CZECH UNIVERSITY OF LIFE SCIENCES PRAGUE

Faculty of Forestry and Wood Sciences

Department of Applied Ecology

The influence of damming on landscape structure change in the vicinity of flooded areas: Case studies in the Czech Republic

M.Sc. DIPLOMA THESIS

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DIPLOMA THESIS ASSIGNMENT

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Objectives of thesis

This study focuses on the evaluation of landscape structure changes, due to the realization of important hydrological facilities and more specifically to:

- evaluate those landscape structure changes;
- analyse the microstructure of landscape changes during the monitoring period;
- compare the development of landscape characteristics in both areas during the reporting time period;
- evaluate the level of nature and human impact on the landscape as a driving force.

Methodology

This study is presented from the perspective of landscape ecology. The principal issues will compare and contrast the interaction between human activities and semi-natural and natural areas and more specifically to:

- projection of the land use structure changes using aerial photo and GIS analysis

- comparison of place of interest

- prediction of future landscape structure development in the hydrological important areas in Czech Republic.

The proposed extent of the thesis

Approximately 60 pages of text and 10 pages of annexes

Keywords

Landscape patterns, GIS, aerial photo, hydrological facilities

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Recommended information sources

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Declaration

I hereby declare that this thesis is a presentation of my research study, which I wrote independently. This study was done under the guidance of my supervisor Ing. Zdeněk Keken, Ph. D., who provided me with other information. I have listed all literature and publications from which I have acquired ideas.

Whenever contributors of others are involved is made to indicate this research clearly.

In Prague, date ……………..   Signature ….………………………

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This work is dedicated to my family, and foremost to my grandfathers, who have always been an inspiration.

Abstract

The aim of this work was to analyze, evaluate and present landscape structure changes, due to realization of important hydraulic facility in four different areas in Czech Republic. The main objective of this work was to provide relevant scientific conclusions to help in future decision process within construction of dams and its impact on landscape structure change. Through study of historical aerial photographs from 1950s, and current orthophotos (2014 and 2015) from each area, has been analyzed the development of landscape microstructure characteristics, and the influence of significant water retention in the landscape. The analytic part was processed in the geographic information system (GIS), version 10.2, provided by Environmental Systems Research Institute (ESRI). For calculation of the landscape microstructure was used V-LATE extension for ArcGIS software, providing metrics to cover basic ecological and structure-related investigations. Other objectives of diploma thesis were to evaluate the level of nature and human impact on landscapes as driving a force, and capture the importance of involvement various sciences in decision process within construction of hydrologic facilities. The results has confirmed hypothesis of long-term increase in proportion of forest and urban areas in Czech Republic, with a maximum increase during the last 50 years. Specific characteristics of each dam site had the predominant impact on changes in landscape structure. Koryčany land cover structure has changed on 995.29 ha (from total area of 2085.76 ha) till today, where the most affected category was arable land - with loss of 97.34 % of the original state (in 1950). Number of patches (NP) index value in general has increased in all of the studied sites - specifically in forest land, arable land, and roads and facilities category, only except of Šance site, where the number in category of forest area has not changed. In case of Koryčany forest land category, the number has threefold. In Pilská increased from 13 to 34. The increased number of this index deduce that the level of fragmentation is now higher than in the past. In case of all four sites, Shannon's Evenness Index (SEI) had grown, but the values remain in the range and close to maximum number 1 - which indicate even representation of LC categories.

Key words: landscape patterns, GIS, aerial photo, hydrological facilities

Abstrakt

Cílem diplomové práce bylo analyzovat, vyhodnotit a prezentovat změny struktury krajiny v oblastech realizace vodních přehrad ve čtyřech různých lokalitách v České Republice. Hlavním cílem této práce bylo poskytnout relevantní vědecké výsledky, které by mohly být v budoucnu využity při rozhodovacích procesech v rámci výstavby významných hydrologických zařízení. Studiem historických leteckých snímků z roku 1950 a aktuálních ortofotomap (2014 a 2015) u jednotlivých zájmových lokalit byl analyzován vývoj charakteristik mikrostruktury krajiny a vliv významného zadržení vody v krajině. Analytická část byla zpracována v geografickém informačním systému (GIS), verze 10.2, kterou poskytuje společnost ESRI (Environmental Systems Research Institute). Pro výpočet krajinné mikrostruktury byl použit softwarový doplněk V-LATE pro ArcGis, jehož pomocí lze vypočítat řadu indexů ekologického stavu krajinných složek. Dalšími cíli diplomové práce bylo zhodnotit úroveň přírodních a antropogenních vlivů na krajinu a nastínit důležitost spolupráce různých vědeckých oborů v rámci rozhodovacího procesu v kontextu výstavby přehrad. Výsledky potvrdily hypotézu dlouhodobého zvýšení podílu lesů a zastavěných území v České Republice, s největším nárůstem za posledních 50 let. Jedinečná charakteristika umístění jednotlivých přehrad měla převažující vliv na změny struktury krajiny. Část výsledků ukázala, že od roku 1950 se struktura ve studované oblasti Koryčan změnila na ploše 995.29 ha (z celkové rozlohy 2085.76 ha), kde nejvíce zasažená kategorie byla orná půda - se ztrátou 97.34 % z původního stavu (do roku 1950). Hodnota indexu NP (number of patches) se obecně zvýšila ve všech zkoumaných lokalitách - nejvíce v případě lesní půdy, orné půdy a zástavby - pouze s výjimkou oblasti Šance, kde se hodnota NP u kategorie lesního pokryvu nezměnila. V případě Koryčan se NP u lesní půdy ztrojnásobilo, na území Pilská se zvýšilo z 13 na 34. Růst hodnoty tohoto indexu vypovídá o tom, že úroveň fragmentace krajiny je nyní vyšší než v minulosti. V případě všech čtyř oblastí zaznamenal Shannonův index vyrovnanosti (SEI) vzrůst, ale hodnoty zůstaly v rozmezí maximální hranice 1 – kde hodnota 1 znamená největší stabilitu území.

Klíčová slova: reliéf, GIS, letecké snímky, vodní díla, krajinná struktura

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List of used Abbreviations

GIS	Geographic informational software
LASW	Locations for the accumulation of surface water
LULC	Land use and Land cover
PLA	Protected landscape area
ESRI	Environmental Systems Research Institute
DIBAVOD	Digital water management data base
V- LATE	vector-based landscape analysis tools extension
MPS	Mean patch size
NP	Number of patches
MPE	Mean patch Edge
MSI	Mean shape index
MPAR	Mean perimeter-Area ratio
SEI	Shannon’s Diversity Index

1. INTRODUCTION

Landscape and water resources are very dynamic aspects of life on Earth, and both has changing on scale of time and space, where world landscapes are used and altered by humans more than other species. The tempo of the changes is increasing last decade dramatically, and the terrestrial transformation has history at least since Neolithic revolution more than 10,000 years ago. Till today more than 80 % of Earth's surface has been marked by human activity, where water is one of the main concern of climate change, and greatly threatened resource. With its essential role for any life on Earth has to be managed appropriately to its importance, beginning on the local level with regard to global scale.

Dam construction has been over the time of its long history very controversial topic, due to its indisputable impacts on the environment and ecology of many aquatic and terrestrial species, and with the effects on the transformation of the land cover and land use structure. For this very reason, complex of various research and analysis has to be done within the planning and management of potential reservoir realization. Not only immediate consequences appear after the built of the dam, but many of them conversely starting to show after decades, therefore long-term analysis is useful approach in the case of this field. Water scarcity and droughts occurrence has dramatically escalated over the world, where Europe and the Czech Republic territory is not an exception. It has become to be in the center of discussion in many studies and not only within ecological scientific disciplines, but in the socioeconomic sphere as well. According to the efforts of the needed solutions and applications of fight with the drought and water scarcity phenomena can dam realization play an important role as well, and has been already reflected in EU policies and national initiatives. For example one of the approaches within the Czech Republic is Locations for the accumulation of surface water (LASW) as one of the adaptation measures for possible solution in question of climate change issue.

ArcMap GIS program has been used in this work, which is very useful tool for landscape structure analysis and offers various of tools for digitizing and additional extensions for evaluating of landscape microstructure, which is essential in ecological research approaches.

Each of the study site within this study is in the area of Czech Republic and has some specific characteristic and factors, which has influenced the development of all components in the territory.

2. LITERATURE REVIEW

2.1. Surface water hydrology

2.1.1. Substance of water and its dynamic

Since the first single-cell organisms appeared on Earth, all life is depended on water, and from that time, until recent history, there was a balance between needs of living organisms and water resources. Human species appeared less than 100,000 years ago, about 10,000 years ago developed stone tools and learned how to grow their own food. In last hundred years the world population tripled and water use even sixfold (Cosgrove and Rijsberman, 2000).
With growing number of people has grown their needs as well, and water always been vital part of human life - for drinking, crops and fiber production, and last decades for the biggest water consumer - industry. Furthermore, water provides recreational benefits and it is one of the greatest aesthetic element of the landscapes. There is also wide range of cultural, spiritual, and religious values related to water, especially in arid regions.
Compare to other natural resources, water is exceptional with its greatly distribution on our planet. Basically, water is present everywhere and plays vital role in both environment, and human life (Shiklomanov, 1998).

Water is present in three different states: liquid forming oceans, lakes and rivers; solid as ice and snow; and in the air as water vapor. It is part of composition of different minerals of the Earth’s crust and core. Water is extraordinary by its extension, and very dynamic, continually changing within all its forms, therefore is complicated to assess the total water storage on the Earth.

According to estimates from 1998 - which can be found in the Monograph on world water resources - Earth's hydrosphere contains about 1386 million cubic kilometers, but about 97.5 % of this amount are saline water and only 2.5% is fresh water. Therefore, when we consider that circa 68.7% of the fresh water is in the form of ice and permanent snow cover, and next 29.9% exist as fresh ground waters, only 0.26% of the total amount are concentrated in surface water system (Shiklomanov, 1998).

The vital process of global hydrological cycle on Earth turns over every year about 577,000 km^3 of water (Shiklomanov, 1998). It is possibly the most basic cycle, with strong influence on the other biochemical cycles - for example on turnover of carbon, nitrogen, or phosphorus. Moreover, it directly affects the global circulation of both atmosphere and ocean, and it is auxiliary in shaping weather and climate (Eagleson, 1986). The turnover of water includes processes of oceanic surface evaporation, atmospheric precipitation and both river and groundwater runoff, where all of them are source of fresh water. Each element of the hydrologic cycle is replenished during the turnover, varying in length. For example, full recharge of oceanic water takes about 2500 years, permafrost and ice around 10,000 years, and rivers some 16 days (Shiklomanov, 1998).

2.1.2. Static storage components, renewable water resources and river runoff

In hydrology water resources are often distinguished into static storage components and renewable water resources. The first mentioned includes freshwaters with a long refill period - many years or decades - such as large lakes, groundwater or glaciers. With longer renewal time are these components more fragile and their restoration takes even several decades. The second group, renewable water resources, takes only months or years in the hydrologic cycle event. According to Shiklomanov (1998), the mean value of renewable global water resources is measured at 42,700 km^3 per year, and the greatest renewable water resources are concentrated in six main countries of the world, which have more than 40% of total annual river runoff (ARR): Brazil, Russia, Canada, USA, China and India. River Amazon for example produces about 16% ARR. Despite the river great ability of self- purification, it is at the same time one of the most exposed, and affected waterbody. While rivers are the most widely distributed over the land surface, the value of river runoff is in practice used to estimate water availability, or deficit in water resources. River runoff is estimated as the volume per unit of time (e.g. m^3/s), and it is irregularly distributed during the year, where about two thirds is produced during spring flood periods. Therefore, there is a need of regulation of the flow, by creating reservoirs and other hydrologic facilities (Shiklomanov, 1998).

2.1.3. Water use and water consumption

Water resources were used by human as long, as our history is, consumed and freely used for wide range of purposes. The great ability of renovation during water cycle and self-purification, allows condition of relative purity, quantity and quality for long time. Unfortunately, these amazing capabilities of water gave us illusion over time, that it is “bottomless” source and free gift from the mother nature. Water resources has been treated in this way for centuries, and all the unfavorable man’s activities have consequences, which have now being discovered. The main breakthrough in history was Neolithic revolution, and Industry revolution, which have drastically shifted the insignificant, and entirely local impacts to a global threat . Since 1950s, along with scientific and technological revolution, started harsh increase in global water withdrawal, bringing expansion of irrigated areas, growth in heat and power engineering water consumption, and intensive water reservoir construction, everywhere in the world (Shiklomanov, 1998).

2.1.4. Anthropogenic changes and their impacts on the terrestrial water system

Some of the major agents of anthropogenic change according to analysis of Vörösmarty and Sahagian (2000) are: aquatic mining, surface water diversion, desertification, wetland drainage, soil erosion in agricultural regions, deforestation and dam construction. Some globally urgent and commonly recognized are discussed below:

- Aquatic mining

Mined fossil groundwater is in most arid and semi-arid regions main resource for irrigation and other uses, but rates of water recharge are very low, thus most of it is transferred to atmosphere. This translocation means reduction of continental storage and at least transitory increase in atmospheric water vapor through the enhanced evaporative flux (Vörösmarty and Sahagian, 2000).

- Agriculture and surface water diversion

Irrigation has been practiced as long as human cultivate the land, but the dramatic expansion has mainly taken place during the 20th century. Agriculture is now counted to be the largest consumer of water, with some 80% of total water use, which was in 2007 about 2 722 km^3, from which some 1 676 km^3 was withdrawn only in Southern and Eastern Asia (FAO, 2015). Population growth is one of the main accelerator, which brings increasing demand of necessity to maximize the food supply for humanity. Moreover, agriculture in more dry regions leads to increased evaporation, and net loss of continental water, but more importantly to disrupted and restructured natural river flow regimes. It could cause significant changes in both long-term net runoff and timing and magnitude of downstream peak and low flows. Soil erosion is another result of some cropping practices, which makes soils to erode, evaporate less and more likely to be less productive (Vörösmarty and Sahagian, 2000).

One of the anthropogenic influence is terrestrial landscape fragmentation - for example stream channelization, flow regulation, and water extraction - causing hydrologic connectivity shatter as well (Pringle 2001).

- Desertification

Overgrazing is one of the main cause of drying marginal soils, particularly in semi-arid lands, reducing evaporation and increasing storm runoff, and also causing a net loss of soil water storage (Vörösmarty and Sahagian, 2000).

- Deforestation

It is commonly known that forest is a great water storage. Therefore is believed, that extensive deforestation leads to a reduction in the recycling rate of water between plant canopies and the atmosphere, and thereby affects the climate system (Vörösmarty and Sahagian, 2000).

- Municipality water use

Water withdrawn by populations depends on various factors. The major are: the size of an urban area, water availability, climatic conditions, as well the level of technical development of the area. Municipal water withdrawal in world makes 462 km^3 per year in total, where 72 km^3 is in Europe and only 27 km^3 whole Africa (FAO, 2015).When we consider all the mentioned major factors, which are affecting the amount of water withdrawn, these numbers corresponds to the reality in these areas. A bigger part of the water is being returned to the hydrological system, after use as waste water, if urban sanitation works effectively, purified or not, depending on level of development of the area (Shiklomanov, 1998).

- Water in industry

Industrial total water withdrawal in the world is about 734 km^3 per year (FAO, 2015), and it is used for cooling, transportation, and as a solvent in washing. Major users are thermal and atomic power plant, where great amount of water is required to cool assemblies. As well as in case of municipality water use, it depends on climatic conditions and on particular technology of the industrial processes and production. Industry by itself is one of the biggest source of water pollution, where much of the intake is discharged as waste water to natural water courses. One of the anthropogenic factor is also terrestrial landscape fragmentation - for example stream channelization, flow regulation, and water extraction - causing hydrologic connectivity shatter as well (Pringle, 2001).

2.1.5. Forecasting of future water requirements

According to Wallace (2000), the greatest and most major global change is massive increase of world population, which will occur next 50 years. He points out, that this change is more certain and more important than issue of atmospheric CO_2 concentration, and that the water requirements associated with producing food for future world population are enormous, and more than likely to occur (Wallace, 2000). Fisher and Heilig (1997) pointed out, that the world's population would double by 2050, and that most of the increase will occur next 20 to 30 years, which means very short time for us to get prepare for these conditions.

