on map legends with way worse quality. Speaking of easiness of data reading, it was less difficult to process and transfer all the information to orthophoto layer, than to aerial photos layer as aerial photos from 1953 are black and white, which made them hard to read.

# 6 Results

## 6.1 Land Use development in study area

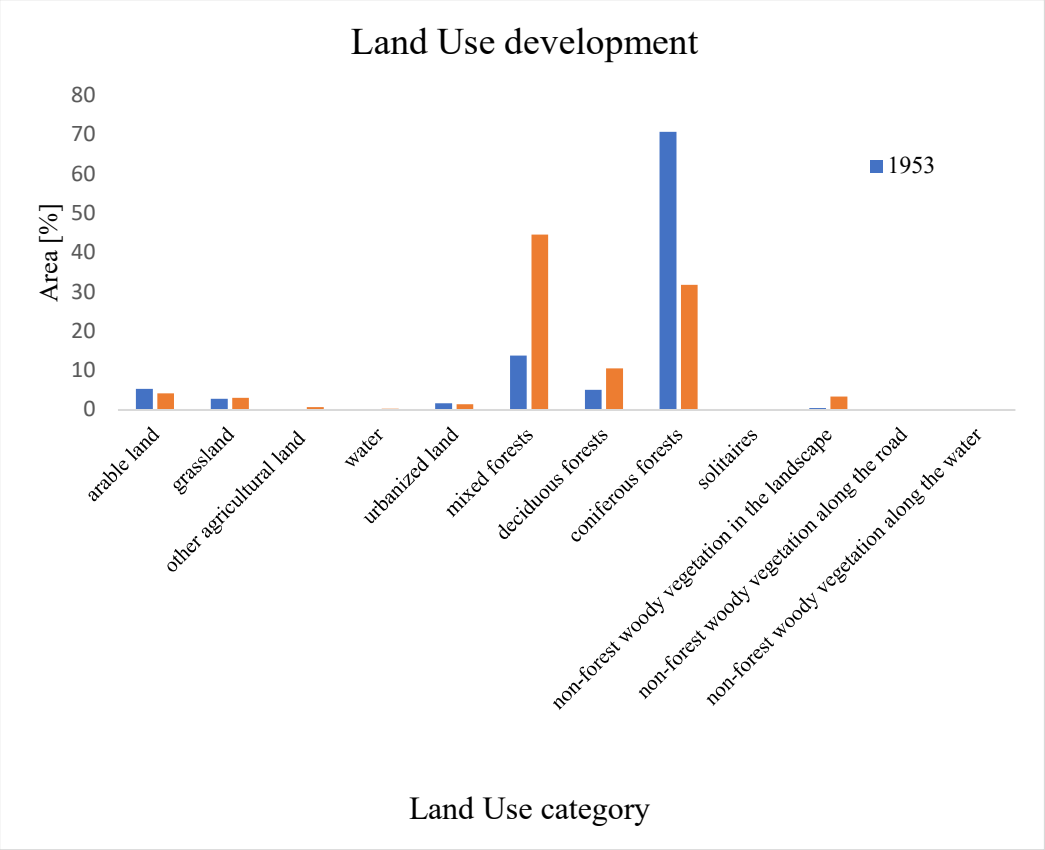
As a study area is historical forest (mixed, deciduous, coniferous), dominant Land Use are forests, followed with the arable Land Use as the second dominant in both time periods. The same applies to grassland and water in the order. The rest of the Land Use are present in small percentage (up to 1,5 %), except Land Use other agricultural land (Land Use code 300), which is not present at all in 1953 and less than 1 % percent in 2020 (Table no. 5).

| Land Use code | Land Use category | Total study area | | | |
|---|---|---|---|---|---|
| | | Area [ha] | | Area [%] | |
| | | 1953 | 2020 | 1953 | 2020 |
| 100 | arable land | 53,04 | 42,34 | 5,31 | 4,16 |
| 200 | grassland | 28,38 | 30,76 | 2,79 | 3,02 |
| 300 | other agricultural land | 0,00 | 6,68 | 0,00 | 0,66 |
| 400 | water | 1,52 | 2,27 | 0,15 | 0,22 |
| 500 | urbanized land | 16,95 | 14,38 | 1,66 | 1,41 |
| 610 | mixed forests | 141,09 | 454,45 | 13,82 | 44,61 |
| 620 | deciduous forests | 51,75 | 107,27 | 5,08 | 10,53 |
| 630 | coniferous forests | 721,58 | 323,77 | 70,75 | 31,78 |
| 700 | solitaires | 0,37 | 0,59 | 0,04 | 0,06 |
| 810 | non-forest woody vegetation in the landscape | 3,86 | 34,26 | 0,38 | 3,36 |
| 820 | non-forest woody vegetation along the road | 0,16 | 1,01 | 0,02 | 0,10 |
| 830 | non-forest woody vegetation along the water | 0,00 | 0,89 | 0,00 | 0,09 |
| | Total | 1018,70 | 1018,70 | 100 | 100 |

*Table no. 5: Land Use development in study area.*

In whole studied area from the point of categories consisting of forests (mixed, deciduous, and coniferous) is noticeable decrease of 3 % from the 1953 to 2020. From the point of each Land Use, the only area decreases, marks area with coniferous forest, and it decrease for more than double from 1953 to 2020. Three other Land Uses increase, where the biggest difference in change is noticed in deciduous forests (Land Use code 620) (Picture no. 8).

Solitaires (Land Use code 700), non-forest woody vegetation in the landscape (Land Use code 810), non-forest woody vegetation along the road (Land Use code 820), and non-forest woody vegetation along the water (Land Use code 830), on which this thesis is focused, mark small change differences except, where non-forest woody vegetation in the landscape has increased for 3 % (Picture no. 8).




*Picture no. 8: Land Use development in study area.*

## 6.2 Spatial changes analysis

### 6.2.1 Non-forest woody vegetation development in cadaster unit Albrechtice nad Orlicí

The smallest part of the study area, located in cadaster unit Albrechtice nad Orlicí is widespread on the territory of 12,27 ha. The most dominant Land Use are forests, with the coniferous (Land Use code 630) as the most dominant, followed by deciduous (Land Use code 620) and mixed (Land Use code 610) forests (Table no. 6).

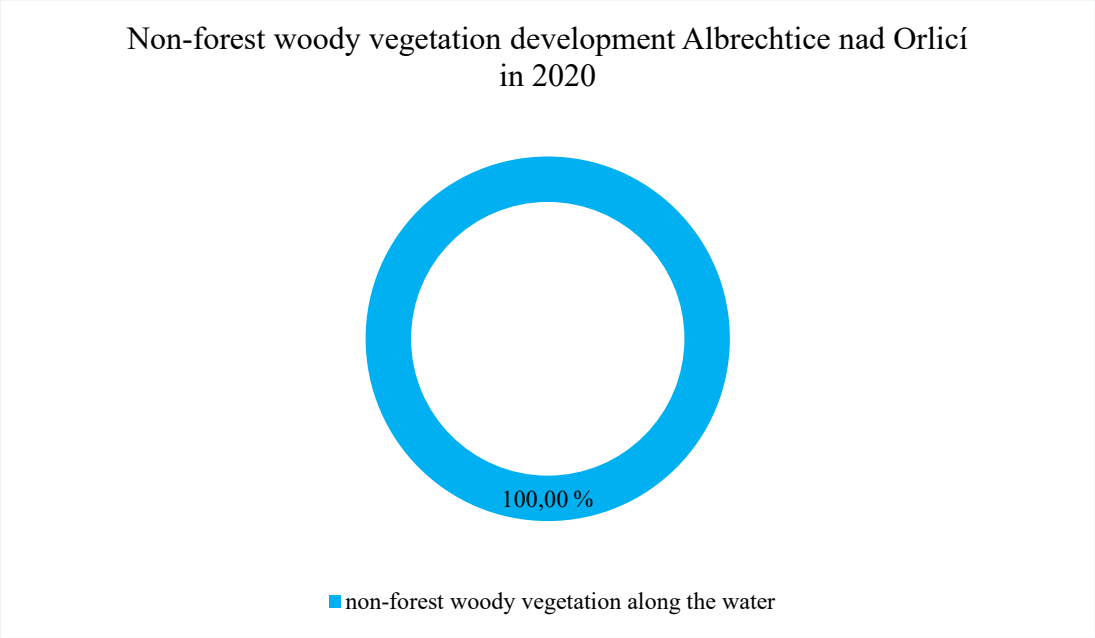
| Land Use code | Land Use category | Albrechtiice nad Orlicí | | | |
|---|---|---|---|---|---|
| | | Area [ha] | | Area [%] | |
| | | 1953 | 2020 | 1953 | 2020 |
| 100 | arable land | 0,00 | 0,00 | 0,00 | 0,00 |
| 200 | grassland | 0,00 | 2,66 | 0,00 | 21,68 |
| 300 | other agricultural land | 0,00 | 0,00 | 0,00 | 0,00 |
| 400 | water | 0,00 | 0,12 | 0,00 | 0,97 |
| 500 | urbanized land | 0,54 | 0,81 | 24,05 | 6,60 |
| 610 | mixed forests | 0,07 | 1,12 | 7,76 | 9,12 |
| 620 | deciduous forests | 0,01 | 0,38 | 16,62 | 3,09 |
| 630 | coniferous forests | 11,65 | 5,77 | 51,58 | 47,02 |
| 700 | solitaires | 0,00 | 0,00 | 0,00 | 0,00 |
| 810 | non-forest woody vegetation in the landscape | 0,00 | 0,00 | 0,00 | 0,00 |
| 820 | non-forest woody vegetation along the road | 0,00 | 0,00 | 0,00 | 0,00 |
| 830 | non-forest woody vegetation along the water | 0,00 | 1,41 | 0,00 | 11,73 |
| | Total | 12,27 | 12,27 | 100 | 100 |

