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BACHELOR THESIS

Function of trees in agricultural landscape - environmental impacts and sustainability

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2. Volba hodnocených dopadových kategorií
3. Sběr dat k dopadovým kategoriím.
4. Vytvoření přehledu dopadů stromů v zemědělské krajině a shrnutí jejich vlivu z environmentálního pohledu
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Abstract

This thesis discusses the role of trees in agricultural landscape with a focus on the impact on the environment and on sustainability. First, general problems of current agriculture, and its effects on the components of the environment, are described. Then, I give a brief historical context of deforestation in the development of agricultural landscape is captioned. The main focus of the thesis is to explain the effect of various tree functions on the components of agricultural landscape. The effects of trees on atmosphere, hydrology, biology and soil are also described. Furthermore, I explain the elements of non-forest woody vegetation, which can be found in agricultural landscape, are described. The final part of the thesis evaluates the various functions of trees according to the number of references, presented in literature in the form of tables and graphs.

Key words

Trees, landscape, environment, sustainability, agriculture

Abstrakt

Bakalářská práce se zabývá úlohou stromů v zemědělské krajině se zaměřením na jejich dopad na životní prostředí a udržitelnost. Nejprve je popsána obecná problematika dnešního zemědělství a jeho efekt na složky životního prostředí. Dále je popsán stručný historický kontext odlesňování v utváření zemědělské krajiny. Hlavní částí práce je popis vlivu jednotlivých funkcí stromů na složky zemědělské krajiny. Účinky stromů na atmosféru, hydrologii, biologii a půdu jsou popsány. Dále jsou popsány prvky nelesní dřevinné vegetace nacházející se v zemědělské krajině. Poslední část práce vyhodnocuje jednotlivé funkce stromů podle četnosti zmínek v použité literatuře a to ve formě tabulek a grafů.

Klíčová slova

Stromy, krajina, životní prostředí, udržitelnost, zemědělství

Contents

1 Introduction

The goal of this thesis is to bring about a new view on the role of trees in our agriculture models and landscape management using the latest understanding of the problematics of tree ecology, biodiversity, water management, soil erosion, pest control, climate change etc. to preserve our natural heritage within sustainable agriculture. To understand such a complex topic it is necessary to overcome our simplified view on the position of trees in our landscape and build up a broader and more holistic approach. The conclusion of the thesis should be that a better understanding of the value of trees in landscape is necessary to provide sustainable food security and a happy life for the animals and humans on our Planet. At the same time, that as a society, we should reassess our values and principles towards caring and respectful relationship with nature. It is not possible to endanger the future of next generations in exchange for short-term profits. Our economical models and money-oriented thinking only provide us with limited and short-term beneficial approaches. Long-term policies should be set to protect these giants of the plant world and bring a balance to the nature once again.

2 Literature research

2.1 Agriculture and sustainability

The switch from a hunter-gatherer way of life to agriculture and pasture can be considered as the one of the most important revolutions in human history (Kravčík et al., 2008). The degree of transformation of the world caused by human activity over last 50 years has created a biosphere with no past analogues (Oldfield, 2005). These impacts are so unique that specialists have started to call this period the Anthropocene. The opinion about the beginning of this era differs among scientists.

In the year 2000 atmospheric chemist Paul Cruzen, a Nobel Prize winner for chemistry of atmosphere, claimed that anthropogenic influences on climate are so serious that we can't talk about the natural period of climate anymore. According to his conviction, the invention of the steam engine in 1784 and the start of the industrial revolution caused mankind to change Earth's atmosphere in such a way that we can talk about a new geological era. On the other hand, paleoclimatologist Willam F. Rudiman is an author of a thesis claiming that a natural cycle of climate was disrupted much earlier. The start of the Anthropocene, according to his thesis, is connected with the invention of agriculture about 8000 years ago (Behringer, 2007).

Nevertheless it is without doubt that the impact of human management of the land, especially through agriculture has a great effect on the environment (Macák, 2006). It is important to understand that while we talk about the environment, nature cannot be divided in to limited and disconnected units, because we deal with complex systems.

Central to any understanding of how the Earth’s system operates are the processes that change fluxes of energy within atmosphere and between atmosphere, hydrosphere, cryosphere and biosphere (Oldfield, 2005). Therefore, agricultural impacts cannot be easily simplified as the influences of changes in landscape and vegetation go much further, affecting the climate and well being of humanity.