2.1.6. Challenges for hydrologic science

Hydrology made great progress in understanding of the manner of small and relatively unchanging systems, in the shorter time scale. However, nowadays is bigger need to focus and do more research on large-scale issues, where is necessary to have more sophisticated understanding of the nonlinearly interacting parts (Killeen and Abrajano, 2008). Furthermore, we should be now prepared to implement recent advances in the technological ability to observe, store, analyze, visualize, and transmit relevant data collected over large parts of the world at appropriately fine resolutions.

All threats like water scarcity, floods, and other environmental consequences of human behavior, poses to us enormous challenge, which way we will lead hydrologic science (Wagener et al., 2010).

2.2. Climate change

Climate change is nowadays accepted without doubts as a real, and urgent global issue. The main concerns are - how much climate change there will be, what impacts will result, and how to adapt to them. And moreover, how to alleviate the causes. There abide many objections to either the quality of science behind global warming, and the nature of cause and effect. The politicians are increasingly aware that the climate change risks are to extensive to ignore them, and delaying get into an action would be far more costly than not doing so. And the possibility that the scientists are wrong is not worth taking as well (FAO, 2015).

Its commonly known that most of the impacts of climate change will relate to water, and will affect every element in the water cycle. Water plays crucial role in agriculture sector (crop and animal production), forest ecology, and in fact in any part of ecosystem, including livelihoods of societies; and therefore water management should be in the center of climate change adaptation strategies (FAO, 2015).

Changes in the distribution of precipitation, with longer periods between rainfall events and more intense precipitation, are expected everywhere. This may lead to increased occurrence of extreme weather events, including floods and droughts (FAO, 2015).

As consequences of growing human population and great development of technology, we continue to modify atmospheric composition, water quality, and land surfaces, as well as introduce a host of novel chemicals into environment. Moreover, we have moved species beyond their natural boundaries, creating exotic invasions. Not only changes which occur on a global scale (e.g. changes caused by greenhouse effect), but even regional changes (e.g. habitat fragmentations) has sufficient frequency enough to be global in scope (Root and Schneider, 1995).

“Water availability will be a serious constraint to achieving the food requirements projected for 2025. The need for irrigation is likely to be greater than currently anticipated, and the available supply of it less than anticipated. Groundwater overdraft, salinization of soils, and re-allocation of water from agriculture to cities and aquatic ecosystems will combine to limit irrigated crop production in many important food - producing regions. At the same time, more and more countries will see their populations exceed the level than can be fully sustained by available water supplies” (Postel, 1998).

2.2.1. Extreme events in changing climate - Water scarcity and droughts

Economic, social and environmental development, where is water strategic resource, is now challenged by water scarcity and droughts. Regard to this circumstances, it is reflected in European Union (EU) water policies, and in national growing initiatives (Estrela and Vargas, 2011).

Deficiency of precipitation from expected or normal leads to drought, which can leads into insufficient amounts to meet the water demands of human activities and the environment (Wilhite and Buchanan, 2005).

The impacts produced by droughts are numerous, as keeping populations receive a minimum water supply, having effect on crop yields and environmental ecosystems, or increase pressure among users, among the problems. It can be worsened when they occur in regions already affected by low water levels, with imbalances between the available resources and the water demands. Moreover, it is expected that climate change will create negative direct impacts on the available water resources in the most assailable EU regions (Solomon, 2007).

There are relevant EU policy tools such as the Water Framework Directive 2000/60/EC (European Parliament and Council of European Union 2000), or a specific communication on water scarcity and droughts entitled: “Addressing the challenge of water scarcity and droughts in the European Union”, from the European Commission (EC) to the European Parliament and Council in 2007. In addition, a policy review on water scarcity and droughts is currently being carried out to be integrated into the “Blueprint to safeguard European Waters” (an EU policy response to recent water challenges, related to the EU 2020 Strategy and the Resources Efficiency Roadmap). The Water Framework Directive (WFD) determine a legislative framework for community action in the field of water policy, introducing a new perspective from a modern view of water policy to all member states of the European

Union, and aiming at improving and protecting the status of water bodies along Europe, with specific environmental objectives for 2015. The WFD also provides general criteria to consider drought impacts in the status of water bodies.
The communication of EC, which responds how to address water scarcity and drought issues, and has introduced different technical and political initiatives to mitigate their impacts, emphasizes that water saving must become the priority, and recommends shifting from a risk to a planned drought management approach, that would become evident like in other areas, such as the United States (Wilhite et al., 2000).

In relation to droughts, in Europe have been carried out important efforts in the scientific and technical field, such as ARIDE, SEDEMED, WAMME, PRODIM, MEDROPLAN, WATCH, MIRAGE, XEROCHORE and others. These projects are trying to increase the knowledge on droughts in different research areas and regions, providing additional tools and experiences for policy makers and water managers (Estrela and Vargas, 2012).
These initiatives started to appear not only in southern Europe, but in other European countries as well, and there was a need to make a document dealing with this issue at the European level, including recommendation what the drought and water scarcity management plans should include and how would they look like. Therefore, so-called Drought management plan report have been made (European Communities, 2007). For effective planning during the season of droughts and water scarcity within individual countries of EU, not only good legislation is needed, but also a quality monitoring as a base of it. For that reason European Drought Observatory (EDO) by Joint Research Centre (JRC) was founded, aiming to contribute better understanding of consequences on each region and enable to compare them (Treml, 2013). In central Europe is complex monitoring system still missing, most of them are too simplified, only in Bavaria (Germany) is more developed. There are more sophisticated systems in the world, probably the most elaborated is in USA, where the drought management plans are made for each state and complex monitoring covers the whole area – e.c. U.S. Drought Monitor (Treml, 2013).

Similar project is in Czech republic as well, with ambition to cover the problematic of droughts with complex monitoring and group of scientists covering variety of disciplines. One of their objectives is to study history of these events and try to find a solutions for future crisis. The main concern is to develop this project on the same level as can be found in the world (Brázdil, 2015).

In drought management planning concepts may be included Master Plan of Locations Protected for Accumulation of Surface Waters as well, which will be more discussed later (Ministry of agriculture, Ministry of environment of Czech Republic, 2011),(Treml, 2013).

2.2.2. Impacts of climate change on water balance and water resources in the Czech Republic

Hydrological regime affected by climate change is visible in Czech Republic already for several years. Changes of air temperature are the most evident, which in the periods of 1961-1980 and 1981-2005 had approximately grown in average by 0,6 to 1,2 °C. Temperature is essential factor influencing hydrological balance, in particular because with rising temperature the evapotranspiration is growing. Observed growth of air temperature leads to evapotranspiration increase in year average approximately about 5 to 10 %. The growth of evapotranspiration is in most of area of the Czech Republic compensated by precipitation increase, however some river basins in central part of the country are incapable of this compensation, and their hydrological balance is passive for a long time. River basins in these area are the most affected by the climate change, leading to water resources scarcity during some years. Climate change may bring - or extend problems in both climatic extremes of the hydrologic cycle, either drought periods, and floods appearance. In both cases are the conditions not ideal from social human needs point of view - as water demand and waste water drainage dilution in case of droughts; and as demand for safety of populated areas, in case of flooding episodes. Both extremes could affect ecosystems at areal level, especially river basin ecosystems. Crucial is, that appearance of water scarcity periods are expected more likely than increase of flood causing heavy rainfalls (Pretel et al.,2010).

There were made few more or less detailed cataloged adaptation measures at the European level, however not all of them are suitable for use in Czech Republic. Therefore overview of major adaptation measures was made within the project of Ministry of the Environment, which could be use in our conditions.

Possible adaptation measures:

- Adaptation in landscape - organizational (support of areal diversity within complex land regulations, afforestation and grassing, restriction of crops causing impervious subterranean layer,e.g. corn), agro-technical (e.g. crop rotation practices supporting infiltration) and biotechnical.
- Measures of water streams and floodplains - river basin restoration.
- Measures in urban areas - increase of rain water infiltration (retention and infiltration facilities) and rain water use.
- New water reservoir construction and reconstruction of old ones.
- Effective management of water resources - temporary utilization of still underground water reserve, artificial infiltration, multiple water usage, capacity of water resources evaluation and redistribution
- Water use reduction - waterworks water loses reduction, priorities of critical water scarcity condition assessment, and melioration of waste water purification (Pretel et al.,2010).

2.2.3. Sites for Accumulation of surface water in the Czech Republic

One of the most significant hydrology measures is slowing of outflow and retaining water in landscape. Use of water reservoirs is documented since the birth of the first civilizations (4000 BC in India), and water cisterns are mentioned even in the Bible (Lancaster, 2008). Specific territorial demands for building water reservoirs and polders has gradually increased, and need to prevent potential conflicts with other human activities has appeared. Therefore, morphologically, geologically and hydrologically suitable locations were actively searched, and protected for potential future implementation of hydrological facilities. Technical suitability is only first precondition, and it has to be put in context with other socioeconomics and environmental aspects of those locations. Only based on all these conditions is possible to find objective conclusion of decision making processes and may lead to realization of hydrological facility (Martiš, 2011).

Locations for the accumulation of surface water (LASW) are one of the adaptation measures for possible solution in question of climate change issue in horizon of the next 50 to 100 years, while some areas suffer from water scarcity or flood periods. Each of the planned water reservoirs is multipurpose with one priority function. By declaring individual LASW was created essential basis for land protection within landscape planning, until the first river basin management plans are accepted. So the hydrological important areas were supposed to be protected from any activities, that could complicate or stop the dam construction in the future (Zdražil et al., 2011).

For the area of Czech Republic was territorial protection of LASW first time comprehensively specified within processing The baseline ČSR water management plan, approved in 1975 (MLVH, 1975), (Zdražil et al., 2011).

Some of the locations was excluded during the years, because of the conflicts with nature and landscape conservation interests, or with existing settlement infrastructure. The parameters were for certain locations modified to eliminate disturbing effects on the environment, in terms of reduce landscape aesthetic value, population displacement or flooding of natural monuments (Zdražil et al., 2011).

Updated list of LASW could be found in the Master Plan of Locations Protected for Accumulation of Surface Waters according to § 28 Act No 254/2001 Coll., amended, with publication date in 2011. In purpose of making this plan was established working group, composed from representatives of Ministry of Agriculture and Mistry of the Environment (Franková and Dobrovský, 2009).

The localities are designed in two categories:

- Strategic locations, which are usable for drinking water supply, while the real need of utilization will be assessed in the horizon of 50 years and linked to evaluation of climate change consequences. At the same time, locations must enable fill the tanks even in case of anticipated climate changes, particularly in case of extreme fluctuations in the distribution of rainfall during the year. They are evaluated from the nature conservation point of view as well, and excluded in case of conflict of interest (e.g. presence of endemic species, unique nature area).
- Locations appropriate for water accumulation for purpose of flood control protection, meeting requirements to ensure environmental flows of watercourses. Areas are excluded in case of conflict with nature conservation at national level or with specially protected territories of national nature reserves and national natural monument category and with first and second zone of national park.

Based on unacceptable conflicts, 69 localities were proposed, and about half of them still struggles with issues of overlaps with nature and landscape conservation. Discussions are still going on at six sites in the most valuable parts of the national parks and protected areas. Possibility of exclusion some areas out of the Master Plan is still being discussed, based on sufficient territorial protection of the Act No 114/1992 Coll., On nature and landscape protection, as amended (Zdražil et al., 2011). Based on the water law (254/2001 Coll.), LASW are specified as morphologically, geologically and hydrologically suitable areas for accumulation of surface water, in purpose for reducing impacts of floods and droughts; which can be specified in the Territorial Development Policy and the territorial planning documentation as territories protected for accumulation of surface waters against other development activities. It is only possible to change the existing utilization, locate buildings or perform other activities on these territories, if they do not exclude- or significantly complicate their future utilization.

There are some protective limits resulting from the definition of LASW territorial reserve, specifying which projects and placement is not possible to make, especially:

- Technical and transport infrastructure buildings of an international, national and other supralocal importance.
- Buildings and equipment for the industry, power engineering, mining, farming; and other facilities or activities, that might interrupt the geological and morphological situation on the projected dam site, or otherwise affect the future hydrological utilization of the water reservoir by the actual size of the buildings on the specified territory (e.g. complexes of housing structures – housing satellites).
- Large commercial areas and demanding lines of technical infrastructures and their subsequent operation (e.g. dump sites for special and hazardous wastes, sludge lagoons, fuel storages, etc.), (Martiš, 2011).

Territorial protection of LASW is still being perceived as controversial, despite its more than 35 years history. Current level of protection level does not exceed the level of protection, for example, in case of areas designated for nature and landscape protection under Act No 114/1992 Coll., as amended. However it is obvious while analyzing the individual local plans , that more than a quarter of valid land use plans does not have required levels of area protection for these locations so far. Regard to final number of potential usable area (limited by morphological, geological and hydrological conditions) is need to align all levels of territorial planning documentation as soon as possible (Zdražil et al., 2011).

2.3. Surface water retention - effects on spatial and temporal change of land use

2.3.1. Land use and land change

Till today about 50 % of the earth's ice-free land surface has been transformed, and in fact, there is no place on Earth which would be untouched either directly - by such processes as co-adapted landscapes, or indirectly - by climate change and tropospheric pollution. Implications of global environmental change of ecosystem and sustainability are today major research challenge for the scientists (Foley, 2005).

2.3.2. Water retention - dams

Scientists nowadays are challenged by the environment changes and its consequences, and one of important measures is water retention and deceleration of runoff in landscape (Zdražil et al., 2011).

First mentions about water reservoirs may be found already 2300 years B.C. in China. In the area of Czech Republic is larger expand of ponds dated in 12th and 13th century, during the reign of Jan Lucemburský (called John the Blind), but first mentions could be already found in 10th century, mostly in association to water retention for technical purposes.

Dam could be defined as a barrier that impounds water or underground streams, suppress floods; and also provide water for such activities as irrigation, human consumption, industrial use, aquaculture, and navigability. Hydropower constructions are used to generate electricity as well, largely expanded in developing countries. Dams can also be used to collect water, or as a storage of water for even distribution within landscape, as well for recreational purposes. Large numbers of dams have been constructed to date, to meet water and energy demands. Many of the post-dam era changes became evident only over a long time period (Woldemichael et al., 2012). But some dry landscapes could have immediate response by the increase of the water surface area, causes that more water is exposed to air and direct sunlight, therefore increases evaporation and enhance moisture supply for precipitation, hence serving as a feedback on precipitation. This means water flowing to atmosphere, and it is referred as consumed, because it is removed from the system of the area. This water consumption can be quite substantial in some conditions (FAO, 2014).

Recently has been developed a method for estimating evaporative source regions for extreme precipitation at selected European locations (Gangoiti et al., 2011).

By using a mesoscale model and kinematic 3D back trajectory techniques, their study had shown, that terrestrial evaporation can play crucial role in creating extreme precipitation episodes. In another study by Kunstmann and Knoche (2011) has been demonstrated, by tracking the evaporated moisture from lake until it has returned to the source as precipitation, that up to 8 percent of the precipitation can be traced to water evaporated from the lake region (Kunstmann and Knoche, 2011). Close landscapes are influenced by dams not only by evaporative feedback mechanisms, but through major changes in the land scape and land use changes- such as road facilities or urbanization of downstream area, which become inhabitable, owing to a reduced risk of flooding (Woldemichael, 2014). In addition to that, other important phenomenon created by urbanization can be found. Urban heat island (UHI), which induce a kind of air circulation, that is characterized by differential heating capacity between the rural and urban areas (Shepherd et al., 2005). This phenomenon of UHI effect may also be enhanced by the emission of pollutants from industries, automobiles, and building facilities, which can serve as cloud condensation nuclei (CCN) and ice nuclei (IN) associated with the formation of precipitation (Marshall et al., 2004; Huff, 1986; Rosenfeld et al., 1995).