*Table no. 6: Land Use development in cadaster unit Albrechtice nad Orlicí.*

Speaking about non-forest woody Land Uses, the most and only dominant one is Land Use non-forest woody vegetation (Land Use code 830) present just in 2020, comparing to 1953 where non-forest woody vegetation is not present at all. The reason for the poor Land Use diversity is a small area of the study area in this cadaster, which by years changed from other agricultural Land Use (Land Use code 300) to non-forest woody vegetation along the water (Land Use code 830) (Table no. 7, Picture no. 9).

| Land Use code | Land Use category | Albrechtiice nad Orlicí | | | |
|---|---|---|---|---|---|
| | | Area [ha] | | Area [%] | |
| | | 1953 | 2020 | 1953 | 2020 |
| 700 | solitaires | 0,00 | 0,00 | 0,00 | 0,00 |
| 810 | non-forest woody vegetation in the landscape | 0,00 | 0,00 | 0,00 | 0,00 |
| 820 | non-forest woody vegetation along the road | 0,00 | 0,00 | 0,00 | 0,00 |
| 830 | non-forest woody vegetation along the water | 0,00 | 1,41 | 0,00 | 100,00 |
| | Total | 0,00 | 1,41 | 100 | 100 |

*Table no. 7: Non-forest woody vegetation development in cadaster unit Albrechtice nad Orlicí.*

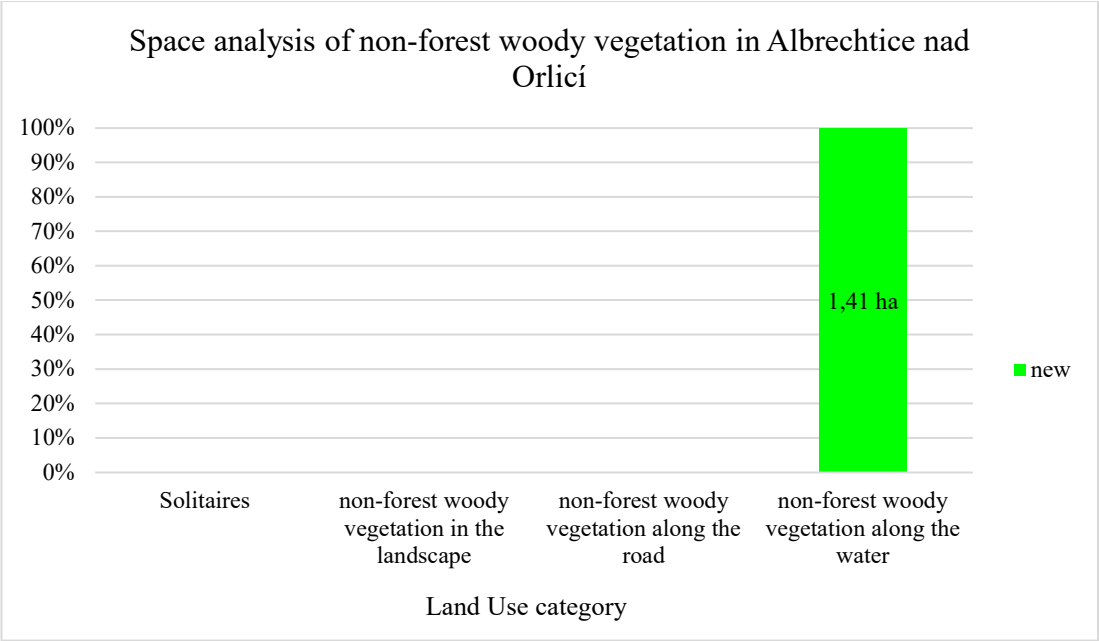



*Picture no. 9: Non-forest woody vegetation development in cadaster unit Albrechtice nad Orlicí.*

From the point of the space analizis of non-forest woody vegetation, Table no. 8 shows how non-forest woody Land Uses were only developting, Specifically, in the already mentioned non-forest woody vegetation along the water (Land Use code 830), for 1,41 ha in total (Table no. 8, Picture no. 10).

| **Albrechtiice nad Orlicí** | | | | | | |
|---|---|---|---|---|---|---|
| **Land Use code** | **Land Use category** | **Area [ha]** | | **Spatial horizon code [ha]** | | |
| | | **1953** | **2020** | **continuous** | **excint** | **new** |
| 700 | solitaires | / | / | / | / | / |
| 810 | non-forest woody vegetation in the landscape | / | / | / | / | / |
| 820 | non-forest woody vegetation along the road | / | / | / | / | / |
| 830 | non-forest woody vegetation along the water | / | 1,41 | / | / | 1,41 |

*Table no. 8: Space analysis of non-forest woody vegetation in cadaster unit Albrechtice nad Orlicí.*




*Picture no. 10: Space analysis of non-forest woody vegetation in cadaster unit Albrechtice nad Orlicí.*

### 6.2.2 Non-forest woody vegetation development in cadastral unit Poběžovice u Holic

More interesting study area to research, was area taking place in cadaster unit Poběžovice u Holic. In this part of study area, the diversity of non-forest woody Land Use categories is slowly, but visibly expands comparing to the previously analyzed one, which Table no. 9 shows.

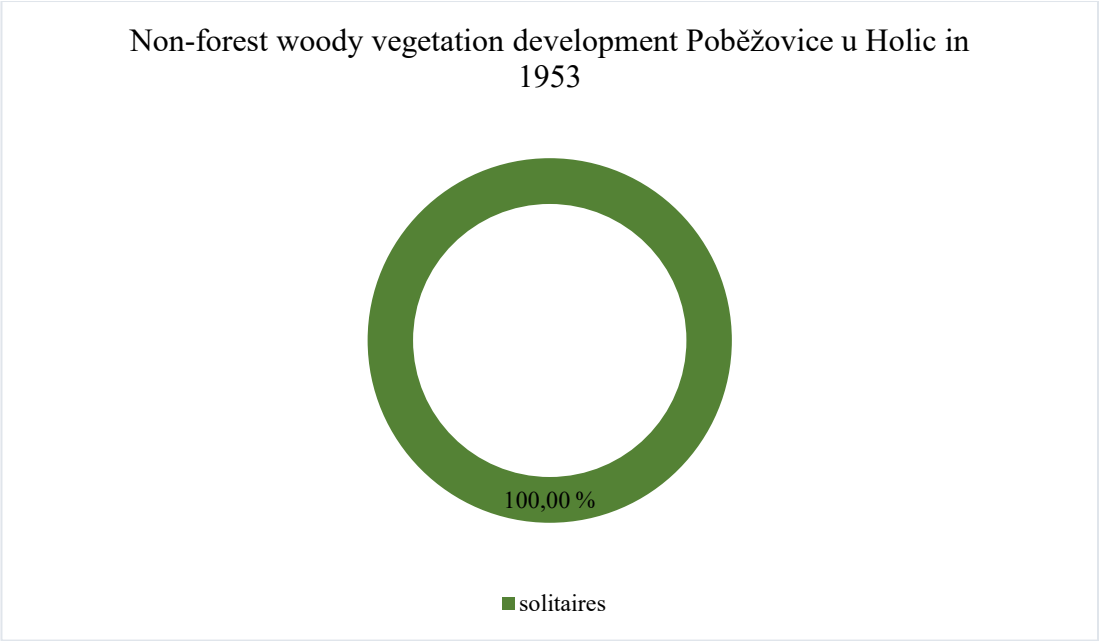
The biggest increase notes non-forest woody vegetation in the landscape (Land Use code 810), with 0 % in 1953, to almost 80 % of the area of non-forest woody vegetation in 2020. Solitaires (Land Use code 700) are also present in 1953, with an increase of 7,65 %. The opposite from Albrechtice nad Orlicí, non-forest woody vegetation next to the water is the only one Land Use of all non-forest woody vegetation categories are not present in neither of both time horizon (Table no. 10, Picture no. 11 and 12).