2.1.1 Is our agriculture sustainable?

Agriculture brings with it the potential for overproduction, which leads to excess wealth, hoarding, and trade. Trade leads to cities; cities isolate their inhabitants from the natural world. Paradoxically, more efficient utilization of plant resources through agriculture led to a breaking away from the symbiotic relationship that had bound human beings to nature (McKenna, 1993, p. 56).

The 20th century showed us amazing possibilities in agricultural development towards higher yields and efficiency, providing us with food security and abundance throughout all seasons of the year. With the discovery of intensification and mechanisation, less people are involved in agriculture now more than ever (Reganold et al., 1987). An introduction of various chemicals allowed us to prevent losses caused by weeds and pests and to predict our yields more accurately. These inventions made international food trading possible, and made it so that self-sufficiency of much of the world's countries is not an issue anymore. On the other hand, once food trade became common, our food demands started to be isolated from our local environment and its limitations (Macák, 2006). With the raise of mechanisation and utilisation of chemicals agriculture became dependent on the petrochemical industry. Dependency on petrochemical products and food trade causes great pollution of the environment and deepens the ecological footprint of our food production; moreover it threats life and biodiversity (Geiger et al., 2010).

2.1.2 Sustainable agriculture

If we do have a food crisis, it will not be caused by the insufficiency of nature's productive power, but by the extravagance of human desire (Fukuoka, 2009, p. 114).

Desirable relation between agriculture and the environment can be described as sustainable agriculture (Macák, 2006). Sustainable agriculture can be classified as a group of methods allowing sufficient food production without depleting Earth's natural resources and minimising pollution of its environment. This allows the preservation of soil fertility and water quality, vital for sustaining life (Earles, 2005). According to Macák (2006) first a fall, sustainable agriculture represents a way of managing natural resources which allows its availability for future generations. This kind of management should include protection of landscape, biotopes, and biodiversity. From this broader point of view the protection of the environment and cultural heritage have to be taken into account while we talk about use of land and natural resources.

The challenge of present and future agriculture is being able to provide and maintain food security while not depleting natural resources, both essential for human well being. According to the Human Development Report by the United Nations (2003), the growth of population will not stop untill half way through this century and will reach about 9 billion people. Such growth will put pressure on our food supplies and agriculture in general. To handle such a demand requires an international cooperation on many levels as our world is getting more and more globally interconnected. This implies the cooperation of governments, scientists and companies, as well as that of the general public.

The eminent problem of our food production as mentioned above is the increasing lack of appreciation towards the limitations of local environment. As food production is being led by forces of the market, the price of a product is usually the most important aspect of the production. This leads to the preference of monocultures and an excessive usage of chemicals and machinery in agriculture (Jackie and Toesmeier, 2005). Big agricultural concerns and companies also control substantial part of the market and set prices for small-scale farmers. However, local and small-scale farmers often carry a heritage of their ancestors and may better understand the local environment and respect its natural limitations.

The global food trade also involves consumers in the problem. If consumers buy products from a foreign country, their ecological footprint is higher than if they were to buy local produce. They are disconnected from the processes of growing and manufacturing the product. As these activities take place out of the consumers' sight their awareness of the environmental impacts of such food production is then limited by the transparency of that particular company. Therefore the consumers' responsibility and their education also play an important role while we talk about sustainable agriculture.

According to Kováč et al. (2008), ecological footprint can be understood as an area of biologically productive landscape, necessary to provide various natural resources to fill continuous needs of energy and material inputs for a given population, and simultaneously to absorb all waste produced at a given technology. If it is said that The Netherlands consumes seven times more resources than its area is able to yield, it can be understood that the ecological footprint of its economy is 7x higher than the potential of the country. The efforts made by different countries and regions to protect natural resources may differ. Some countries compromise their environment in exchange for short-term income.

2.2 Agriculture and its influence on single components of the environment

2.2.1 Atmosphere

One of the most ominous problems of our age is climate change. This paper is not aimed at proving or questioning the problems of the climate warming or whether our contribution to this phenomenon is its leading driver. However, when we talk about sustainable agriculture, it is not possible to neglect the effects of our food production in relation to the changing concentration of gases in the atmosphere.

We can't understand climate as a self-contained atmospheric component being separated from processes that interact with it, rather we should view human actions as key agents that are transforming the Earth system (Oldfield, 2005).

Anthropogenic emissions of greenhouse gases considerably affect the process of the climate change (Macák, 2006). Human activities such as land cover changes and industrialisation are both key drivers of changes in atmospheric composition (Oldfield, 2005).