2.3.3. Adverse environmental impacts of dams and mitigation options

- Flooding of natural habitats

Flooding of natural habitats is one of the immediate impact, which can have great consequences like global species extinction. It could be seen the most in tropical regions, due to rich biodiversity and very large size of the built dams, but it affects all riparian ecosystems, from conservation point of view. Aquatic habitats created by the construction are usually not that valuable like the flooded ones. On the other hand, occasionally in dry zones can reservoirs provide an oasis for migratory waterfowl and other fauna (Quintero and Ledec, 2003).

- Involuntary Displacement

Displacement of people and whole villages is another negative impact, not only from social perspective, but it also has environmental implications such as conversion of natural habitats to take resettled rural populations. The physical relocation itself includes resettlement of displaced populations, including replacement lands, new housing and other material assistance. This situation could be very difficult in case of ethnic minorities, where people are more susceptible to those changes (Quintero and Ledec, 2003).

- Deterioration of Water Quality

Discontinuation of river and hence riparian zone, can greatly affect all interconnectedness within it, and cause serious water deterioration in reservoirs, as result of reduced oxygenation and dilution of pollutants by relatively stagnant water. It results underwater decomposition of flooded biomass and causing stratification of the reservoir in layers, where the low layer lack oxygen. These phenomena can be partly mitigated by selective forest clearing within the impoundment area before filling the reservoir (Quintero and Ledec, 2003).

- Downriver Hydrological Changes

Riparian ecosystems, as was already mentioned, are dependent on regular natural flooding and could be greatly affected or destroyed by segregation of these channels. Especially in downriver and estuaries parts, the biological and economic productivity get damaged, due to limited income of nutrients and absence of natural flows.

Dam holds back sediments that would naturally refill downstream ecosystems, and when the down sited stream is devoid of its sediment supply, it is trying to recapture it by eroding the downstream river bed and banks. Fact that the riverbed is getting deeper, will also lower groundwater tables along the river, lowering the water table available to plant roots. Transforming the riverbed also reduces habitat for fish that spawning in river bottoms, and for invertebrates. Minimizing these disruptions can be done through cautious management of water releases-like ensuring adequate downriver water supply for riparian ecosystems and downriver fish survival, increasing reservoir and downriver water quality, natural water debris presence. Controlling aquatic weed presence, and other measures, which are critical for maintaining physical processes and habitats downstream of the dam (include the maintenance of productive deltas, barrier islands, fertile floodplains and coastal wetlands), (Quintero and Ledec, 2003).

- Water-Related Diseases

Transformation of fast-flowing rivers into partly stagnant water bodies can cause spreading of some infectious diseases around the reservoir, especially in tropical climates, where some of the diseases have vectors born in water and others are spread by contaminated water (Quintero and Ledec, 2003).

- Fish and Other Aquatic Life

There is numerous and various environmental consequences of dam construction, including direct impacts to the biological, chemical and physical features of rivers and riparian environments, affecting fish and other aquatic life. Certain species could be favored by new conditions of the reservoir, but most of them are hit negatively. The dam blocks fish migrations; which in some cases could completely separate spawning habitats from rearing habitats; and captures sediments critical for maintaining physical processes, and habitats downstream of the dam (comprise the maintenance of productive deltas, barrier islands, fertile floodplains and coastal wetlands). Water in the reservoirs may become thermally stratified, depending on a number of factors, like water retention time and the depth of the reservoir (FAO, 2014). All the changes in temperature, chemical composition and the physical properties of a reservoir are often not acceptable by the aquatic plants and animals that evolved within river system. In addition to it, newly built reservoirs often host alien and invasive species, that further disturb the river's natural communities of plants and animals. Alleviate of negative impacts on fish and aquatic life becoming one of the biggest challenge of nature conservation.

Management of water releases may be needed for the survival of certain fish species; in and below the reservoir; building fish passage facilities, (e.g. fish ladders, elevators, or trap-and-truck operations), to enable movement for migratory species. Often essential measure in downstream area- fishing regulation- could help to maintain viable populations of commercially valuable species. In particular in the waters immediately below a dam where migratory fish species concentrate in high numbers, and are unnaturally easy to catch (Quintero and Ledec, 2003).

- Floating Aquatic Vegetation

Increased amount of aquatic vegetation could be another "post-dam" effect, which can cause degradation of habitat for some species of fish and other aquatic life, improve breeding grounds for some insect species and disease vectors.

Solution for dealing with aquatic weed outbreaks seems to be very difficult to achieve. Despite fact that physical removal or containment of floating aquatic weeds is effective, it imposes a high and recurrent expense, especially for large reservoirs. Occasional drawdown of water levels may be effective in killing some weeds, but it has to be very carefully considered, where the decreased water levels would be compatible with other objectives as fish survival, power generation and other possible affected areas (Quintero and Ledec, 2003).

- Loss of Cultural Property

Inundation of cultural areas by reservoirs itself, or destroyed by associated road and other construction, is another circumstance which occur with water reservoir establishment. In this case, local policies and laws should be in charge, and historians having decision-making power in preconstruction assessment (Quintero and Ledec, 2003).

- Reservoir Sedimentation

Some hydroelectric projects might not be renewable over long term, or functionality may be reduced by reservoir sedimentation. Establishment of protected areas in upper catchment could reduce sediment flows into the tank, and effectively implemented watershed management, which can reduce sedimentation and may extend a reservoir functional physical life, such as control of road construction, mining, agriculture, and other land use in the upper catchment area. Other practices may be practicable, for instance upstream check structures, protecting dam outlets, reservoir flushing, mechanical removal, and increasing the dam's height (Quintero and Ledec, 2003).

- Greenhouse Gases

Globally, dammed rivers have also impact on processes in the broader biosphere. Most of the reservoirs, especially those in the tropics, are significant contributors to greenhouse gas emissions. Carbon dioxide and methane are released to the atmosphere either slowly, as flooded organic matter decomposes; or rapidly, when the forest is cut down or burned before reservoir filling. It may be defended, that many hydropower plants generate ample electricity to offset the greenhouse gases otherwise created by burning fossil fuels in power factories. However, it is not a case of giant projects affecting large surface area, practiced mainly in tropics (e.g. Tucuruí or Balbina dam). Salvage of commercial timber and fuelwood could mitigate greenhouse releases, but it is often not being done due to costs linked with harvesting and transportation of timber, and result. More secure solution is to choose dam sites that minimize flooding of forests in particular (Quintero and Ledec, 2003).

2.3.3.1. Impacts of complementary civil works

- Access Roads

Environmental impacts of new road network leads to deforestation, resulting in loss of biodiversity, accelerated erosion; and as well as for other post-dam impacts, extension of the response is depending on size of the reservoir and presence of additional constructions, and variety of other objectives of the facility. Soil erosion could be ameliorated by implementing proper drainage systems on forest roads, strict rules for all contractors and future users of them - for example for waste disposal, camping or hiking and other possible human actions.

- Power Transmission Lines

Electro-power transmissions lines directly reduce and fragment forest ecosystem; and could injure or kill some of larger bird species, and last but not least, are disruption of the aesthetic landscape values. As in the case of access road impacts, power lines has to be built in accordance with environmental rules, and for example provided with a visible plastic devices on the top to protect birds from collisions with them.

- Quarries and Borrow Pits

Quarries and borrow used to provide material for the construction is another additional impact, which should be ideally situated within the future flooded area (Quintero and Ledec, 2003).

2.3.3.2. Impact of induced development

Dam construction can bring additional projects, including irrigation, urban expansion and building of other industrial facilities, related to the new water supply (Quintero and Ledec, 2003).

2.3.4. Physical impacts and LULC change

Dams may greatly influence nearby landscapes by major changes in landscape use and land cover (LULC) types. For example, expansion of irrigation systems, urbanization, cooling surrounding surface temperature by decreasing the sensible heat fluxes and increasing latent heat fluxes (Reddy and Boucher, 2004; Lee et al., 2011). This topic is more discussed later in separate chapter.

2.4. Landscape ecology

Landscape ecology got several different definitions. One of the most common according to Forman and Gordon (1986) is the study of patterns, processes and changes, at scale of hectares to square kilometers. Landscape structure can be taken to be the spatial relationship between landscape elements or patches, and landscape function like interaction between these spatial elements, where landscape change is the alteration in structure and function occurring through time. While people became one of the main biological forces on the planet, much of the focus of this field focus on interaction between human population and the biosphere (Hobbs, 1997).

Earth and its landscape facing great threat from human behavior and it is calling for action to deal with these threats. These actions has to be always based on more than simply biophysical or socio-economic subjects, but on a wide range of disciplines and approaches together. Landscape ecology should be at leading place of those efforts, bringing all landscape planners, architects, geographers, ecologists, modelers together, and benefit from knowledge from all of them (Hobbs, 1997).

2.4.1. History and origins of landscape ecology

Landscape ecology was developed as an effort to bring together geography and ecology issues. It has been found largely in Europe - with its long history and with great human influence since Neolithic revolution - it is now appropriate scientific base for land use planning, resource use, conservation and land reclamation. Landscape plans started to examine impacts on entire ecosystem, and on the nutrient and energy flows through it. Subject of landscape ecology has started to include aspects of psychology, sociology, economics, and cultural studies. Yet ecological impact assessments has tended to focus only on area, where is the impact instantly seen, and usually not on the effects of human activities on the entire landscape (Franklin et al., 1993).

2.4.2. Principles of landscape ecology

We may distinguish some principles as a major concepts of landscape ecology, which interact in any given landscape, determining, at least in part, the integrity of the landscape and the health of the species which live there.

- *Time and space*

Consequences of any disturbance may appear either next season, or more treacherously - in horizon of decades, and that interference on any given site will be reflected in dynamics of the whole landscape. Those changes are mostly extending well with time. Some of them may be partly mitigated, but never erased (Forman, 1987).

- *Heterogeneity*

Heterogeneity within landscape ecology could be another basic concept, as important aspect ensuring all the parts are available for forest function.

- *Connectivity*

Ecosystem is dependent within any landscape on good connectivity of diverse patches and habitats of various plants, animals, and microorganisms. Connectivity is provided by movement corridors such as riparian zones or groundwater, which both serve for many species of plants and animals, but for nutrients and energy as well. Disruption of these paths might have great consequences (Forman and Gordon, 1986).

2.4.3. The importance of riparian zones

As was already mentioned, riparian zones are important movement corridors providing transfer of nutrients and energy within the landscape, but moreover functioning of them moderate water temperature, control sedimentation and provides source of food and nutrients for wildlife (Verhoeven et al., 1992).

2.4.4. Landscape water potential as a new indicator for monitoring macrostructural landscape changes

Regarding to Skaloš et al. (2014), landscape water potential (LWP) is featured as a new quantitative indicator for monitoring of quantitative changes of landscape macrostructural change. It is indicated as a simple ratio of areas with high water potential to areas of low water potential, where LWP is equal to area of landscape elements with high water potential (H) divided by area of the elements of low water potential (L) , as LWP= H/L. From the result is LWP from 1 to 9 taken as high, and 10 to 15 as low. Landscape water potential is possibly an important characteristic of landscape functionality, based on the average potential landscape element evapotranspiration, which is mostly affected by the biotope character and type of management (Pielke, 2005; Pielke et al., 2011).

Evapotranspiration plays fundamental role in energy dispersal and is highly dependent on the amount of vegetation cover and water availability. Therefore, land use and subsequent land changes, on regional scale, should be taken into account when measuring the benefits of evapotranspiration (Pielke, 2005; Pielke et al., 2011). Development of sustainable strategies for water courses should be based on wide range of information about landscape changes, pattern processes and effects of human activities on landscape. Using LWP may be significant step in research of landscape changes as an efficient indicator for the innovative evaluation of landscape macrostructural changes (Skaloš et al., 2014).

2.4.5. Integration of historical and landscape ecological perspectives

Another approach within landscape ecology by Bürgi and Russel (2000), is introducing attempt to integrate methods and knowledge both from history and ecology as well, to study landscape dynamics. Following the principle of time and space - where society and the environment are interconnected - looking at the forces driving landscape changes, is an important direction to study society and nature interconnections in general. Real world environmental threats - such as decrease of regional water supply and loss of biodiversity - occur in both space and time, and therefore integrating landscape ecology and history is not only academic interest, but an interdisciplinary approach, which has the potential to address these practical problems. (Bürgi and Russel, 2000)

2.5. Methods and techniques to assess land use and land cover changes

Land use and landscape changes are subjects both of landscape ecology and geography. Each science have developed its own methodology to examine changes in horizontal landscape structure. According to which data are used - as scale, size and type of the area - various methods can be used. Landscape structure and its changes represent a crucial issue of landscape ecology. First, because any changes in landscape structure alter the functioning of the landscape - for example flows of energy, matter and information - and these alternations drive landscape dynamics. And second, driving factors of landscape developments, where in sense of feedback path are reflected again in landscape structure. Landscape ecology dealing with very dynamic events - in structure and functions- where landscape changes are running on different time scales. Landscapes ecology is focused on three large topics: 1. Structure; 2. Functions and processes; 3. Changes and developments (Lipský, 2007).

Land use changes around the world are monitored by the LUCC (Land use, Land cover Change) Working Group, in the frame of International Geographical Union (Himiyama et al., 2005).

Amount of papers dealing with the issue of landscape changes has increased significantly during last 15 years. The number of international conferences and workshops focusing on this issue of landscape character assessment increased as well, where Czech Republic is not an exception - during last ten years were in our country organized four conferences (Lipský, 2007).

2.5.1. Landscape structure

Landscape structure has vital impact on landscape functionality, and could be differentiated on three classes: 1. Vertical; 2. horizontal; 3. chronological. The second one is the subject of the research in landscape ecology. There are many studies dealing with landscape structure analysis issue. In general, changes in land cover could be assess from commonly use macrostructure and microstructure approach (Lipský, 2007).

Another terminological approach is used as well, which distinguish three substructures of landscape. These are known as primary, secondary and tertiary structure, and they combine both vertical and horizontal landscape structure. Primary structure includes natural vegetation and conditions, like soils, water, geological substrate and climatic conditions. Secondary structure is defined as landscape influenced and modified by man activities, and in addition with newly created man-made elements. The comparison of the primary and secondary structure could be helpful to determine the state of naturalness or man-made conversion of the landscape. The tertiary structure is formed from elements and spatial subsystems of socioeconomic sector. It could be also defined as a set of intangible elements, like landscape history, memory, and traditions, which contribute to the specific area character, but is not directly expressed in physiognomic of the landscape. These three landscape substructures are most often used on example of small areas, and represent layers into which we divide the real landscape (Lipský, 2007).

2.5.2. Methods of monitoring and assessment of landscape macrostructure

Studies dealing with landscape macrostructure are commonly divided in two approaches. The first one is studying the structure and dynamics of the main forms of human land use (agriculture, forestry, water bodies, urban area),and it is based on summary of statistical data on land use and land cover (Brandt et al., 1999). This method is convenient in case of large areas, and it is commonly used by human geography (Bičík et al., 1996). However, statistical data have got only restricted spatial links related to the administrative boundaries, and do not correspond with the natural landscape mosaic - natural boundaries of catchments and other landscape units. Therefore, it is not the best solution from ecological point of view. The second method is been used in smaller areas with different landscape types, and it is more subject of biologists and landscape ecologists. As the statistical data on land use per cadastral units are composite with methods, using detailed field mapping and aerial photographs, or old maps. There exist close co-operation within the Central European countries, as these countries have common history, therefore equal structure of historical data on land use (Lipský, 2007).

Within the analysis of landscape changes is paid attention as well to ecological stability assessment. Míchal has defined ecological stability, as ability of the system to remain stable and even, in case of disturbances. The simplest coefficient of ecological stability is after Míchal, and it is commonly used in the Czech republic. The coefficient is counted as: $Kes = S/L$, where S represents total area of ecologically stable land use categories and L expresses the total area of all ecologically relatively unstable land use categories. In general, coefficient of ecological stability is formulated as the ratio of ecological stable areas like waters, forests, grasslands; and ecologically unstable areas - as built up areas, arable lands and industrial sites (Míchal, 1992). There is more similar approaches to quantify ecological stability in landscape, but all of them are insufficient from ecologic point of view, because they are not able quantitate different ecological quality categories like arable lands, grasslands and other classes in different historical periods (Lipský, 2007).