| Land Use code | Land Use category | Poběžovice u Holic | | | |
|---|---|---|---|---|---|
| | | Area [ha] | | Area [%] | |
| | | 1953 | 2020 | 1953 | 2020 |
| 100 | arable land | 37,33 | 27,13 | 56,88 | 41,38 |
| 200 | grassland | 0,00 | 9,03 | 0,00 | 13,93 |
| 300 | other agricultural land | 0,00 | 0,00 | 0,00 | 0,00 |
| 400 | water | 0,00 | 0,00 | 0,00 | 0,00 |
| 500 | urbanized land | 4,69 | 5,16 | 7,12 | 7,78 |
| 610 | mixed forests | 0,00 | 4,17 | 0,00 | 6,36 |
| 620 | deciduous forests | 0,00 | 0,06 | 0,00 | 0,09 |
| 630 | coniferous forests | 23,53 | 18,18 | 35,85 | 27,73 |
| 700 | solitaires | 0,01 | 0,14 | 0,01 | 0,21 |
| 810 | non-forest woody vegetation in the landscape | 0,00 | 1,46 | 0,00 | 2,27 |
| 820 | non-forest woody vegetation along the road | 0,00 | 0,23 | 0,00 | 0,35 |
| 830 | non-forest woody vegetation along the water | 0,00 | 0,00 | 0,00 | 0,00 |
| | Total | 65,56 | 65,56 | 100 | 100 |

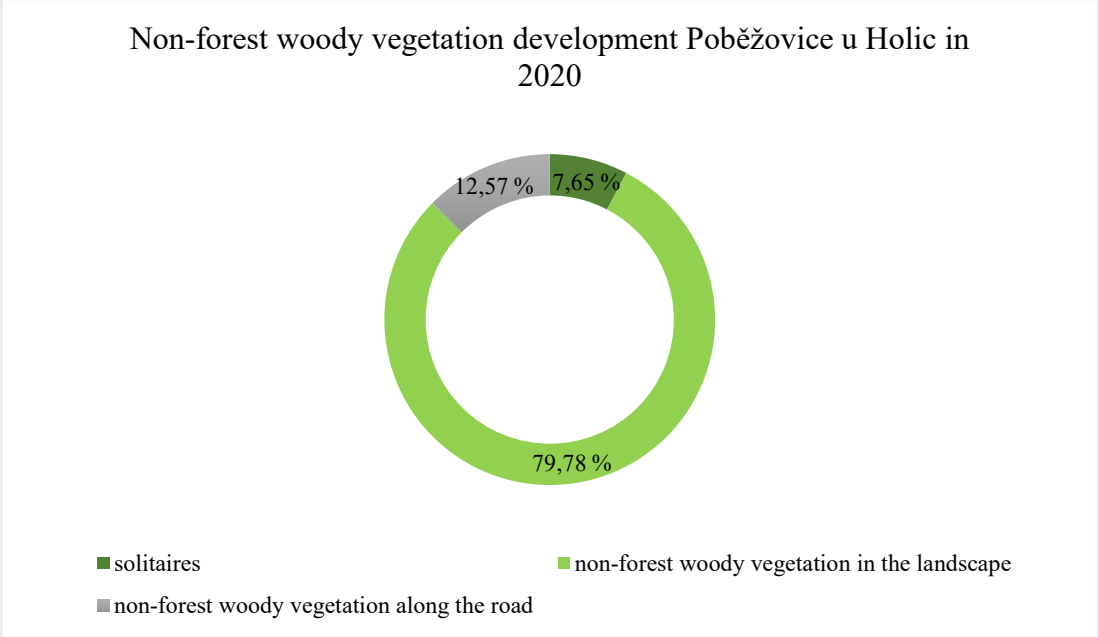
*Table no. 9: Land Use development in cadaster unit Poběžovice u Holic.*

| Land Use code | Land Use category | Poběžovice u Holic | | | |
|---|---|---|---|---|---|
| | | Area [ha] | | Area [%] | |
| | | 1953 | 2020 | 1953 | 2020 |
| 700 | solitaires | 0,01 | 0,14 | 0,00 | 7,65 |
| 810 | non-forest woody vegetation in the landscape | 0,00 | 1,46 | 0,00 | 79,78 |
| 820 | non-forest woody vegetation along the road | 0,00 | 0,23 | 0,00 | 12,57 |
| 830 | non-forest woody vegetation along the water | 0,00 | 0,00 | 0,00 | 00,00 |
| | Total | 0,00 | 1,83 | 100 | 100 |

*Table no. 10: Non-forest woody vegetation development in cadaster unit Poběžovice u Holic.*




*Picture no. 11: Non-forest woody vegetation development in cadaster unit Poběžovice u Holic in 1953.*

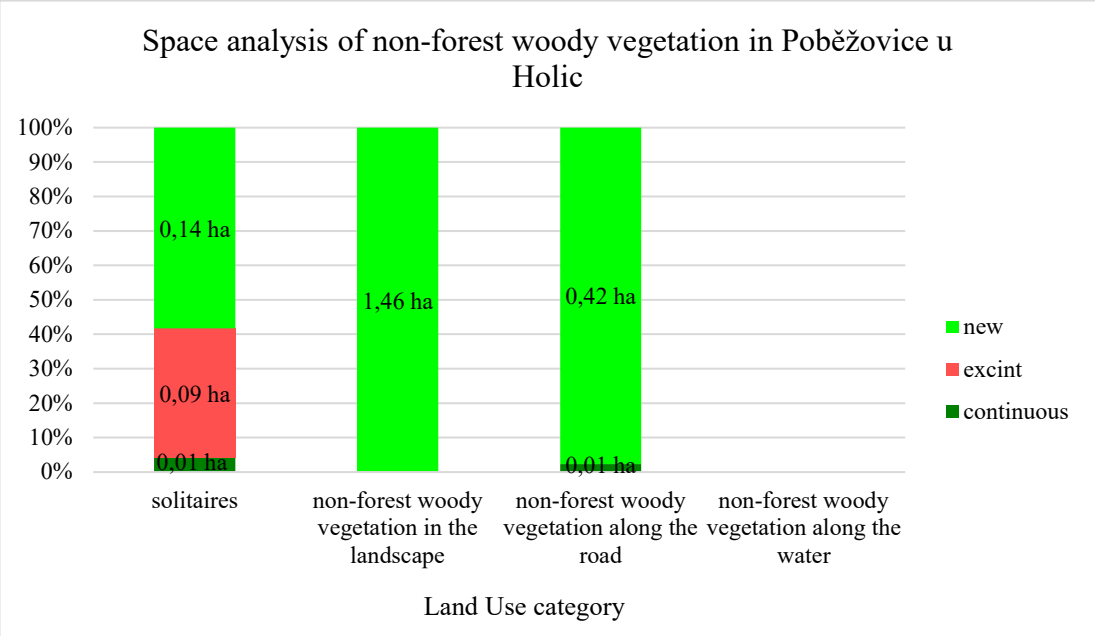



*Picture no. 12: Non-forest woody vegetation development in cadaster unit unit Poběžovice u Holic in 2020.*

A space analyzing of the study area in the cadaster unit Poběžovice u Holic, which Table no. 11 and Picture no. 13 show us, is visible the development in all Land Uses, except Land Use of non-forest woody vegetation next to the water (Land Use code 830). Every increased Land Use category, also, develop without any extinct Land Use.

| Poběžovice u Holic | | | | | | |
|---|---|---|---|---|---|---|
| **Land Use code** | **Land Use category** | **Area [ha]** | | **Spatial horizon code [ha]** | | |
| | | **1953** | **2020** | **continuous** | **excint** | **new** |
| 700 | solitaires | 0,10 | 0,15 | 0,01 | 0,09 | 0,14 |
| 810 | non-forest woody vegetation in the landscape | / | 1,46 | / | / | 1,46 |
| 820 | non-forest woody vegetation along the road | 0,01 | 0,43 | 0,01 | / | 0,42 |
| 830 | non-forest woody vegetation along the water | / | / | / | / | / |

*Table no. 11: Space analysis of non-forest woody vegetation in cadaster unit Poběžovice u Holic.*




*Picture no. 13: Space analysis of non-forest woody vegetation in cadaster unit Poběžovice u Holic.*

### 6.2.3 Non-forest woody vegetation development in cadastral unit Nová Ves u Albrechtic

The third part of the study area took a place in cadaster unit Nová Ves u Albrechtic, with surface area 449,02 ha (Table no. 12).