2.5.3. Methods of monitoring and assessment of landscape microstructure

Landscape microstructure basically focus at the space composition of landscape units, and both their connections and individual parameters of each components as well (Lipský, 2007). Researches focusing on landscape microstructure has been influenced by Forman´s concept of landscape structure and his definition of landscape, as a heterogeneous area composed of a cluster of interacting ecosystems (Forman, 1995). Due to rapid development in computer techniques, the possibility of using more quantitative methods has been enabled. And there is a lot of analytical and statistical methods for investigating changes in landscape microstructure, based on measuring and calculation of landscape metrics and indexes (Turner and Gardner, 1990). Because it's difficult to describe landscape pattern with the use of only one index or metrics, complex of metrics need to be used. Just limited number of primary measurements - as for example shape, patch size, length or perimeter area and ratio – can be used for evaluation of many metrics. Practical application of landscape pattern quantification with landscape metrics contain description of temporal land use changes, and predictions considering landscape change and evaluating differences in landscape pattern among landscapes in future (Pixová, 2005). Remote sensing is one of the techniques with great potential to record temporal landscape changes.

2.5.4. GIS and remote sensing

Remote sensing is in generally speaking technique for acquisition of information about an object or phenomenon, without making physical contact with it. In comparison with field observation, it is fast and effective method, which can also collect data from inaccessible areas. The multispectral and multiple spatial domain data rendered by remote sensors are greatly suitable for integration into geographic information systems (GIS), hence it forms large part of input data in practice (Lipský, 2007). Remote sensing has proved in recent years to be very efficient tool for effective natural resources management. The beginnings of GIS could be found already around 1960s, at research level within universities, and scientific workplaces. From 1980s has been already commonly used in landscape ecology researches (Kovář, 2012).

Due to development in technology, there is various possibilities within assessment of the landscape structure, some of the used methods are:

- Aerial photography
- Aerial digital photography
- Satellite imagery

More significant development of aerial photography was made during times of first and afterwards second world war, where the images were used mostly for military uses. So the main advantage of these pictures is long history, thus they are available for investigating of the landscapes development in time, as it is for instance case of this work. The images are often in high spatial resolution, and stereoscopic view captures height and topography. Despite their importance as one of the crucial element of ecosystem management, they have got some disadvantages. They could for example have limited spatial coverage dependent on needs of original project, and limited or inconsistent metadata (Morgan et al., 2010).

Digital aerial photographs have shorter time scale series, since about 1990s and have similar handicaps as the film based photographs, but the digital storage allows its reuse and safer storage in memory devices (Morgan et al., 2010).

There is variety of basic characteristics, which are used to define and classify polygons, like tone or color, shape , size, pattern, texture, shadows, site and context. Tone and color are the main attribute for feature identification, where both are basically relate to the intensity of light reflected by the elements on the surface. Texture is another important characteristic especially beneficial for landform and land cover classification, and it is connected to variation in biophysical parameters, landscape heterogeneity and forest structural characteristics. (Avery and Berlin, 1992). Manual interpretation requires knowledge in the field and may get relatively subjective.

The history of satellite image is connected with development of rocketry in 1970s, and there are four types of resolution in remote sensing: spatial, spectral, temporal, and radiometric. This spectrum of resolutions is one of the main advantage of satellite imagery as they can be used in various sciences, for example in forestry, biodiversity conservation, cartography etc. Moreover it is cost effective alternative to aerial photographs (Morgan et al., 2010).

2.5.5. Scale

Scale is term which entails a lot of confusion, because it has various meaning across disciplines. The term of scale has many different meanings, conducive to its ambiguous usage in the ecological literature (Schneider, 2001). From the most commonly used ecology perspective, scale refers primarily to grain (or resolution), and extent in space or/and time. Scale may be absolute - evaluated in spatial or time units, or relative - imply a ratio. Scale main concerns are spatial resolution, temporal resolution and the unit analysis. The spatial resolution includes the spatial resolution and extent. Temporal resolution is expressed by time duration of the exemplary. And finally the unit analysis is associated with the human decision making processes. As the human actions have extensive impact on land use and land cover changes, it is essential that models of these processes clarify factors that affect human decision making (Agarwal et al., 2002).

2.5.6. Spatial data analysis

Most of the benefits of GIS dependent on its ability to manage and manipulate spatial data location attributes, which are one of the systems feature. They are expressed by means of the geometric features of lines, points and polygons in a plain (Anselin, 1989). Spatial analysis is subject includes both absolute sense (coordinates), and relative sense (spatial arrangement, distance). Spatial data are dependent on location - which could be expressed by First law of geography by Tobler - saying that everything depends on everything else, but closer things more so (Tobler, 1979). Another effect is spatial heterogeneity, which express the geological characteristics, for instance terrain formations.

2.5.7. Landscape metrics

Landscape metrics are algorithms that quantitatively determine specific spatial characteristics of patches, classes of patches, or entire landscape mosaics. These metrics can be divided in two general categories. First one quantify the composition of the map without reference to spatial attributes. The second category quantify the spatial configuration of the map, requiring spatial information for their calculation (McGarigal and Marks, 1995; Gustafson, 1998).

- **Composition in landscape metrics**

Composition refers to features related with the variety and abundance of patch types within the landscape, but regardless to the spatial character, placement, or location of patches within the mosaic. Composition metrics are only applicable at the landscape level, as composition requires integration over all patch types. We can find aplenty techniques of composition landscape metrics, due to many ways in which diversity can be measured, involving the proportion of the landscape in each patch type, patch richness, patch evenness, and patch diversity. The right choice of used metrics has to be considered regard to the purpose of the research (McGarigal, 2002).

The principle measures of composition are:

- Proportional Abundance of each class - proportion of each class relative to the entire map.
- Richness - the number of different patch types.
- Evenness - the relative abundance of different patch types, usually accentuating either relative dominance or its compliment, equitability.
- Diversity - combine measure of richness and evenness. Can be calculated in a many different forms, according to the relative emphasis placed on these two components. (McGarigal, 2002).

- **Spatial configuration**

Spatial configuration relates to the spatial character and arrangement, position or orientation of patches within the class or landscape, and it is much more difficult to quantify. In case of some aspects of arrangements - such as patch isolation or patch contagion - are measures of the placement of patch types relative to other patches, other patch types, or other features of interest. The other features of configuration - as shape and core area - are measures of the spatial character of the patches. Configuration can be measured in the sense of landscape unit itself (i.e. patch). The spatial pattern is the spatial character of the individual patches, even though the assemblage is across patches at the class or landscape level. A various of configuration metrics can be formulated, either in terms of the individual patches, or in terms of the whole class or landscape, according on the object of the study (McGarigal, 2002).

3. AIM OF WORK

3.1. Purpose of the diploma thesis

The objective of my diploma thesis is to analyze, evaluate and present landscape structure changes, due to realization of important hydraulic construction in four different areas in Czech Republic (Fig.2) The main intention of this work is to provide relevant scientific material to help in future decision process within construction of significant hydrologic facilities. Through study of historical aerial photographs from 1950s, and current orthophoto from each area, has been analyzed the development of landscape microstructure characteristics during the referred period, and the influence of this significant water retention in the landscape.

Objectives of diploma thesis:

- Evaluate the level of nature and human impact on landscapes as driving force.
- Analysis of influence of water retention on surrounding landscapes and their ecology.
- Compare of changes in microstructure characteristics in each area during the reporting time period.
- Capture the importance of involvement various sciences in decision process within construction of hydrologic facilities.
- Assess the importance of dam constructions in context of climate change and drought occurrence on global scale and in the area of Czech Republic.

3.2. Design of the research

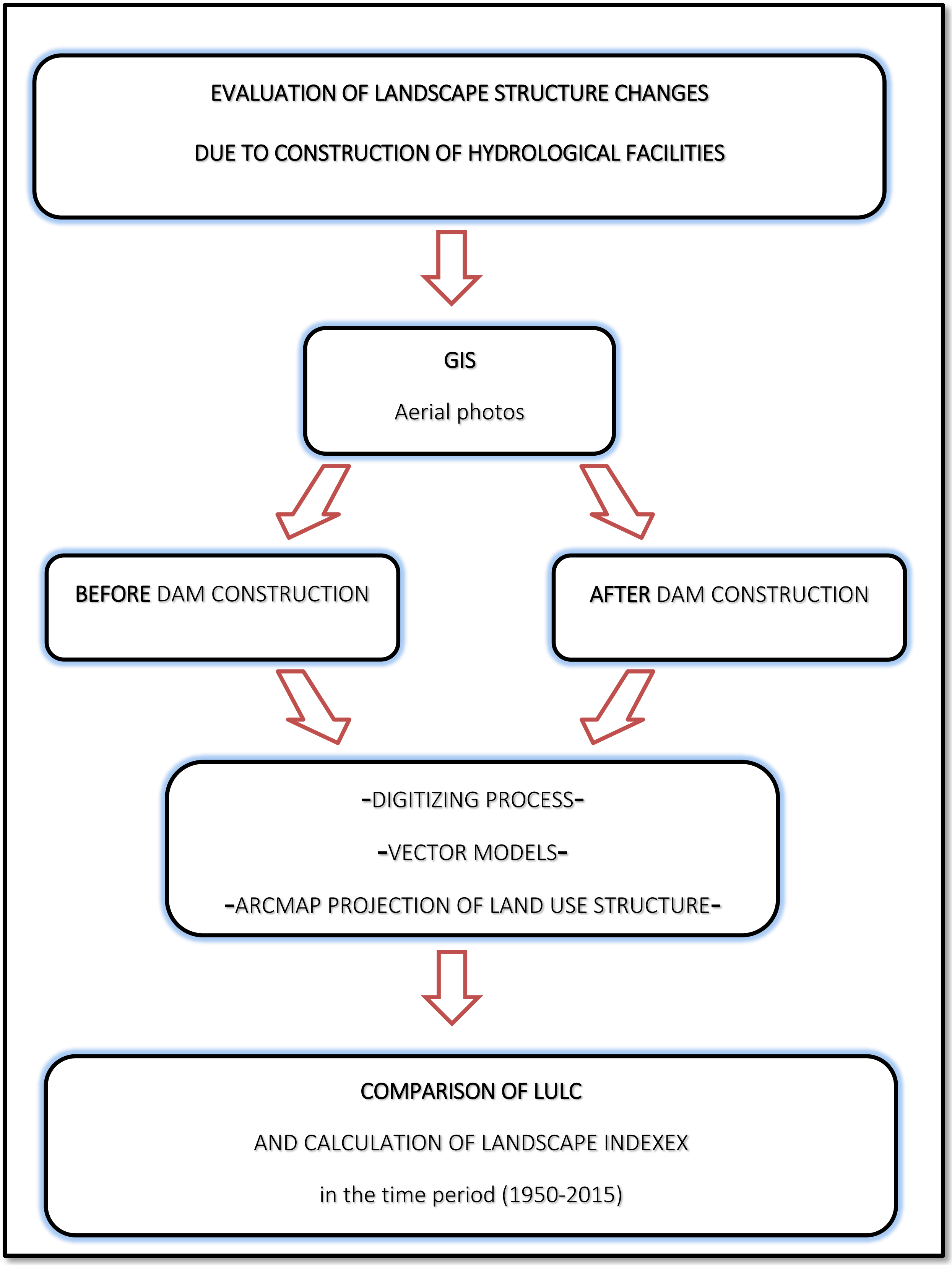

Figure 1. Design of the research

4. CHARACTERISTIC OF THE STUDY AREA

All of the four studied areas are situated in the Czech Republic, in the middle of Europe, with its characteristic continental and temperate climate, with four seasons (Fig.2). In the context of Czech Republic, where are commonly used three climatic zones, are three of the sites - namely Koryčany, Pilská, and Hracholusky - located in the moderately warm zone, with mean annual temperature between 7 to 8 °C, and mean annual rainfalls of 600 to 700 mm. Only Šance reservoir is in cold zone and part of the territory with the biggest annual rainfall in the country. Except Hracholusky reservoir, which is used for industrial water supply and recreation, the rest of the dams main purpose is drinking water supply function, and additional use for flood control. This four sites, with their various placement within the country, can be good representation of water reservoirs effects on the environment and land use and land cover changes in the referred time period. The specifics of each reservoir are more analyzed in following chapters.

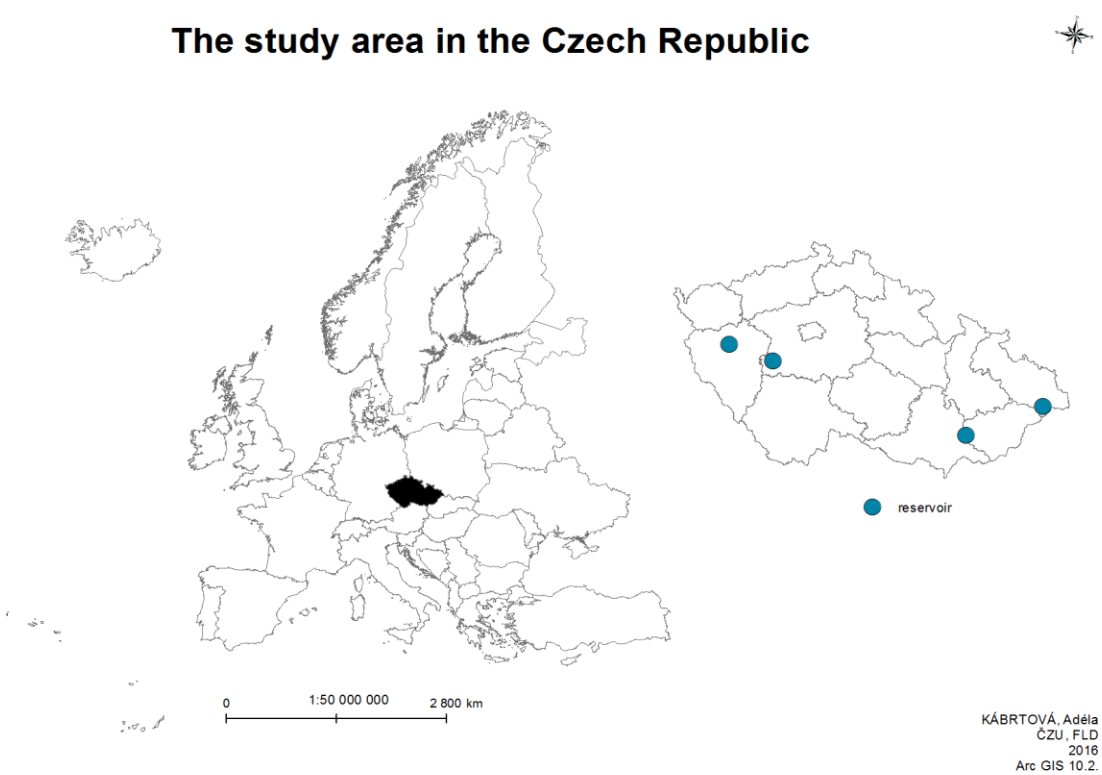

Figure 2. Location of the study area – Czech Republic

4.1. Koryčany reservoir

Koryčany reservoir is situated on river Kyjovka, about 1 km east of the city of Koryčany, in the western part of foothills Chřiby , in Zlínský region (Fig. 3).The dam was built in years 1953 and 1958, and put in service in 1963. The reservoir has 35.3 hectares of flooded area and capacity of 2.56 million m^3. The maximum depth is 18.7 meters and mean annual runoff of 0.16 m^3/s. The main function of the reservoir is water accumulation, flood control and ensuring a minimum steady flow. The dam includes small hydroelectric power station. While it is a source of drinking water, the whole area of the reservoir is in hygienic First protection zone. Therefore the use for recreation and other utilization for public is completely excluded.