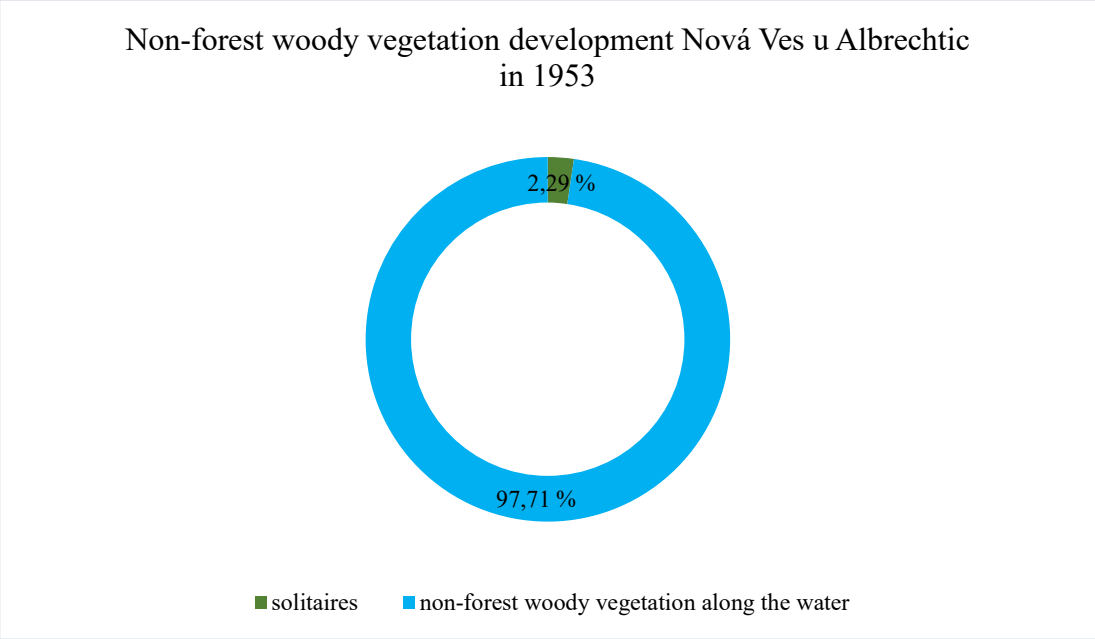
| Land Use code | Land Use category | Nová Ves u Albrechtic | | | |
|---|---|---|---|---|---|
| | | Area [ha] | | Area [%] | |
| | | 1953 | 2020 | 1953 | 2020 |
| 100 | arable land | 7,62 | 0,86 | 1,70 | 0,19 |
| 200 | grassland | 23,38 | 8,00 | 5,22 | 1,78 |
| 300 | other agricultural land | 0,00 | 6,68 | 0,00 | 0,00 |
| 400 | water | 1,36 | 1,67 | 0,31 | 0,37 |
| 500 | urbanized land | 5,01 | 3,66 | 1,20 | 0,81 |
| 610 | mixed forests | 68,84 | 238,06 | 15,35 | 53,00 |
| 620 | deciduous forests | 5,25 | 73,93 | 1,19 | 17,70 |
| 630 | coniferous forests | 331,48 | 104,23 | 73,82 | 23,20 |
| 700 | solitaires9 | 0,03 | 0,28 | 0,01 | 0,06 |
| 810 | non-forest woody vegetation in the landscape | 0,00 | 10,26 | 0,00 | 2,28 |
| 820 | non-forest woody vegetation along the road | 0,00 | 0,50 | 0,00 | 0,11 |
| 830 | non-forest woody vegetation along the water | 1,05 | 0,89 | 0,25 | 0,20 |
| | Total | 449,02 | 449,02 | 100 | 100 |

*Table no. 12: Land Use development in cadaster unit Nová Ves u Albrechtic.*

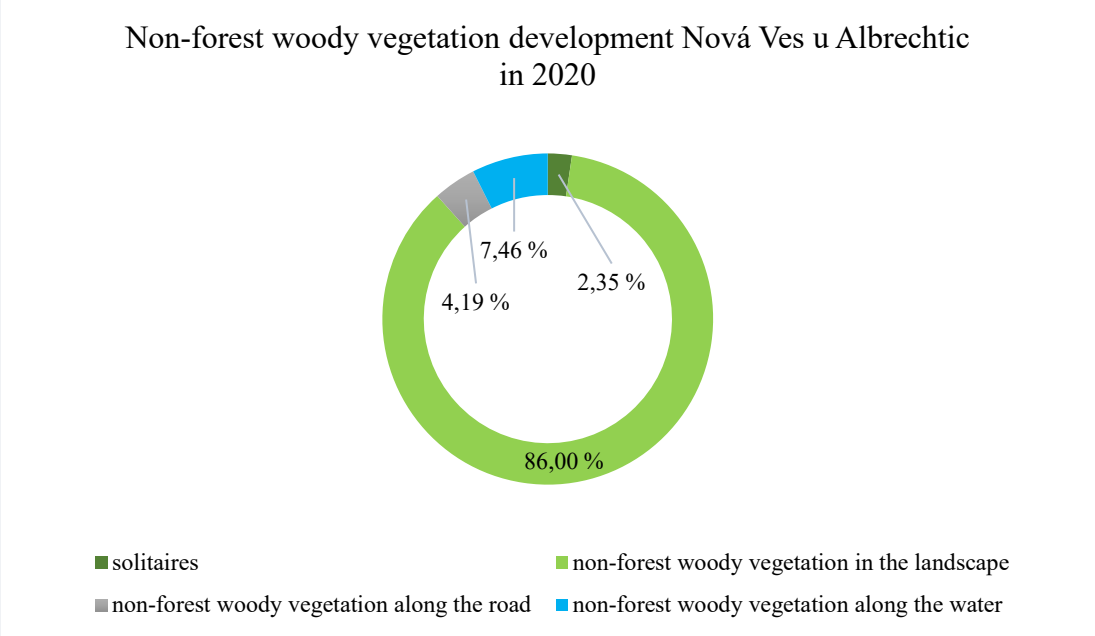
| Land Use code | Land Use category | Nová Ves u Albrechtic | | | |
|---|---|---|---|---|---|
| | | Area [ha] | | Area [%] | |
| | | 1953 | 2020 | 1953 | 2020 |
| 700 | solitaires | 0,03 | 0,28 | 2,28 | 2,35 |
| 810 | non-forest woody vegetation in the landscape | 0,00 | 10,46 | 0,00 | 86,00 |
| 820 | non-forest woody vegetation along the road | 0,00 | 0,50 | 0,00 | 4,19 |
| 830 | non-forest woody vegetation along the water | 1,05 | 0,89 | 97,22 | 7,46 |
| | Total | 1,08 | 11,93 | 100 | 100 |

*Table no. 13: Non-forest woody vegetation development in cadaster unit Nová Ves u Albrechtic.*

As the diversity is drastically getting bigger in every Land Use category, it is also happening in all non-forest woody vegetation Land Uses, comparing total surface area in 1953 (1,08 ha), and 2020 with almost 12 times bigger area (11,93 ha) (Table no. 13, Picture no. 14 and 15).