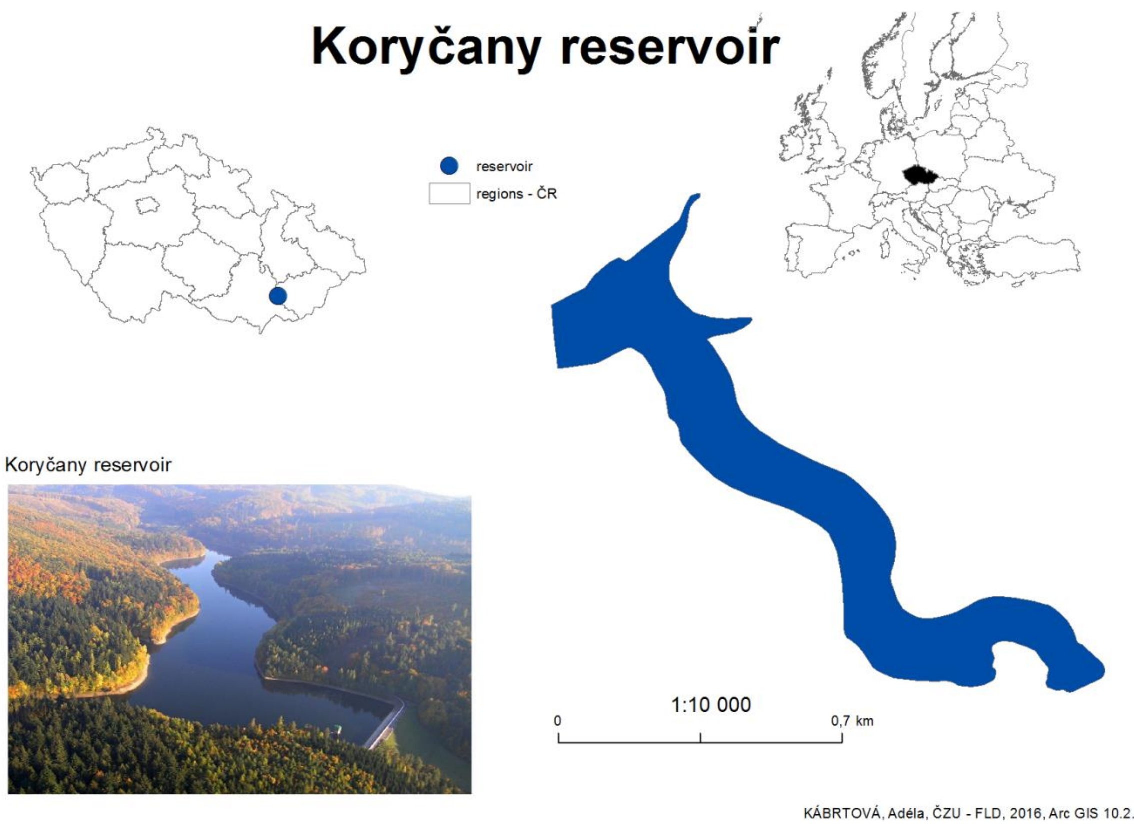

Figure 3. Location of Koryčany reservoir

- Geomorphological characteristic and land lover types

The basin of river Kyjovka belongs to the old settlement area, with human influence since Prehistoric times. It belongs to the geologic unit of Western Carpathians, and it is part of bioregion with predominant of forest lands, more specifically beech and coniferous cultures. The rest is covered with arable land and grasslands. The flooded area was originally forest land, and for the reservoir construction purposes was the vegetation completely removed.

The area is affected by soil erosion, mainly because of the sloping terrain, and water erosion. Air erosion influence is present as well, due to southeast winds flowing through the territory of the White Carpathians.

- Climatic conditions

The area of the river basin belongs to the regions with the smallest annual rainfall, about 500-600 mm. The mean annual temperature is between 8-9 °C.

4.2. Pilská reservoir

Pilská reservoir was built on Pilský potok stream, located 2 km from city of Příbram, in region of Central Bohemia, part of Brdy region (Fig.4). The construction was finished in 1853, with flooded area of 22.5 ha and capacity of 1.8 million m^3. Pilská is reservoir of drinking water, so as well as in the case of Koryčany dam, other uses are excluded.

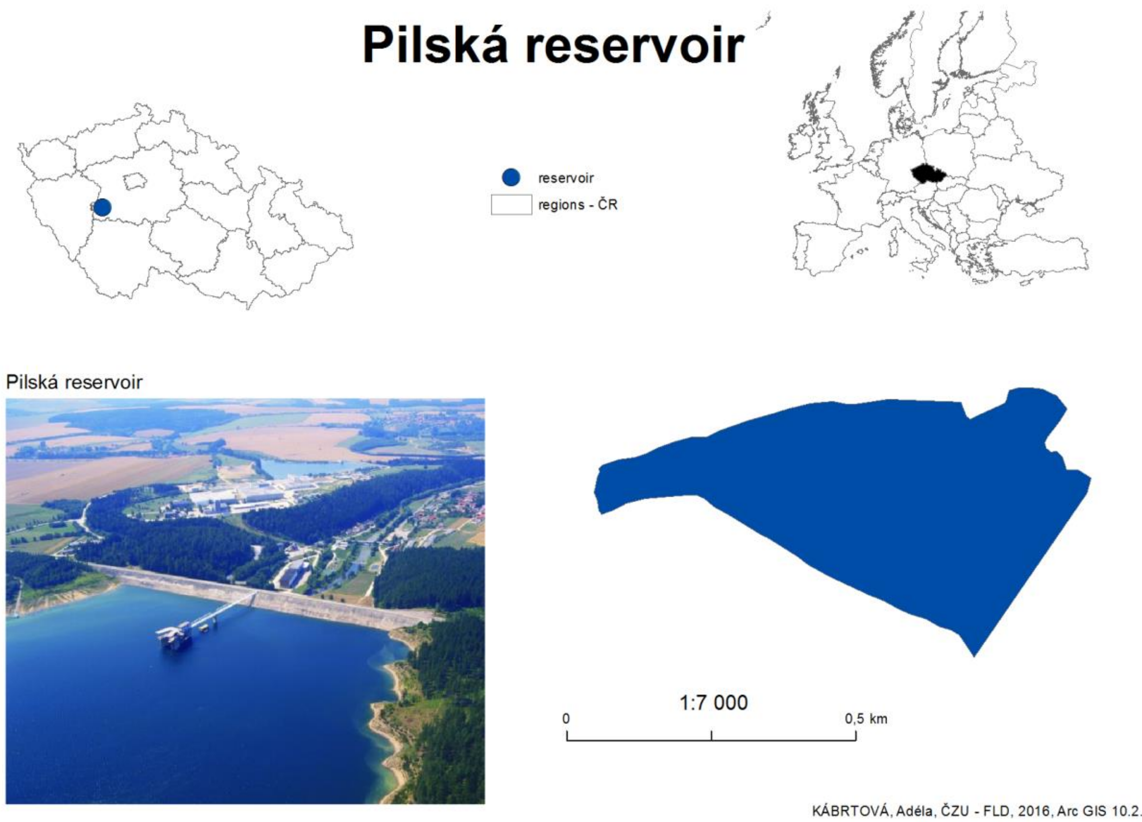

Figure 4. Location of Pilská reservoir

- Historical factors landscape changes

Due to great torrential rainfalls in 1854 - only year after realization- the water has broken through the dam and caused floods, which most affected town of Bohutín. The reservoir was built in forest valley, on the origin area of pond Pilka, for the purpose of water supply for silver mines and mills in Příbram area. Later in 1930s the area has partly became a closed military area, largely banned to public. The Military use of the Brdy mountains gradually decreased after 1989, driven by military cost cutting and eventual professionalization in 2005, however, the closed military status of the central part persists. Finally at 1th of January this year (2016), it became part of Protected Landscape Area of Czech Republic. The historical land use for military purposes caused local partial deforestation.

- Geomorphological characteristic and land lover types

The subsurface of this area is composed from nutrient poor sandstones, conglomerates and consisting quartzites. It is very geologically unstable. The region is mostly stream area, with predominant forest cover- with primarily spruce stands; with exception of the remaining territory of forest clearcuts for military purposes, and water reservoirs. The source of water in this territory is almost solely from rainfalls, and the water stays in the upper parts of soil – in form of numerous wetlands and moors. Therefore the water flows fluctuating character, depending on precipitation, without groundwater supplies (PVL, 2013).

- Climatic conditions

Mean annual rainfall is about 600-700 mm, and mean annual temperature 7-8 °C.

4.3. Hracholusky reservoir

Hracholusky reservoir was built in 1964 on the Mže river in Plzeň region, about 20 km west of the city of Plzeň (Fig.5), with the total capacity of 56.65 million m^3. The maximum depth is 31 meters and annual runoff makes 8.28 m^3/s. The main purpose is water supply for industry, energetic and agricultural use. Partly is used for flood control, and last but not least for recreation purposes.

In the area of 489.62 ha were flooded couple of villages, mills and weirs, as well forest land and shrub lands.

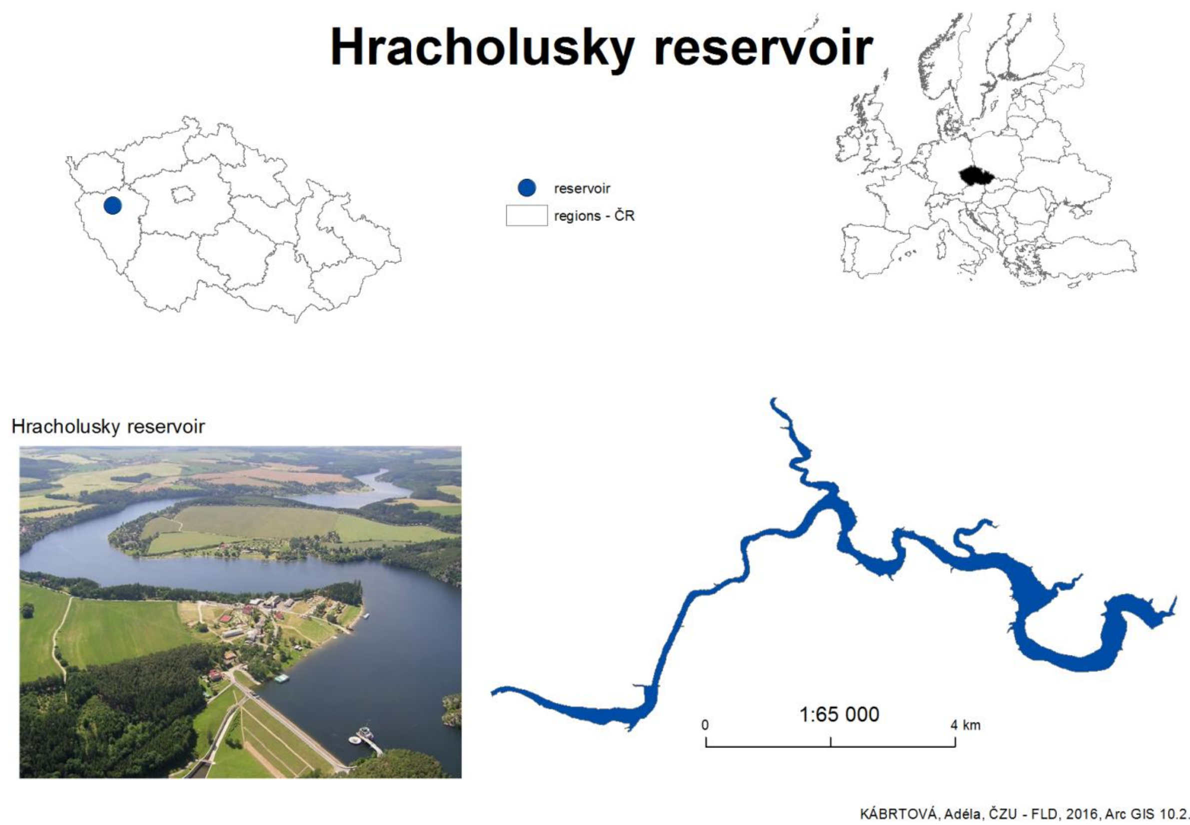

Figure 5. Location of Hracholusky reservoir

- Geomorphological characteristic and land lover types

Territory of the current dam site has been permanently settled since Paleolithic Age, concentrating around the river basins. In the area prevails Brown earth, and Stagnosol.

Plzeň is region with strong industrial history, so it can be found many significant industries the area, for instance Škoda a.s., which is supplied by Hracholusky reservoir. The main land cover types, are forest land and arable land. Forests are represented with some 40% of the region area, with dominance of coniferous species, and partly deciduous forest with beech and oak species. Another approximately 40% cover is arable land. The remain land cover types are grasslands, mixed agriculture stands and urban areas (PVL, 2013).

- Climatic conditions

River basin of Mže is moderately warm climate area, with mean annual temperatures 7-8 °C, and mean annual rainfall 500-600 mm.

4.4. Šance reservoir

The dam Šance was built on upper course of the Ostravice River, in Moravskoslezký region (Fig.6), with capacity of 22.75 million m^3 and covers area of 337 hectares. It was constructed in 1964-1969 and began operating in 1974. Part of the village of Staré Hamry was demolished and subsequently flooded during the construction. Depth of the reservoir is 52 m, and mean annual runoff 3.2 m^3/s. The dam was built as result of lack of water in the post-war years, when the Ostrava region get heavily industrialized, and the surface water quality significantly deteriorated. The current purpose of the dam is mainly collecting supplies for drinking water processing plant in Nová Ves in Frýdlant nad Ostravici, and flooding control function, with regard to significant fluctuation of runoffs and frequent floods.

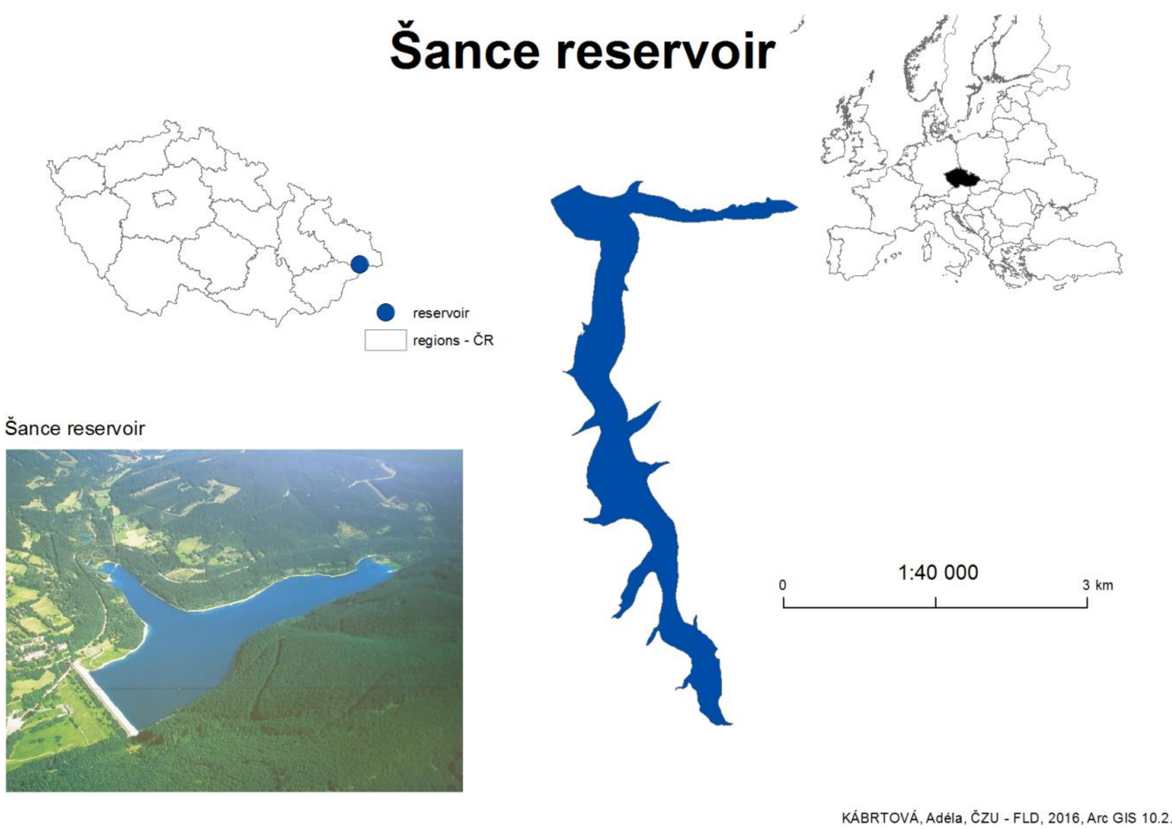

Figure 6. Location of Šance reservoir

- Geomorphological characteristic and land lover types

Ostravice basin belongs to Beskydy biogeographical region, which is part of the West Carpathian biogeographical subprovince. The subsoil is formed from mixture of sandstones, slates and conglomerates. Soil composition makes the area very prone to soil water erosion, causing sediment run-off of sediments into the reservoir, and its silting. Another factor of erosion has an anthropogenic origin- dense network of unpaved forest roads- which worsens the situation as well. Upper area of the reservoir is mainly forest land with relatively low settlement. Beskydy geomorphological unit belongs to Protected Landscape Area (PLA) of Czech Republic and it is included in the European project of Natura 2000, with some rare animal and plant species. The mountains are covered by 80% of forest land, with predominance of plantations of spruce, which were in some parts severely damaged by emissions from the Ostrava industrial region. The area was originally covered by mixed forest, with dominant of beech specie - its restoration is today one of the main intention of the PLA unit (Buzek, 1997).

- Climatic conditions

The mountain range Beskydy is area with the greatest amount of rainfall, with annual rainfall range from 1200 to 1400 mm, where the reservoir is situated just 4 km from Lysá Hora, which is the second most rainiest place in Czech republic. Amount of rainfalls is one of the natural factor causing significant soil erosion. With mean annual temperature of 6-7°C belongs to the cold climate zone in the country.

5. METHODOLOGY

5.1. Programs

The analytic part of this work was processed in the geographic information system (GIS), in 10.2. version, provided by Environmental Systems Research Institute (ESRI). The software is providing components of Arc-Map, Arc-Catalog and Arc-Toolbox, which allows the user analyze, manage, map the geographic data.

5.2. Data source

For the purpose of monitoring microstructure changes have been used both historical aerial photographs taken in 1950s, and present orthophoto from years 2014 and 2015, of each dam site area, obtained from ČÚZK Geoportal. This geoportal is a complete Internet interface to access spatial data produced and updated by organizations of the Czech Office for Surveying, Mapping and Cadastre.

5.3. Processing the data

In order to achieve required microstructure analysis, were necessary to accomplish following steps:

- Interconnect and merge sets of aerial photographs in GIS, into one continuous map.
- Create two buffers, in distance of 1 and 2 kilometers from the reservoirs.
- Conversion of current and historical aerial photos into vector model through digitizing process - creating series of polylines and polygons, within the buffer zones, concurrently recorded to the attribute table.
- Allocation of land cover category to each polygon in the attribute tables.
- Utilization of the categorized data from attribute table for analysis, graphs, tables and visual maps, in both historical and current spatial data cases.

Due to panchromatic (black and white) resolution of historic aerial photos, which make the interpretation not so clear, were necessary to understand some rules to read them correctly, and moreover, to use some additional data sets.

Smaller water courses – like small rivers and streams - were not included, as they don't cover significant area to be counted for the purpose of this study. Moreover, at the resolution of used orthophotos, weren't possible either to distinguish them, or create polygons that would be visible on the output maps, and have impact on the final results. The issue of identification of the water courses from the historical aerial photos could be solved by using data from geographic reference database (DIBAVOD), which are available in format of ESRI shapefile, and therefore can be used for spatial analysis in geographic information systems and processing data reporting under the Framework Directive 2000/60 / EC on water policy. This dataset was used as well in case of this study, in order to achieve more accurate results - when localization the included, significantly large rivers.

5.4. Land cover typology

For correct classification and delineate of created polygons is required to use variety of key characteristics - such as difference of tone/color, size and shape, texture, pattern and interconnection with surrounding environment, and shadows.

Tone and color is related to the intensity of light reflected by a terrestrial object, which forms the land cover. In case of black and white images, tone allows easy distinctions between roads, forests, harvest areas, water, and other elements. Color enable for instance distinction between coniferous and deciduous tree species, grasses, and road surface types.

Texture is defined in terms of smoothness and roughness, and it can offer guides about the density, age, and type of present vegetation.

Size is usually evaluated by looking at objects that the interpreter may be familiar with and comparing their relative size to less familiar objects. Shape is useful for identifying natural features with distinctive forms and in case of cultural attributes, which have got usually specific shapes and obvious edges.

By observing objects and the features surrounding them, we can make inference about what the objects really are. Pattern is within basically repetition of particular shapes.

Each of used landscape structure category got its distinguishing features:

- Forest is category, which has many attributes, desired depending on purpose of study. For instance, texture is usually used to help recognize within tree species, as well as tone and color helps to differentiate between deciduous species, which often reflects more light and appears more lighter than coniferous species. Shadow may be helpful providing silhouettes for identifying species by its typical crown shapes, or revealing the height of the stand, but they occur only at historical photos, while the modern aerial data are collected within two hours of solar noon (Jensen, as cited in Morgan, 2010).
- As water has the ability to absorb the light, water bodies are recognizable by its dark color and lakes are typical by its rounded shape.
- Arable land is typically obvious with its geometric shapes and regular lines.
- Urban areas are usually easily identifiable due to their unnatural shapes, and materials they were made from, which makes them look bright on the photos. Similar rule applies also in case of road networks, moreover they mostly have linear shape.
- Sparse tree vegetation is typically represent by the size and canopy closure.
- Grassland is characterized by smooth texture, while scrublands represent a thin texture.
- Mixture of shrubs & grasses represents a mixture of different share of land cover of both shrubs and grasses.
- Swamps comes with a typical spotted tone.

5.5. Spatial analysis

Landscape metrics, providing the possibility to obtain substantial results of landscape pattern analysis, is very useful to manage land use in sustainable manner. Arc-Map software containing various analytic tools, which were used for geometric intersection, and to gain the location and quantification of temporal and spatial changes in the observed patches, that have not changed over the monitoring period.

5.5.1. Monitoring landscape microstructure

To describe landscape pattern, complex of metrics need to be used, providing information about the internal structure of landscape components and interaction between them. In case of this study were characterized the properties of the surfaces of different categories of land use.

For calculating the landscape metrics and selected statistical indexes was used vector-based landscape analysis tools extension (V-LATE). V-LATE is extension for ArcGIS software, which provide selected set of the most common metrics to cover basic ecological and structure-related investigations. The extension provides seven different types of analyses: area analysis (area calculations), form analysis, edge analysis, core area analysis, proximity analysis, diversity analysis, and subdivision analysis (Oláhová et al., 2013). V-LATE was developed within the SPIN project, financed by the Department of Geo informatics - Z_GIS, University of Salzburg, Austria.

5.5.2. Landscape metrics

In order to quantify landscape structure in this study was chosen following indices:

- Mean patch size (MPS) - average size of the patches evaluating fragmentation. When MPS value is high, it indicates that fragmentation increases in the field. If MPS value decrease, it is understood less fragmentation.
- Number of patches (NP) - is equivalent to number of patches of the landscape, and it does not mediate information about area, distribution, or density of patches. It is probably

the most valuable index, as the base for calculating other metrics, which are more interpretable. (McGarigal and Marks, 1995).

- Mean patch Edge (MPE) - average length of the edges of each class of land use, in meters (Balej, 2011).

5.5.3. Statistical indexes

- Mean shape index (MSI) measures the average patch shape, or the average perimeter - area ratio, for a particular patch type (class), or for all patches in the landscape.
- Mean perimeter-Area ratio (MPAR) - index of average ratio perimeter express small facets and gives information about the shape complexity soles.
- Shannon's Diversity Index (SHI) belongs to the group of indexes identifying landscape diversity, providing information on area composition and richness. It covers the number of different land cover types observed along the straight line and their relative abundances.

6. RESULTS

6.1. Study Area Koryčany - distribution and changes in land cover during 1950–2015

According to the results, almost in half of the studied area has the land use structure changed (Table 2). Even so, forest land occupying the largest part of the study area, almost doesn't change, only by increase of 7.07 % (Table 1).

Until 1950, arable land was after forest area covering 1468.18 ha second biggest unit with 402.66 ha, following by 83.08 ha of roads and urban areas, and with only 9.44 ha of water bodies. Concerning the category of grassland, it occupied 42.92 ha, sparse tree vegetation covered 19.61 ha, and finally mixture of scrubs and grasses occupied not negligible area of 59.87 ha. Swamp areas have absented in this monitoring time. Category of forest land has changed within the monitored period by only 7.07% increase (1572.02 ha).

The most significant change in land cover structure from 1950 to 2015 was increase of roads and facilities, from 83.08 ha to 456.61 ha, followed by threefold increase of water bodies, changed in 220 %, where the great change was caused conclusively by realization of the dam construction. Significant decrease of arable land - easily visible on the ArcMap projection (Fig. 1), particularly has been present in form of small and private owned small crop fields within the Kyjovka river basin, changed from 402.66 ha to 10.71 ha, as it's clearly distinguishable results. Grassland has increased from 42.92 ha to 2.33 ha, similarly as mixture of scrubs and grasses with change of 59.87 ha to 2.07 ha. After built of the dam, has appear relatively small swamp areas of 0.37 ha, what can be possibly explained by amount of retained water in the area and presence of underground streams.

KORYČANY	1950		2015		Changed LC	
Land Use Category	**Area (ha)**	**%**	**Area (ha)**	**%**	**Area (ha)**	**%**
Arable Land	402.66	19.31	10.71	0.51	-391.95	-97.34
Forest Land	1468.18	70.39	1572.02	75.37	103.84	7.07
Grassland	42.92	2.06	2.33	0.11	-40.59	-94.57
Water Bodies	9.44	0.45	30.29	1.45	20.85	220.87
Mixture of scrubs & Grasses	59.87	2.87	2.07	0.10	-57.8	-96.54
Roads & Facilities	83.08	3.98	456.61	21.89	373.53	449.60
Sparse Tree Vegetation	19.61	0.94	11.36	0.54	-8.25	-42.07
Swamp Areas	-	-	0.37	0.02	0.37	-

Table 1. Changes in land cover categories - Koryčany

Total Area (ha)	2085.76
Changed Area (ha)	995.29

Table 2. Change of total area - Koryčany

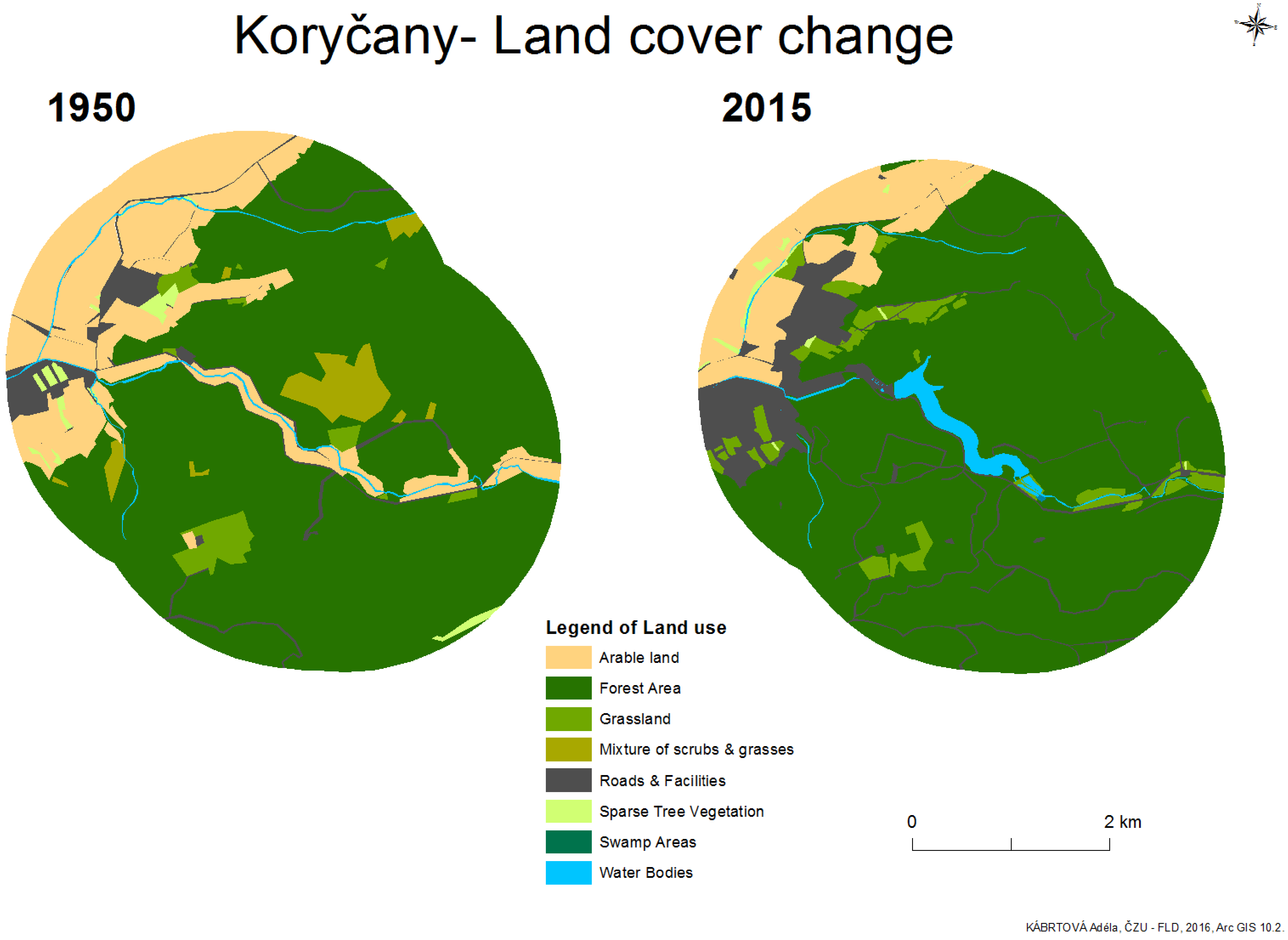

Figure 7. Land cover distribution Koryčany 1950 and 2015

6.1.1. Calculation of statistical indexes of landscape metrics - Koryčany

Number of patches helped to interpret the data, indicating relation to composition and formation of the area (Table 2). The results showed that the number of patches in category of forest area has increased threefold till today, as well in case of water bodies NP has grown from 3 in 1950 to 15 in 2015. Roads and facilities has increased slightly from 9 to 13, in case of grassland no changes has been recorded. Mixture of scrubs and grasses were present in measurable are only in past. For sparse tree vegetation the NP has decreased fivefold, as well as arable land where NP changed from 30 to 11. MSI index is used to evaluate the shape complexity, and MPE follow the development of average patch areas through time. MFRACT and MPAR indexes shows values reaching almost two patches with more complicated complex of perimeters and hence have higher values. Finally the Shannon's Evenness Index values have not shown any significant change during the studied period, only very small decrease from 0.48 to 0.45 in 2015.

KORYČANY Land use	Time period	NP	MPS	MSI	MPAR	MFRACT	MPE
Forest Area	1950	1	14681815	5.081	0.005	1.35	69018.64
	2015	3	5240069	3.753	0.097	1.419	39297.42
Grassland	1950	2	214593.5	2.596	0.021	1.357	4122.33
	2015	3	300762.9	4.593	0.055	1.453	9778.43
Roads & Facilities	1950	9	92315.99	6.357	0.112	1.552	6399.69
	2015	13	130854.3	5.817	0.181	1.551	7351.72
Mixture of scrubs and Grasses	1950	1	598706.5	3.047	0.014	1.358	8358.11
	2015	–	–	–	–	–	–
Sparse Tree Vegetation	1950	5	39211.68	2.391	0.056	1.382	2231.37
	2015	1	113607.9	7.066	0.074	1.553	8442.36
Arable Land	1950	30	134220.5	1.831	0.279	1.336	2068.71
	2015	11	184515.6	1.733	0.027	1.311	2329.06
Water Bodies	1950	3	31461.68	14.263	0.314	1.769	8768.52
	2015	15	25368.73	3.812	31.41	1.521	1842.36

Table 3. Landscape metrics and statistical indexes for each land type in the studied area of Koryčany in 1950 and 2015

SEI	1950	0.48
	2015	0.45

Table 4. Shannon's Evenness Index - Koryčany

6.2. Study Area Pilská - distribution and changes in land cover during 1950–2015

Results suggest that in Pilská studied area has changed only about 20 % of land cover, specifically 301 ha from 1702.69 ha (Table 5). As it is in case of Koryčany study area, forest land didn't change much and is present till now as the biggest part of the area, concretely it has increased from 1370.51 to 1518.74 ha or 10.82 % (Table 4).