*Picture no. 14: Non-forest woody vegetation development in cadaster unit Nová Ves u Albrechtic in 1953.*

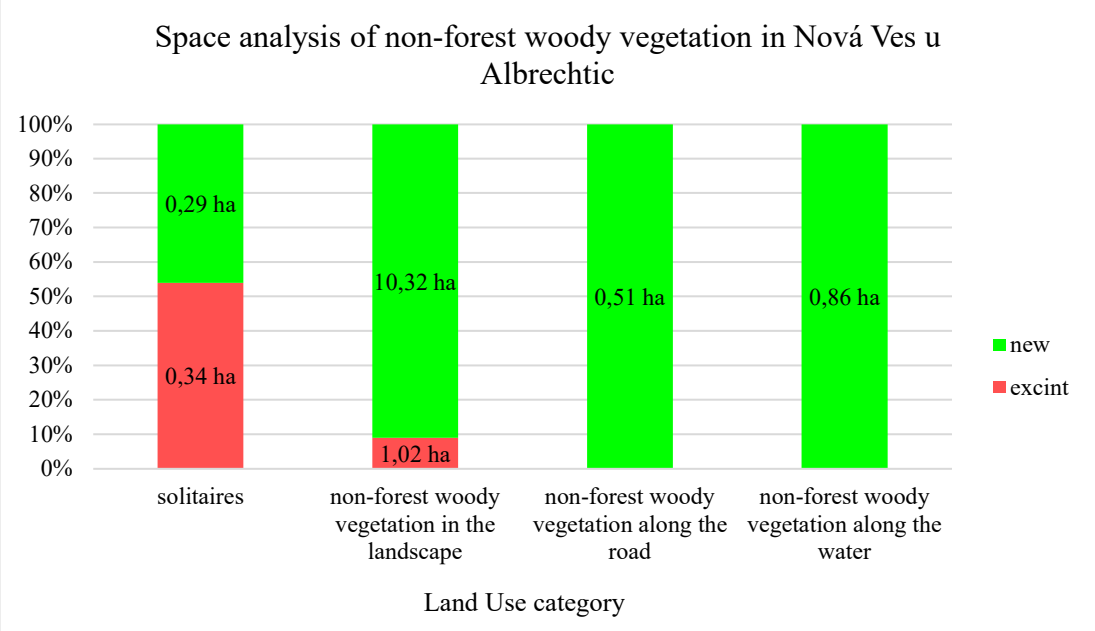



*Picture no. 15: Non-forest woody vegetation development in cadaster unit Nová Ves u Albrechtic in 2020.*

That brings us to spatial analysis development and increasing of new and extinct spatial horizon code. Even the surface area in 2020 is got bigger comparing to area in 1953, it is still visible that Land Uses solitaries and non-forest woody vegetation had some loses and caused creating extinct spatial horizons in both (Table 14, Picture no. 16).

| Nová Ves u Albrechtic | | | | | | |
|---|---|---|---|---|---|---|
| **Land Use code** | **Land Use category** | **Area [ha]** | | **Spatial horizon code [ha]** | | |
| | | **1953** | **2020** | **continuous** | **excint** | **new** |
| 700 | solitaires | 0,34 | 0,29 | / | 0,34 | 0,29 |
| 810 | non-forest woody vegetation in the landscape | 1,02 | 10,32 | / | 1,02 | 10,32 |
| 820 | non-forest woody vegetation along the road | / | 0,51 | / | / | 0,51 |
| 830 | non-forest woody vegetation along the water | / | 0,86 | / | / | 0,86 |

*Table no. 14: Space analysis of non-forest woody vegetation in cadaster unit Nová Ves u Albrechtic.*




*Picture no. 16: Space analysis of non-forest woody vegetation in cadaster unit Nová Ves u Albrechtic.*

### 6.2.4 Non-forest woody vegetation development in cadastral unit Vysoké Chvojno

In this part of the study are, localized in cadaster unit Vysoké Chvojno, total surface is the biggest one: 491,87 ha. It is also the most diverse and the most changed (Table no. 15).

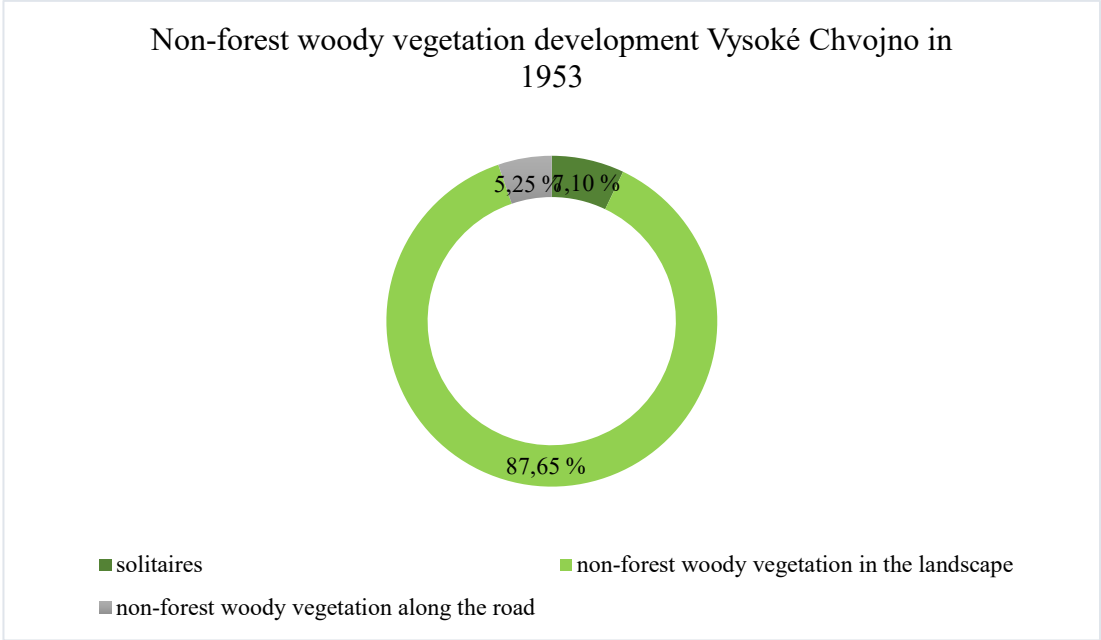
| Land Use code | Land Use category | Vysoké Chvojno | | | |
|---|---|---|---|---|---|
| | | Area [ha] | | Area [%] | |
| | | 1953 | 2020 | 1953 | 2020 |
| 100 | arable land | 8,12 | 14,36 | 1,65 | 2,92 |
| 200 | grassland | 0,00 | 11,10 | 0,00 | 2,26 |
| 300 | other agricultural land | 0,00 | 0,00 | 0,00 | 0,00 |
| 400 | water | 0,16 | 0,48 | 0,03 | 0,10 |
| 500 | urbanized land | 6,73 | 4,74 | 1,73 | 0,96 |
| 610 | mixed forests | 72,18 | 211,13 | 14,67 | 42,92 |
| 620 | deciduous forests | 46,49 | 32,89 | 10,03 | 6,69 |
| 630 | coniferous forests | 354,95 | 195,60 | 72,16 | 39,77 |
| 700 | solitaires9 | 0,23 | 0,17 | 0,05 | 0,03 |
| 810 | non-forest woody vegetation in the landscape | 2,84 | 21,31 | 0,58 | 4,33, |
| 820 | non-forest woody vegetation along the road | 0,17 | 0,28 | 0,03 | 0,06 |
| 830 | non-forest woody vegetation along the water | 0,00 | 0,00 | 0,00 | 0,00 |
| | Total | 491,87 | 491,87 | 100 | 100 |

*Table no. 15: Land Use development in cadaster unit Vysoké Chvojno.*

Land Uses of non-forest woody vegetation has the biggest increase in surface area from all non-forest woody vegetation categories, starting with 2,84 ha in 1953 to 21,31 ha in 2020. Non-forest woody vegetation along the road (Land Use code 830) slightly increases, solitaires (Land Use code 700) on the other hand decreasing. Non-forest woody vegetation is not present in neither of two times horizons (Table no. 16, Picture no. 17 and 18).

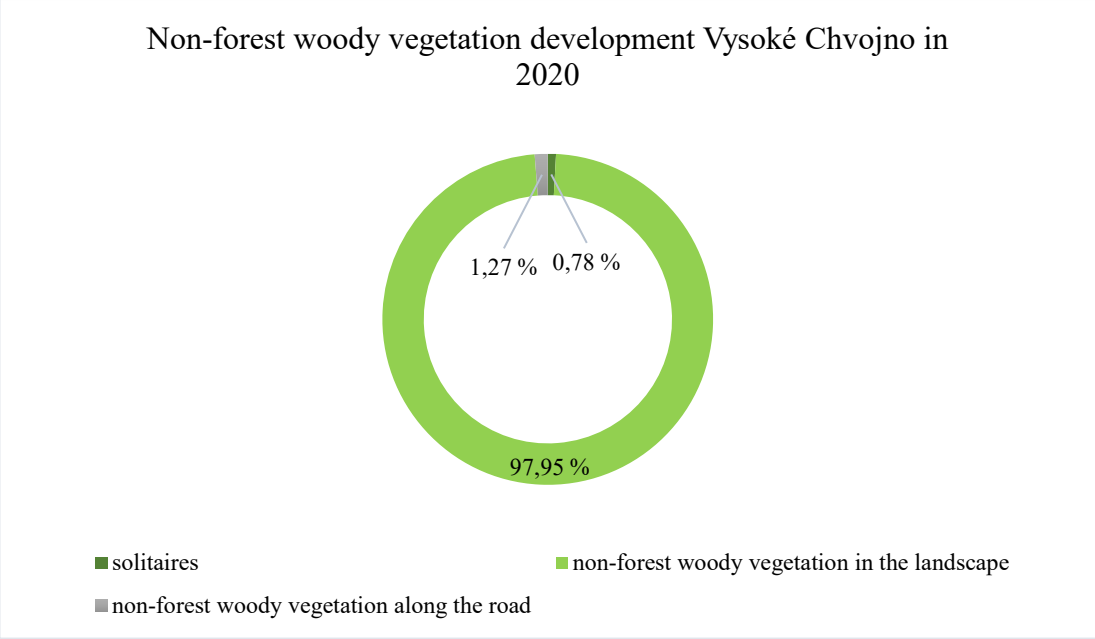
| Land Use code | Land Use category | Vysoké Chvojno | | | |
|---|---|---|---|---|---|
| | | Area [ha] | | Area [%] | |
| | | 1953 | 2020 | 1953 | 2020 |
| 700 | solitaires | 0,23 | 0,17 | 7,10 | 0,78 |
| 810 | non-forest woody vegetation in the landscape | 2,84 | 21,31 | 87,65 | 97,93 |
| 820 | non-forest woody vegetation along the road | 0,17 | 0,28 | 5,25 | 1,27 |
| 830 | non-forest woody vegetation along the water | 0,00 | 0,00 | 0,00 | 0,00 |
| | Total | 3,24 | 21,76 | 100 | 100 |

*Table no. 16: Non-forest woody vegetation development in cadaster unit Vysoké Chvojno.*




*Picture no. 17: Non-forest woody vegetation development in cadaster unit Vysoké Chvojno in 1953.*

As the most diverse study area part of all four, it also has all three categories developed in space and time, with codes continuous, extinct, and new. Even if Land Use category solitaires (Land Use code 700) have new developed category, in total the surface area decreased from 1953 to 2020.

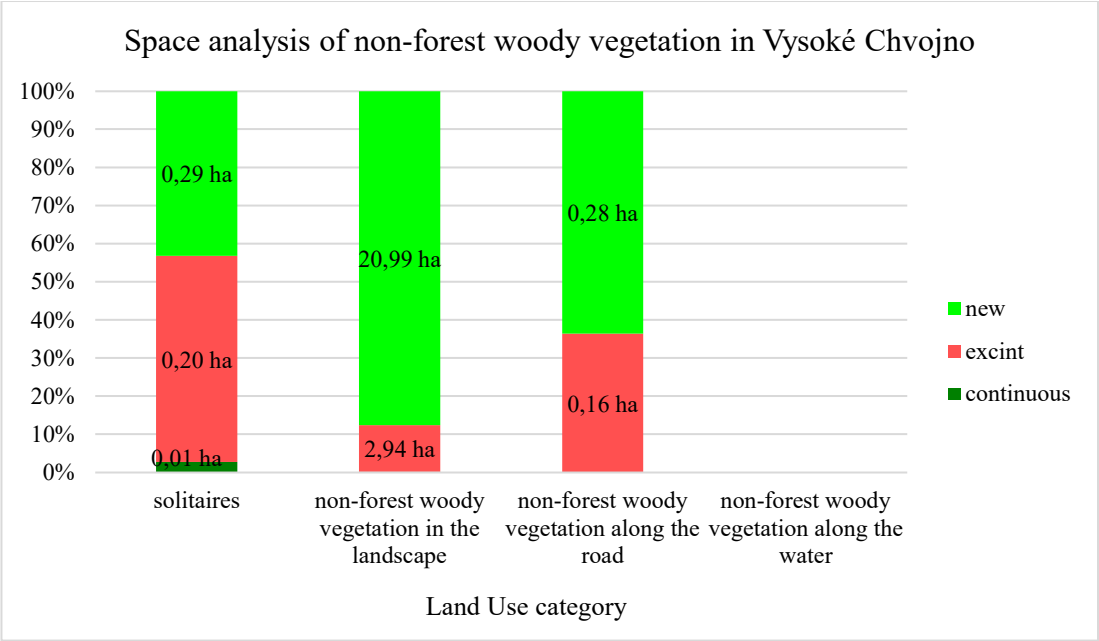



*Picture no. 18: Non-forest woody vegetation development in cadaster unit Vysoké Chvojno in 1953.*

Land Use categories non-forest woody vegetation along the water (Land Use code 810) and non-forest woody vegetation along the road (Land Use code 820) are on the other hand, opposite od solitaires (Land Use code 700) with more surface are increasing then decreasing, while non-forest woody vegetation along the water (Land Use code 830) is not present at all (Table no. 17, Picture no. 19).

| **Vysoké Chvojno** | | | | | | |
|---|---|---|---|---|---|---|
| **Land Use code** | **Land Use category** | **Area [ha]** | | **Spatial horizon code [ha]** | | |
| | | **1953** | **2020** | **continuous** | **excint** | **new** |
| 700 | solitaires | 0,21 | 0,17 | 0,01 | 0,20 | 0,16 |
| 810 | non-forest woody vegetation in the landscape | 2,97 | 21,02 | 0,03 | 2,94 | 20,99 |
| 820 | non-forest woody vegetation along the road | 0,16 | 0,28 | / | 0,16 | 0,28 |
| 830 | non-forest woody vegetation along the water | / | / | / | / | / |

*Table no. 17: Space analysis of non-forest woody vegetation in cadaster unit Vysoké Chvojno.*




*Picture no. 19: Space analysis of non-forest woody vegetation in cadaster unit Vysoké Chvojno.*

# 7 Discussion

## 7.1 Discussion of the results

These results show a change in the size of non-forest and the forest woody vegetation in both time horizons – 1953 and 2020.

Previous results are well showing the development of the forest woody vegetation, which in total shows decreasing by less than 10 % of forest area. Analyzing the values of each forest Land Use category separately, it is visible that mixed forest increased triple, and deciduous increased double in the area, which is explained by trend of gradually grassing over and afforestation arable land in the 1990s after collectivization (Kabrda and Bičík, 2010). Coniferous forests are, on the other hand, decreasing for more than a double in area. As the area of coniferous forests was bigger than the area of mixed and deciduous forest together in 1953, that caused decreasing of forest Land Use in total. One of the reasons of this change is development of the other Land Use categories, including non-forest woody vegetation, which slightly increased in the landscape. The reason of that happened is increased size of solitaires and its spreading to the abandoned areas. Based on European Environment Agency, from 1990 the area of non-forest woody vegetation has been increasing, due to the extensification of the agriculture. Another reason for non-forest woody vegetation increasing is an intensive new tree planting.

Based on Demková (2015), the slight increase of non-forest woody vegetation is also connected with a spontaneous overgrowth of solitaires, and scattered greenery, mostly merge with a and it becomes a part of it. The biggest increase category of non-forest woody vegetation the is noticeable within non-forest woody vegetation in the landscape. Skaloš (2017) also finds similar result, where non-forest woody vegetation slightly increases in total area, but division of them is different in a way of subcategories change - one non-forest Land Use category replaces another in two different time horizons.

In most of the cases non-forest woody vegetation becomes a part of forests, as the result of forest expansion, and arable land together with a grassland becoming non-forest woody vegetation in the landscape or along the roads. The percent of continuous non-forest woody vegetation in a study area in 1841, was not detected.

## 7.2 Methodology discussion

The methodology was based on vectorization of the aerial photographs of the studied area from 1953 and 2020. After that, predefined categories of Land Use were assigned to the polygons created by vectorization.

Black and white aerial photos from 1953 have diverse quality, that could be affected by the atmospheric conditions and the quality of the recording material. Connected to that, there are several issues with identification of categories of Land Use. Particularly to find a difference between grassland, arable land and, and all the other land types defined with code 200. Other factors affecting the definition of the boundaries of small objects are their cast shadows, also dirt on the recorded materials. To make this step easier, have been used historical topographical colorful maps S-1952, scale 1:10 000, which been used in needs for Czechoslovakian army. Other reason for hard defining the border of small polygons, were the shadow and the dirt on the recorded material. Regarding the quality of current orthophoto images, it was way easier to define each Land Use comparing to photos from 1953. In case of hard category defining, it has been verified by field research.