Before 1950, mixture of scrubs and grasses occupied 97.88 ha, sparse tree vegetation 90.8 ha. Roads and urban facilities covered 50.82 ha and grassland 35.45. Arable land constituted only 19.57 ha or 1.15 %. Swamp areas were presented with not insignificant 7.08 ha or 0.42 %. And finally water bodies increased occupied 30.58 ha.

Within the study period, arable land cover has increased to 2.15 ha or 0.13 %, changed with a loss of 17.42 ha or 89.01 %, followed by mixture of scrubs and grasses with an increase of 82.84ha or 84.63 % - in 2015 occupying 15.04 ha or 0.88 %. Grassland has decreased to 22.49 ha or 1.32 %, and has decreased by 12.96 ha or 36.56 %. Sparse tree vegetation changed to total area of 67.58 ha or 3.97 %, with loss of 23.22 or 25.57 %. Category of roads and facilities has increased to 39.11 ha or 2.30 % of total area, decline of 11.71 ha or 23.04 %. At last the water bodies has not grown significantly after built of the dam, specifically to 37.58 ha – with added of 7 ha or 22.89 %, what can be explained by presence of quite extensive ponds before 1950.

PILSKÁ	**1950**		**2015**		**Changed LC**	
Category	**Area (ha)**	**%**	**Area (ha)**	**%**	**Area (ha)**	**%**
Arable Land	19.57	1.15	2.15	0.13	-17.42	-89.01
Forest Land	1370.51	80.49	1518.74	89.20	148.23	10.82
Grassland	35.45	2.08	22.49	1.32	-12.96	-36.56
Water Bodies	30.58	1.80	37.58	2.21	7	22.89
Mixture of scrubs & Grasses	97.88	5.75	15.04	0.88	-82.84	-84.63
Roads & Facilities	50.82	2.98	39.11	2.30	-11.71	-23.04
Sparse Tree Vegetation	90.8	5.33	67.58	3.97	-23.22	-25.57
Swamp Areas	7.08	0.42	-	-	-7.08	-100.00

Table 5. Changes in land cover categories - Pilská

Total Area (ha)	1702.69
Changed Area (ha)	310.46

Table 6. Change of total area - Pilská

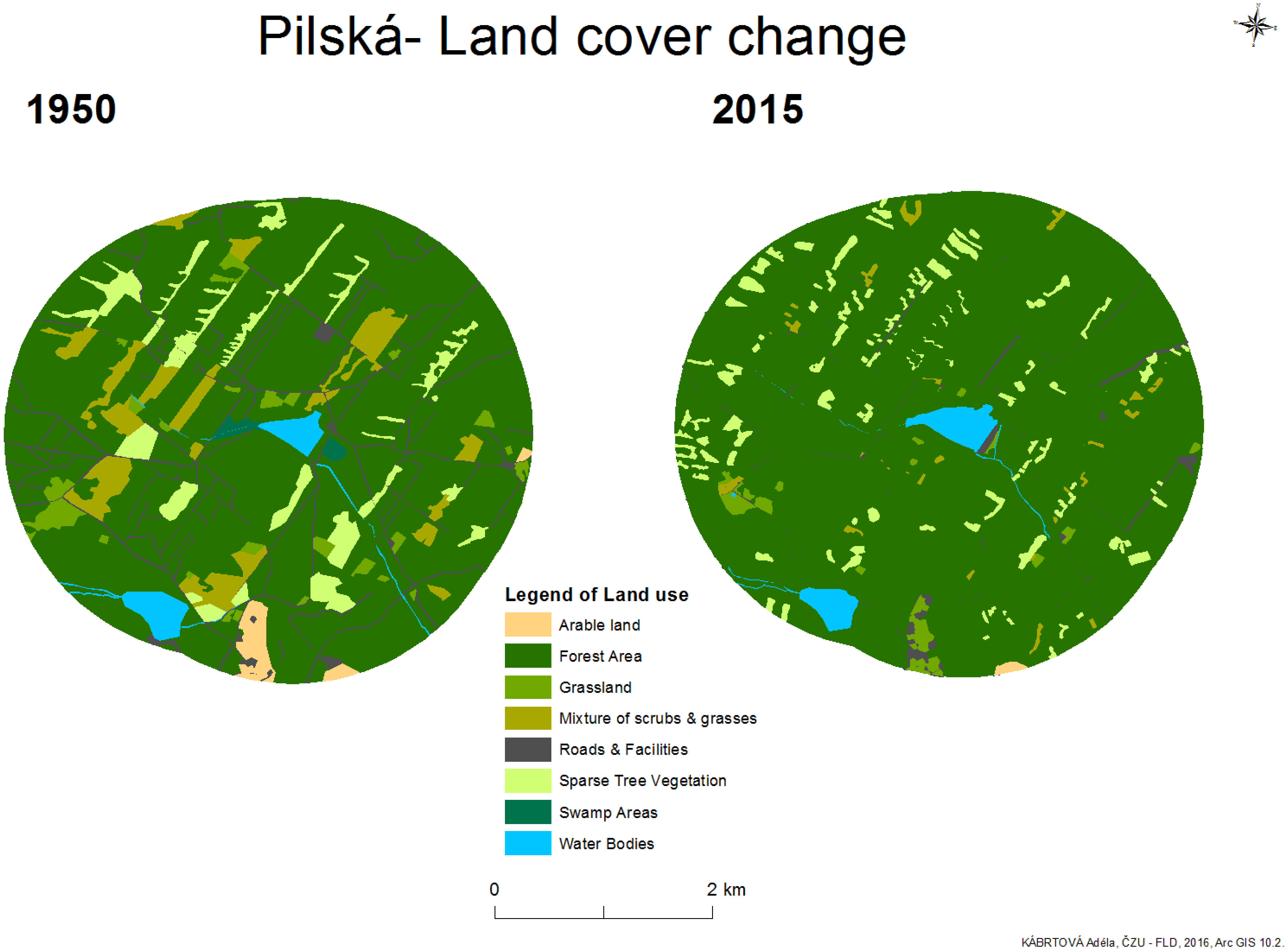

Figure 8. Land cover distribution Pilská 1950 and 2015

6.2.1. Calculation of statistical indexes of landscape metrics - Pilská

In the studied area of Pilská, the results has shown, that number of patches of forest area has increased perceptible from 13 to 34 (Table 6), mixture of scrubs and grasses from 24 to 33, and the most significant was in category of sparse tree vegetation from 32 to 103. Minor increase was in case of grassland and water bodies categories. Decrease in number of patches was recorded in arable land from 5 to 2 and in swamp areas, which has disappeared during the time period. Roads and facilities have not changed. Finally SEI in each monitored year differs slightly (Table 7), taking into account that for a given number of classes the maximum value (one) of the index is reached when all the classes have more or less the same area or the proportional distribution of the area between patch types becomes more unbiased.

PILSKÁ Land use	Time period	NP	MPS	MSI	MPAR	MFRACT	MPE
Forest Area	1950	13	1054236.5	2,342	0.037	1.332	14483.71
	2015	34	446802.27	1,995	0.024	1.321	4500.33
Grassland	1950	17	20853.76	1,467	0.048	1.339	780.87
	2015	20	11246.71	1.424	0.063	1.357	497.69
Water Bodies	1950	8	38227.47	5.95	0.378	1.718	1684.3
	2015	9	41752.16	5.629	0.524	1.714	1551.67
Mixture of scrubs & Grasses	1950	24	40783.09	1.632	0.039	1.339	1067.52
	2015	33	4556.75	1.475	0.109	1.416	326.01
Roads & Facilities	1950	10	50824.95	7.077	0.228	1.576	11877.02
	2015	10	39105.08	8.381	0.235	1.637	8056.2
Arable Land	1950	5	39148.56	1.464	0.041	1.333	930.06
	2015	2	10756.18	1.278	0.061	1.346	428.43
Swamp Area	1950	3	23598.56	1.805	0.045	1.362	941.29
	2015	–	–	–	–	–	–
Sparse Tree Vegetation	1950	32	28374.83	1.936	0.053	1.372	1097.71
	2015	103	6560.73	1.52	0.081	1.392	421.8

Table 7. Landscape metrics and statistical indexes for each land type in the studied area of Pilská in 1950 and 2015

SEI	1950	0.398
	2015	0.26

Table 8. Shannon's Evenness Index - Pilská

6.3. Study Area Hracholusky - distribution and changes in land cover during 1950–2015

Hracholusky studied area has strong industrial history, and according to the results has changed during the monitoring period slightly with some 25 % transformed land cover, changed on 1460.58 ha from 8134.06 total area (Table 9). Forest land with the arable land as the main part of the area haven't changed substantially (Table 8) – arable land decreased from 3569.24 ha (43.88 %) to 3010.5 ha (37.01 %), and forest land increased from 3303.86 ha (40.62 %) to 3359.98 ha (41.31 %).

Until the monitored year in 1950, grassland was present at 442.9 ha (5.45 %), mixture of scrubs and grasses at 105.72 ha, sparse tree vegetation at 175.25 ha or 2.15 %, and swamp areas at 13.36 ha (0.16 %). Roads and facilities category was represented by 422.3 ha or 5.19 %, and covered 101.43 ha (1.25 %).

As it is in other studied areas, result of flooding the area of the reservoir, the most changed category is water bodies, which increased after the built of the dam at 405.25 ha (4.98 %), which is increase of 303.82 ha or 299.54 %. This main change is followed by roads and facilities increase to 299.54 ha (9.74 %), of growth by 370.35 ha or 87.70 %. Mixture of scrubs and grasses has decrease by 56.23 ha (53.19 %) during the time period - to 49.49 ha or 0.61 % in 2015. Grassland slightly decreased to 360.65 ha (4.43 %), with decline of 82.25 ha (18.57 %), sparse tree vegetation was affected by small decrease to 145.58 ha (1.79 %).

HRACHOLUSKY	1950		2015		Changed LC	
Category	**Area (ha)**	**%**	**Area (ha)**	**%**	**Area (ha)**	**%**
Arable Land	3569.24	43.88	3010.5	37.01	-558.74	-15.65
Forest Land	3303.86	40.62	3359.98	41.31	56.12	1.70
Grassland	442.9	5.45	360.65	4.43	-82.25	-18.57
Water Bodies	101.43	1.25	405.25	4.98	303.82	299.54
Mixture of scrubs & Grasses	105.72	1.30	49.49	0.61	-56.23	-53.19
Roads & Facilities	422.3	5.19	792.65	9.74	370.35	87.70
Sparse Tree Vegetation	175.25	2.15	145.58	1.79	-29.67	-16.93
Swamp Areas	13.36	0.16	9.96	0.12	-3.4	-25.45

Table 9. Changes in land cover categories – Hracholusky

Total Area (ha)	8134.06
Changed Area (ha)	1460.58

Table 10. Change of total area - Hracholusky

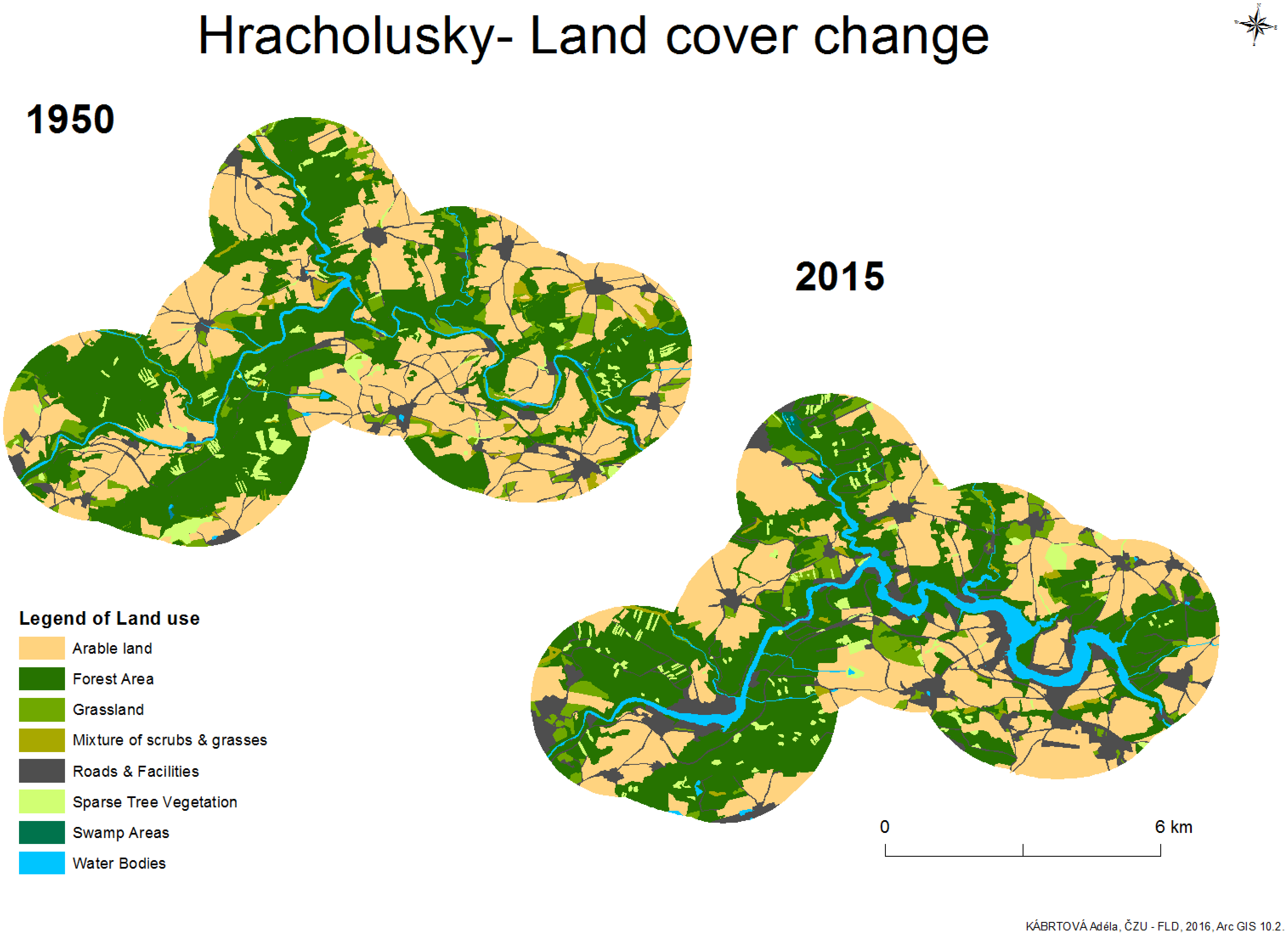

Figure 9. Land cover distribution Hracholusky 1950 and 2015

6.3.1. Calculation of statistical indexes of landscape metrics - Hracholusky

According to the results, number of patches has greatly increased in arable land from 2 to 126 (Table 10), sparse tree vegetation from 41 to 101, and roads and facilities with increase from 4 to 59, and finally grassland form 5 to 32. In contrast to that, mixture of scrubs and grasses decreased from 13 to 3, forest area from 158 to 94, and smaller decline of NP in swamp areas and water bodies. In Table 11 we can see small change in SEI in Hracholusky studied area in the years of monitoring.