# 8 Conclusion

In determined study area, for the period from 1953 to 2020, was monitored landscape, precisely non-forest woody vegetations. Whole study area stayed relative continuous, with the exception of forest Land Use, in a way of forest Land Use category change from one type of the forest Land Use to the another.

The most dominant landscapes in study area are forest, and forest agricultural landscapes, with impurities of arable landscape. That's the reason why the biggest change in the landscape are forest Land Use categories, changing from one to the another.

Talking about non-forest woody vegetation, all four non-forest woody vegetation categories, increased in surface area. The biggest change of non-forest woody vegetation surface area between from 1953 to 2020 was in non-forest woody vegetation, 2,48-35,03ha. The reason of this change is afforesting, which leads to forests destroying and group of trees formatting which can't be defined as a forest. Surface area is constantly changing due to natural, or anthropogenic influence, but the distribution, structure, and density of scattered greenery in the landscape, depends on which way landscape is used.

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**Legislations:**

Act no. 114/1992 Coll., on Nature and landscape protection, nature, and landscape protection, as amended.

Forest Act No. 250/1852 Coll., as amended.

Forest Act No. 289/1995 Coll., as amended.

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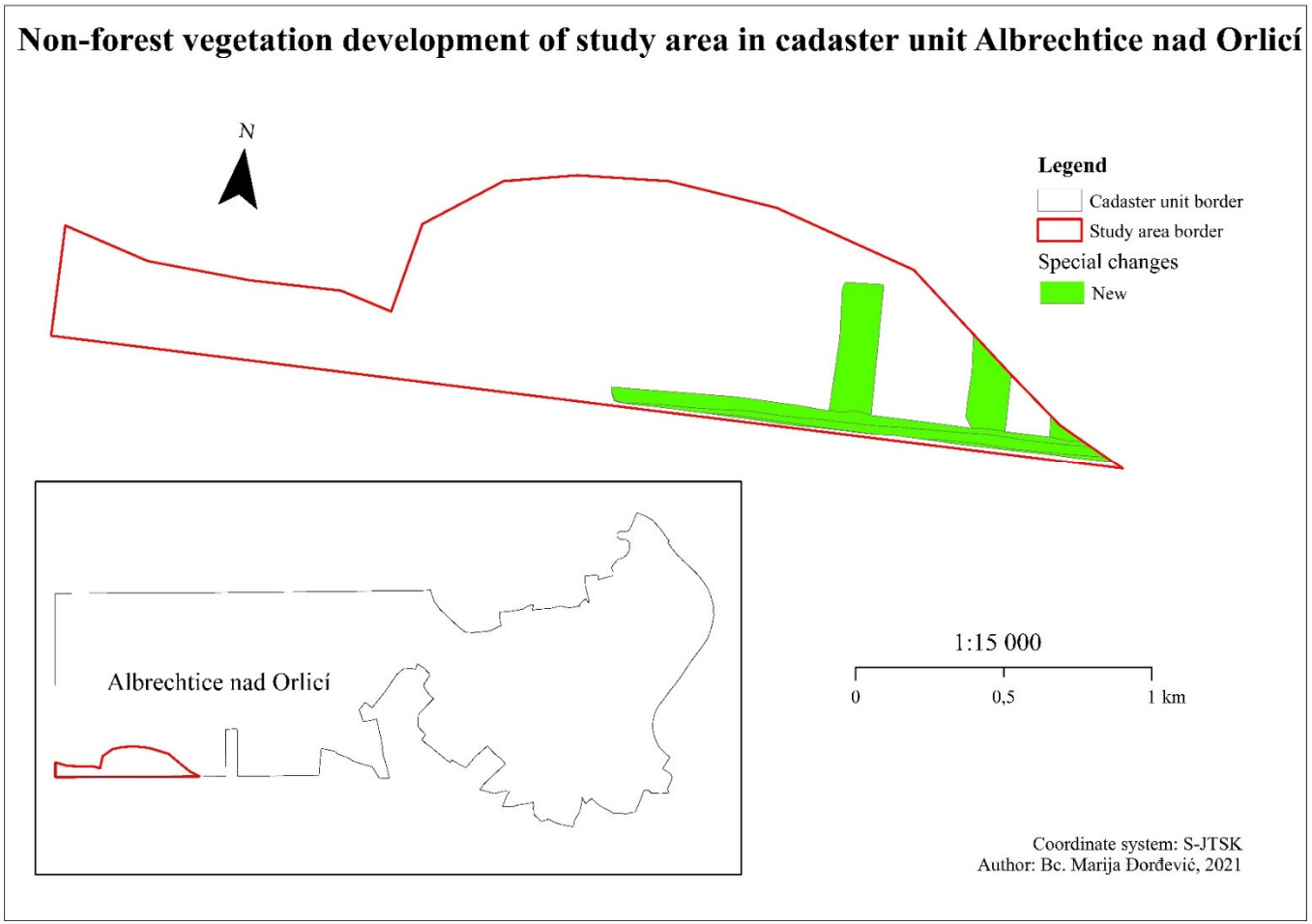
# 10 Attachments

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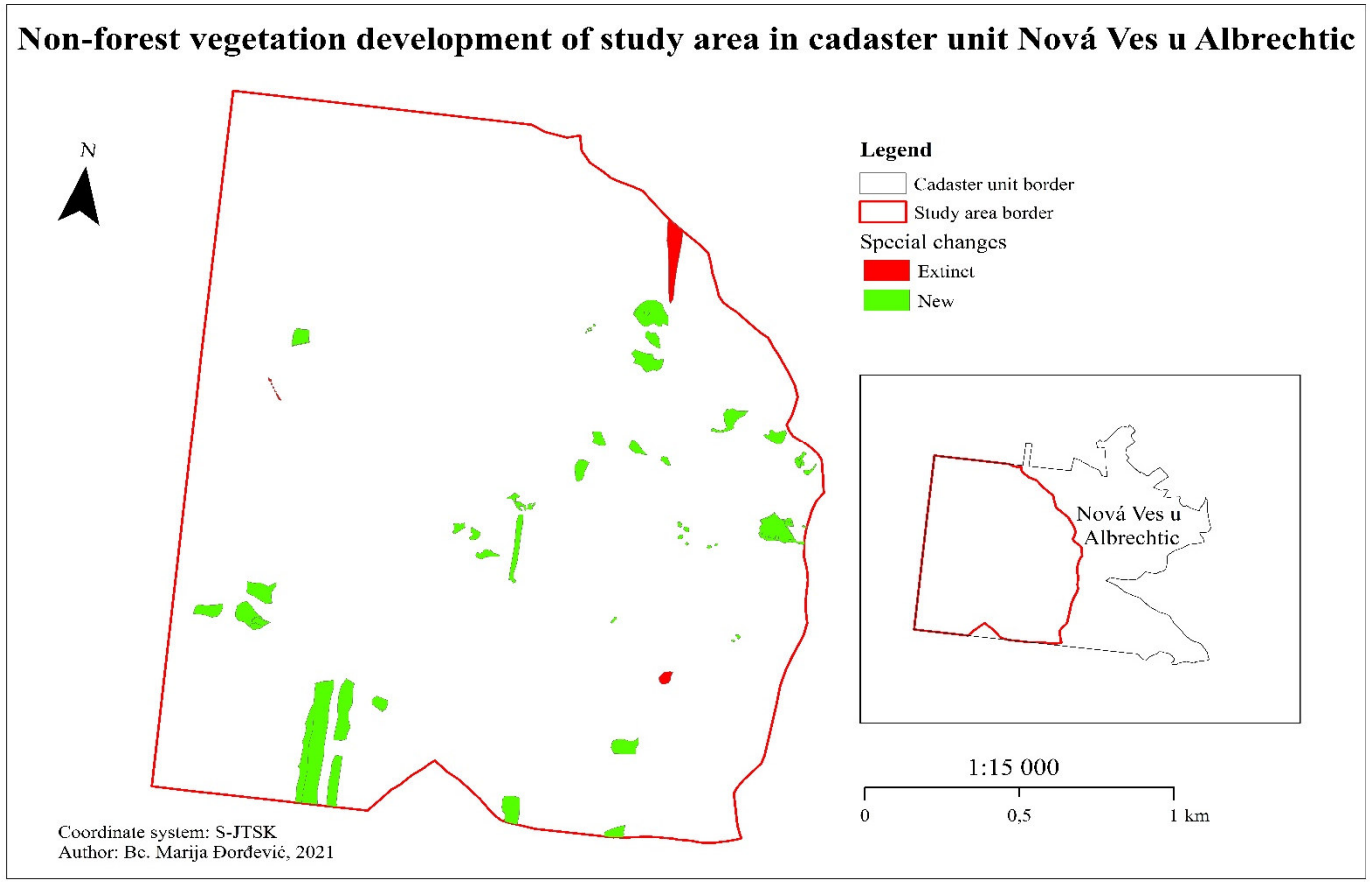


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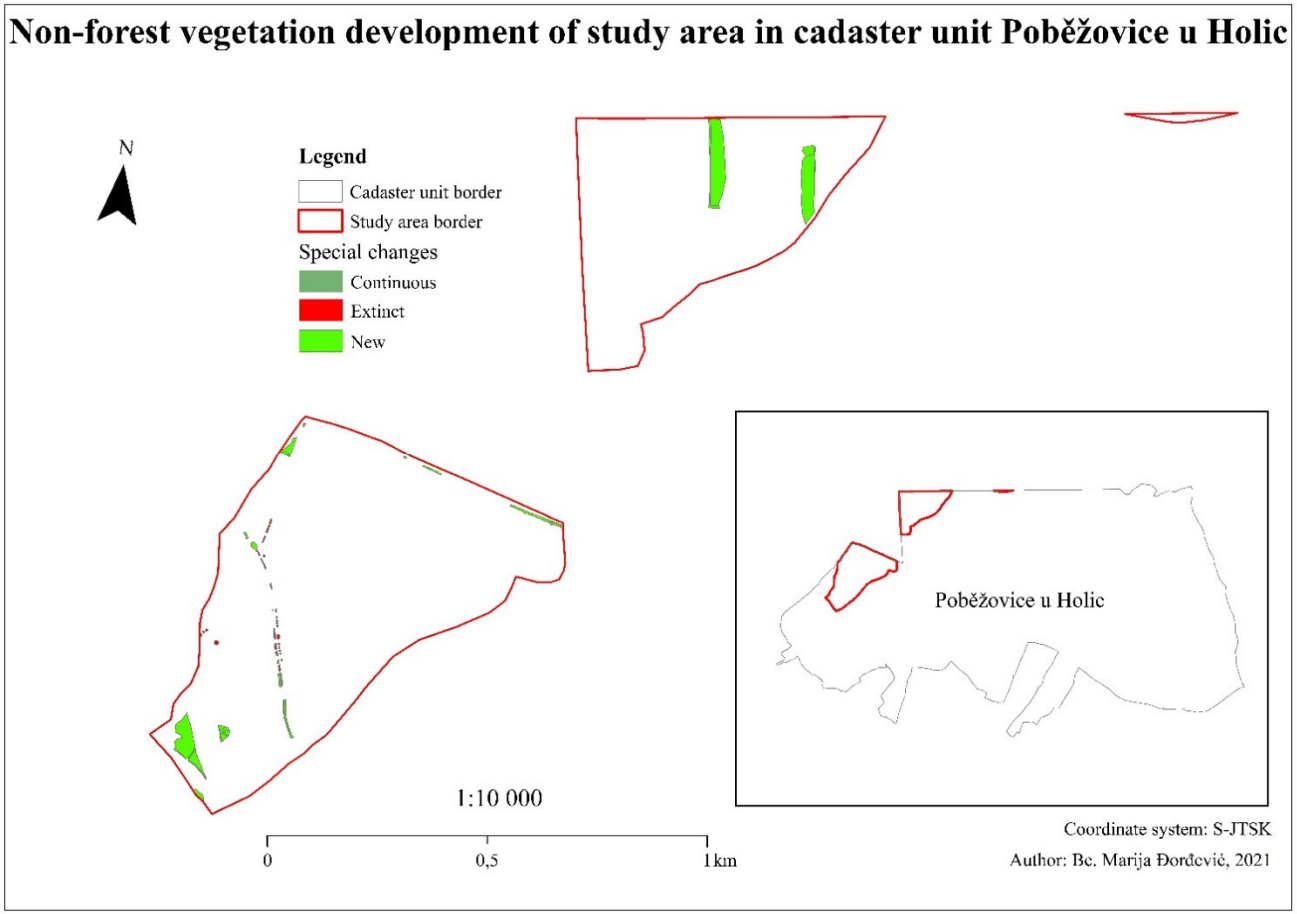
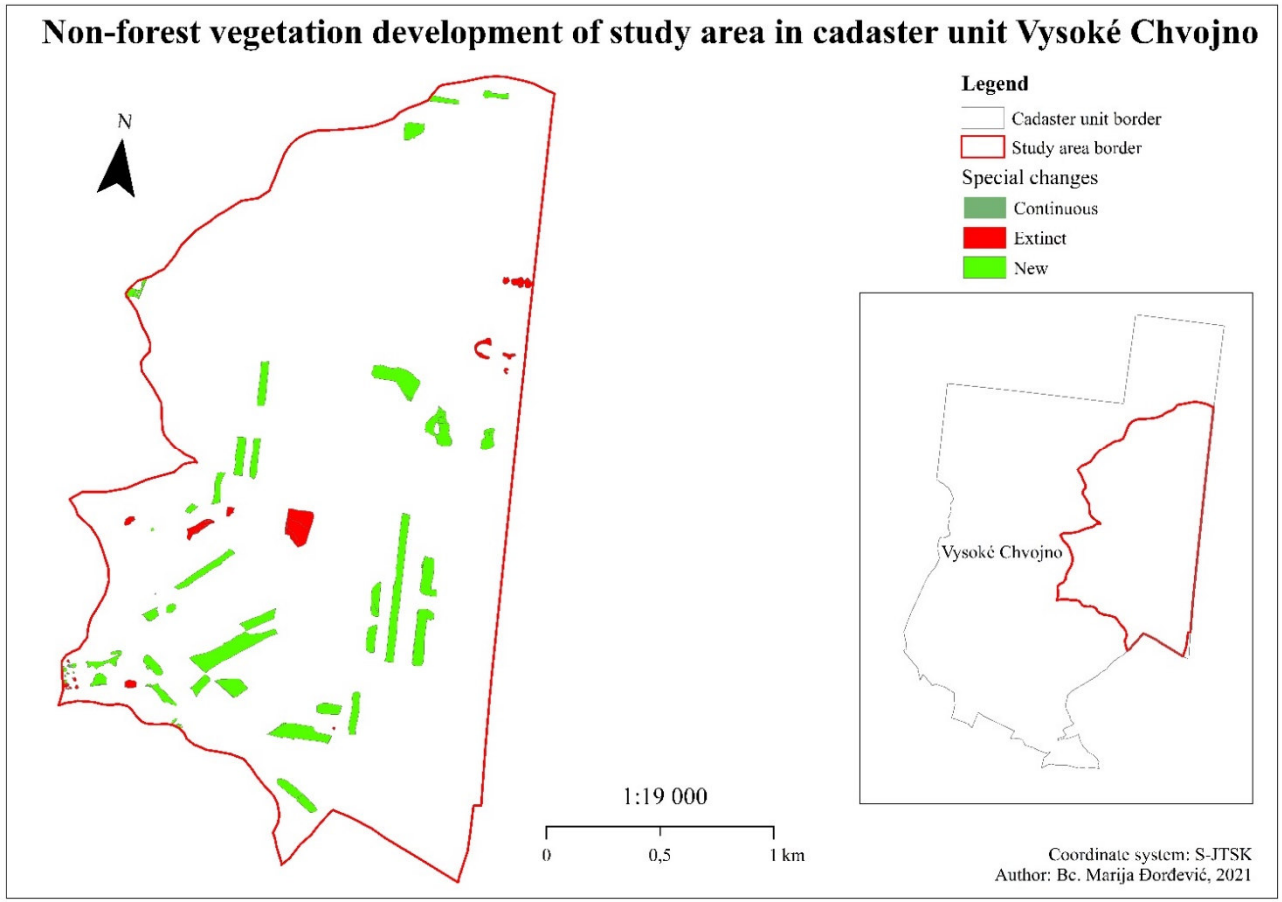



*Attachment no. 3: Non-forest woody-vegetation development of study area – Poběžovice u Holic from 1953-2020.*

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