HRACHOLUSKY Land use	Time period	NP	MPS	MSI	MPAR	MFRACT	MPE
Arable Land	1950	2	17846213.68	10.421	0.016	1.393	205093.9
	2015	126	238928.22	1.556	0.023	1.29	2334.13
Grassland	1950	5	885806.48	5.248	0.051	1.412	29352.35
	2015	32	112703.33	1.613	0.046	1.331	2748.63
Mixture of scrubs and Grasses	1950	13	81321.43	2.415	0.651	1.678	2624.35
	2015	3	164954.45	3.871	0.045	1.412	7248.9
Roads & Facilities	1950	4	1055753.55	18.337	0.191	1.629	106587.03
	2015	59	134347.08	4.764	0.144	1.532	6231.31
Sparse Tree Vegetation	1950	41	42742.83	2.515	0.067	1.421	1930.45
	2015	101	14413.62	1.523	0.069	1.37	686.2
Swamp Areas	1950	2	66793.72	3.427	0.048	1.435	3417.46
	2015	1	99613.67	2.677	0.03	1.391	2995.25
Water Bodies	1950	36	28174.83	5.284	0.482	1.651	2715.44
	2015	28	144730.37	5.76	0.821	1.922	3568.65
Forest Area	1950	158	209104.99	3,341	7,903	3,103	2976,73
	2015	94	357470.82	2,207	0,058	1,365	4505,89

Table 11. Landscape metrics and statistical indexes for each land type in the studied area of Hracholusky in 1950 and 2015

SEI	1950	0.598
	2015	0.65

Table 12. Shannon's Evenness Index - Hracholusky

6.4. Study Area Šance - distribution and changes in land cover during 1950–2015

Results suggest that from total area of 4610.46 ha studied area Šance, has been transformed 1488.42 ha (Table 13), where forest land has covered 3384.73 ha (73.41 ha) till 1950 and changed till now by increase of 377.87 ha or 11.16 % (Table 12), forming the largest part likewise in the previous studied areas.

In the time period till 1950 water bodies occupied 51.05 ha (1.11 %), arable land 394.48 ha (8.56 %), roads and facilities 156.44 ha (3.39 %). Mixture of scrubs and grasses covered 283.2 ha (6.14 %) , grassland 141.61 ha or 3.07 %, and sparse tree vegetation 139.52 ha or 3.03 %. Finally swamp areas has made 59.43 ha (1.29 %) of the area land cover structure.

During the monitored period the most significant change has been in category of water bodies, with fourfold increase to 256.64 ha, where it has been caused - as in previous studied regions - by realization of the dam construction. Urban areas and roads increased doubled to 305.92 ha or 6.62 %. Small increase has been recorded in grassland category, with 152.83 ha by increase of 11.22 ha. Greatest decrease was observed in category of swamp areas by decline of 59.31 ha, present at 0.12 ha in 2015, and arable land with loss of 384.12 ha or 97.37 % of the area in 1950. Mixture of scrubs and grasses declined to 20.74 ha, by decline of 262.46 ha or 92.68 %.

ŠANCE	1950		2015		Changed LC	
Category	Area (ha)	%	Area (ha)	%	Area (ha)	%
Arable Land	394.48	8.56	10.36	0.22	-384.12	-97.37
Forest Land	3384.73	73.41	3762.6	81.67	377.87	11.16
Grassland	141.61	3.07	152.83	3.3	11.22	7.92
Water Bodies	51.05	1.11	256.64	5.55	205.59	402.72
Mixture of scrubs & Grasses	283.2	6.14	20.74	0.45	-262.46	-92.68
Roads & Facilities	156.44	3.39	305.92	6.62	149.48	95.55
Sparse Tree Vegetation	139.52	3.03	101.25	2.19	-38.27	-27.43
Swamp Areas	59.43	1.29	0.12	0	-59.31	-99.80

Table 13. Changes in land cover categories - Šance

Total Area (ha)	4610.46
Changed Area (ha)	1488.42

Table 14. Change of total area - Šance

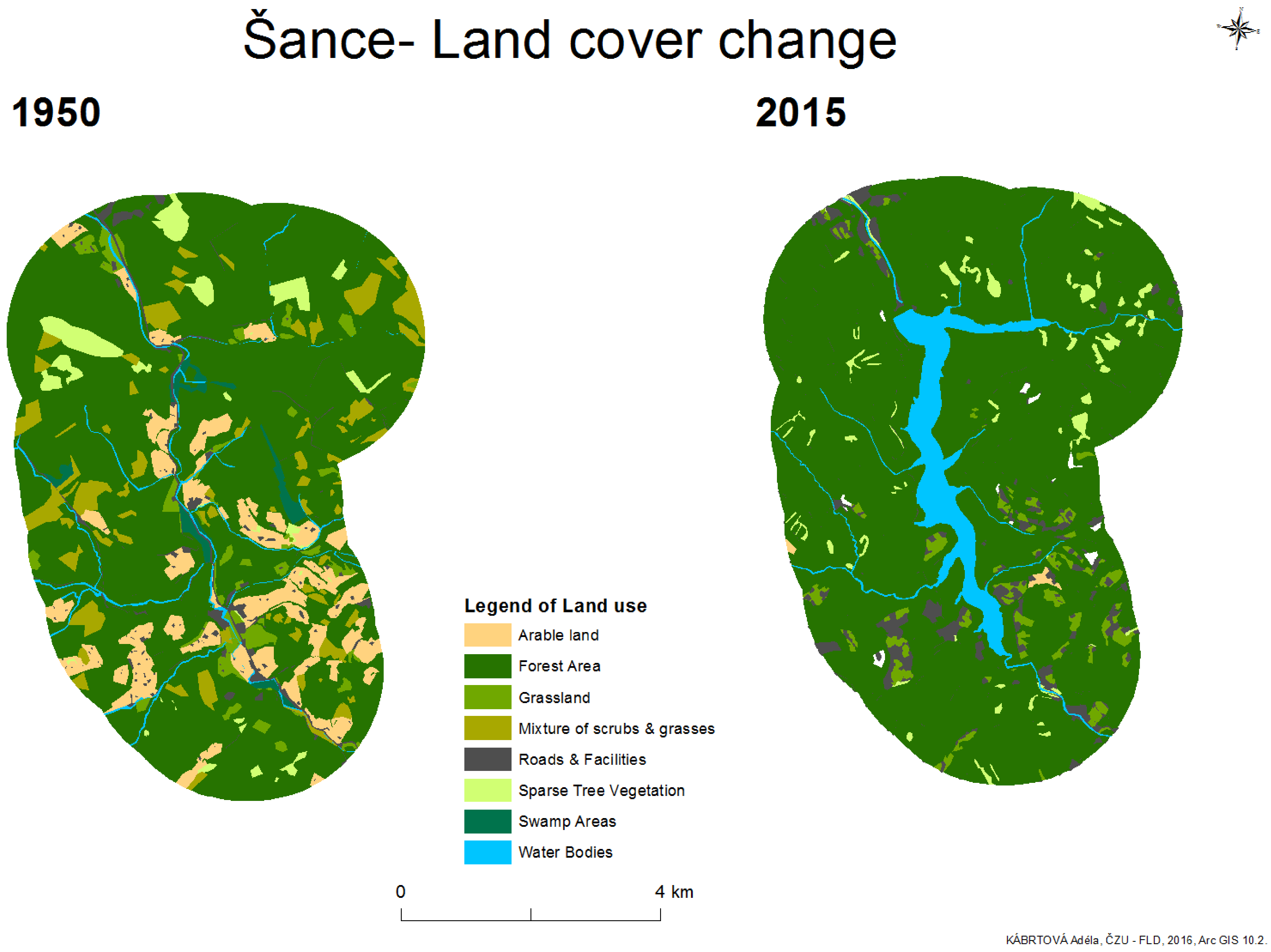

Figure 10. Land cover distribution Šance 1950 and 2015

6.4.1. Calculation of statistical indexes of landscape metrics - Šance

The statistical indexes show that NP has in case of roads and urban areas decreased about 50 %, from 155 to 73 (Table 14), swamp areas decline thirteen times and arable land dramatically from 63 to 1 after the year 1950. NP of mixture of scrubs and grasses changed about six times – from 82 to 13, and water bodies from 24 to 10. Finally grassland with a minor change from 65 to 58. Forest area have not changed in the studied period. Increase in number of patches has appear only in category of sparse tree vegetation with more than doubled NP from 18 to 54. The value of SEI increased during the monitored time period, but it is still in within the maximum value.

ŠANCE Land use	Time period	NP	MPS	MSI	MPAR	MFRACT	MPE
Roads & Facilities	1950	155	10093.07	2.36	0.246	1.626	1060.32
	2015	73	41906.21	3.633	0.116	1.451	4772.28
Water Bodies	1950	24	21270.69	6.404	0.248	1.665	3495.34
	2015	10	256639.58	6.706	0.201	1.629	6182.92
Sparse Tree Vegetation	1950	18	77511.86	1.728	0.049	1.342	1580.27
	2015	54	18749.18	1.922	0.073	1.402	888.92
Swamp Areas	1950	13	45712.74	1.821	0.048	1.368	1283.14
	2015	1	1222.62	1.059	0.107	1.372	131.27
Grassland	1950	65	21785.57	1.614	0.143	1.497	733.56
	2015	58	26349.73	1.572	0.054	1.356	980.48
Forest Area	1950	102	331836.16	2.683	3.31	1.462	3271.28
	2015	97	389351.58	2.297	0.055	1.368	4714.73
Arable Land	1950	63	62615.55	1.925	0.099	1.398	1546.07
	2015	1	103557.73	2.362	0.026	1.368	2693.97
Mixture of scrubs & Grasses	1950	82	34536.1	1.513	0.087	1.361	828.91
	2015	13	15954.67	1.359	0.048	1.336	578.45

Table 15. Landscape metrics and statistical indexes for each land type in the studied area of Šance in 1950 and 2015

SEI	1950	0.501
	2015	0.74

Table 16. Shannon's Evenness Index - Šance

7. DISCUSSION

7.1. Possibilities of used methodology

Aim of this study was to analyze, evaluate and present landscape structure changes, due to realization of important hydraulic construction in four different areas in Czech Republic, in time period from 1950ies to present, by integration of remote sensing and use of GIS – in particular using the aerial historical orthophotos from year 1950, and latest orthophotos from 2015, both available on ČÚZK Geoportal. Analytic tools of GIS program has enabled to determine specific land use and land cover changes in studied area, and result in documenting what changed, and where it changed. This method eliminates limited informative ability of statistical data used in LULC studies, and has been already used in many studies i.e. Keken (2014), Štych (2007). The use of historic aerial photos interpretation has proven to be a useful technique in study of long-term land-use changes and determination of its driving forces - usually used in studies with monitoring time period of 50 years and more, due to its availability in some regions since 1930s (Casson et al., 2003). Limitation can be seen in possible subjectivity of detection correct LC structure from ortophotos. Moreover, due to low visibility of stream and river network - especially on the historic aerial photographs - was necessary to use additional data from geographic reference database (DIBAVOD). Materials obtained in studies of landscape structure are nowadays important base for decision making of landscape formation and conservation, as well as for creation of environmental limits and landscape potential. Simultaneously can be used in the process of decision making on factors on the environment and human health within Environmental Impact Assessment (EIA).

7.2. Indices of landscape metrics

Number of patches is one of the commonly used metrics due to its importance in ability serve the base for calculating other and more interpretable metrics, moreover it is relatively easy to use (Dramstad et al., 2006). The value of NP indicates the level of fragmentation, which is very important index from ecological point of view. In this study value of NP in general has increased in all of the studied sites - specifically in forest land, arable land, and roads and facilities category, only except of Šance site, where the number of patches of forest land has not changed. Overall, the majority of increased number of this index deduce that the level of fragmentation is higher in present comparing to the past state. Shannon Index is identifying landscape diversity and providing information on area composition and richness. It covers the number of different land cover types observed along the straight line and their relative abundances, and has been used in many studies recently, while it's an estimator of landscape structure, and it is relatively easy to use (Dramstad et al., 2006). In case of all four sites, SEI only increased slightly, but the values remain in the range and occur close to maximum number 1 which indicate even representation of LC categories.

7.3. Driving forces of landscape structure change

As a result of historical socio-economic changes and development transforming the anthropogenic influence, we can found many forces which has determined landscape structure in last 60 years. The main social driving forces in the area of Czech Republic were regional politics under reign of communist government between years 1948-1989, change of regime after Velvet revolution – opening to international markets and changes of grand donation in agriculture with the event of becoming part of European union. Moreover, implementation of environmental measures in the landscape after 1990 has accelerated to imitate the anthropogenic activities in the landscape, lead to increase of forest areas and natural LC structure (Štych, 2007). Important natural factor is intensively discussed global climate change - which is particularly in the Czech Republic in form of drought or flood periods, and water scarcity, during the last years in very alarming appearance, and reflected in EU policies (Estrela and Vargas, 2011). Water retention and dam construction is very specific field, where the artificial structure of the construction is associated with a various environmental problems, such as water diversion, habitat fragmentation, disruption in the magnitude or timing of natural river flows (Fried and Wüest, 2002). In contrast to it, dam construction has various benefits, for example support of recreational activities or aesthetic services (Knight et al., 2001), and most importantly flooding control and drinking water supply.

More specifically, while is the Koryčany reservoir studied area source of drinking water, it's part of hygienic First protection zone. It is covered mostly by forests, which in the monitoring period even has grown (Table 1) and most of arable land were transformed into built-up area (Figure 6). Both phenomena are supported in study of Tomanová (2013). An increase of built-up areas, roads and forest is supported by the study of Keken et al., 2014, focusing on the evaluation of landscape structure changes due to realization of dam in Greece, and comparing it with the locality in the Czech Republic, where the dam can be built (Keken et al., 2014)

Pilská reservoir was built on the origin area of pond Pilka, in forest valley with rich stream network, therefore the category of water bodies have increased only slightly (Table 5). Moreover, while the territory has partly became a closed military area, largely banned to public, most of the studied categories of landscape structure remain relatively unchanged (Table 6). Only arable land has decreased significantly, in relation to the total area (Table 5).

Hracholusky are situated in region with strong industrial history, therefore the forest area has even in history - and in year of monitoring (1950) - been creating smaller part of the area compare to the rest of studied sites, concretely 40 % of total area (Table 9). The other dominant category was arable land - following the trend of decline of this category in other studies - with loss of 558.74 ha, where the size seems to be large, but with taking into account the total area, the change is only by 7 % (Table 9). Another phenomena, which can be clearly seen on the output map (Figure 9) is concentration of urban areas and road facilities around the reservoir, what can be explained as a consequence of one of the popular function - recreation purpose.

In observed area of Šance reservoir has been the land cover affected mainly from flooding process itself, with the extent of 337 ha of the built reservoir. The second greatest change happened by decline of arable land, and small increase of forest area –which made already the largest part of the area (Table 13), what is entirely confirming already mentioned theory occurred in previous studied sites.

8. CONCLUSION

Method used in this work for purpose of landscape structure change study, in determined time period of more than 60 years - combining application of both historic and current orthophotos with use of GIS software and its extension V-LATE - was appropriate for this kind of analysis. This approach has enabled to obtain necessary data for desirable characteristics of the particular landscape use and land cover category, and data revealing the environmental aspects of the specific site. In addition, with use of DIBAVOD geographic reference database available for the whole area of the Czech Republic, was possible to identify the river and stream network, which was in majority of cases not recognizable from the pictures. Due to the development of computer technique is the science more capable achieve greater accuracy of the environmental studies over time.

The results of this thesis has confirmed hypothesis of long-term increase in the proportion of forest and urban areas, with a maximum increase during the last 50 years, which can be found already in previously done studies aiming on environmental assessment of our landscapes, for example in work of Miklín (2015). In my opinion, all of the sites were suitable for the placement of the reservoirs in the past for their purpose. Specific characteristics of the locations, which had been chosen for the realization of the four construction, had more likely the greatest influence on changes on the landscape structure. The site of Pilská can be disputable due to its geomorphological conditions, where the subsoil is formed from mixture of sandstones, slates and conglomerates, and therefore not the most suitable area for realization of hydrological construction. Existence of pond Pilka in the flooded area of the dam area can be good explanation as coherent historic development in the territory. All of the dams, when correctly maintained, can be functional and valuable part of our landscapes, moreover to be essential tools in fighting with already present water scarcity and drought threats and climate change.

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