Agriculture is considered to be the third greatest producer of greenhouse gasses after industry and mining activities (Moudrý, Moudrý jr., 2014). According to different sources, annual increase of GHG is estimated from 20% (Cole et al., 1997) to 27% (Cerri et al., 2009).

In general, the climate is strongly influenced by concentration of following gases: CO_2, CH_4, N_2O, SF_6, HFCs and PFCs. Agriculture is not considered as producer of so-called new gases: SF_6, HFCs and PFCs (Macák, 2006).

According to Moudrý, Moudrý jr. (2014), emissions are produced in many ways. CO_2 is released within reduction of organic matter content in soil or released by burning of fossil fuels, while application of fertilizers results in releasing N20.

It's important to point out that amount of CO_2 (the most discussed GHG) produced by agriculture, according to data by Eurostat, represents just about 1-2% of total estimated CO_2 emissions (for OECD countries). However, emissions of N_2O and methane (NH_4) have the most significant effect on climate change among gases produced by agriculture, with their contribution estimated at over 40% (Macák, 2006). Moreover, Moudrý and Moudrý jr. (2014) highlight that N_2O is identified as a major greenhouse gas with it having an effect 300 times greater than the CO_2 effect.

Agriculture has also indisputable effect on distribution of water vapour. In previous chapters we pointed out how important water is within soil. If soil is saturated with water, it can evaporate and circulate in small amounts. This means that the water condensates locally and provides regular precipitation. Bare soil is vulnerable to erosion, it loses water more easily, and its thermal regime is easily disturbed.

Vegetation protects the soil from such undesirable consequences. If vegetation cover is disrupted, solar energy falls on an area with low evapo-transpiration and energy is then changed into heat. Increasing temperature misbalance leads to change of air currents, and then water evaporated from soil is taken away from the country (Kravčík et al., 2008). Because agriculture modifies vegetation cover and soil saturation it also directly affects local climate (microclimate).

Contemporary with oxygen production, trees have great potential in sequestration of the atmospheric CO_2 in biomass. According to Nátr (2000), with reduction of deforestation and increase of afforestation, the rising speed of CO_2 concentration could be slowed down. Intergovernmental Panel on Climate Change has recommended a catalogue of solutions to mitigate increasing CO_2 emissions (reforestation, afforestation, conversion of agricultural land into agrosylvicultural systems) (IPCC, 2001).

2.2.2 Water

Water regime has been affected by agricultural development on many levels. The extent of this paper is too limited to embrace all aspects. However, it is crucial to point out at least the most important ones.

Ground water and soil moisture represent alongside glaciers, the largest wealth of water on land (0,685%). Visible surface water in rivers represents just 0.0001% and 0.01% in lakes including salt lakes and inner seas (Kravčík et al., 2008).

Through agricultural processes water quality and its circulation are extensively impacted. In the previous chapter we talked about how erosion affects the moisture-holding capacity of soil and transport of nutrients. If such erosion is caused by water runoffs carrying soil components, it directly aggravates water quality of watercourses. This is usually caused by the lack of natural barriers, improper tillage or wrong rotation of crops.

The unquestionable threat to water quality presents utilisation of pesticides and morforegulators. Residues of such substances significantly contaminate surface and ground water, and the entire environment. Even low concentrations harm also aquatic animals (Moudrý, Moudrý jr., 2014).

In Europe, agriculture is also the most important source of the growing level of nitrates in water systems. Especially in western and central Europe 50-80% of the occurring nitrate stresses can be ascribed to intensive agricultural policy (Macák, 2006).

Talking about water, it is important to highlight also the problematics of water cycle and water availability. Because of the changes in land use and the general ongoing transformation of landscape thanks to agriculture, deforestation and urban or suburban development, patterns of water flow have been significantly disrupted.

We can distinguish many types of agricultural methods according to their approach to water. This may differ according to climatic region, accessibility of water, or character of land cover. The great civilizations which originally formed around big rivers (Nile, Euphrates and Tigris, the Indus, the Yellow River) also called *hydraulic civilizations* used extensive networks of canals to irrigate crops or deal with seasonal floods. Such agriculture is called alluvial and is fully dependent on surface water courses (Kravčík et al., 2008).

Our ancestors in central Europe needed to face completely opposite challenges. Landscapes covered by great areas of primeval forests and swamps well stocked with water meant that potentially the only problem for farmers was the lack of arable land and the abundance of water. This led to continuous deforestation and land drainage, which in many places still occurs today and affects both water cycle and biosphere. Already during the Bronze Age, great areas of European forests had been transformed due to deforestation and land cultivation (Behringer, 2007).

The most important period in the sense of the negative effects on water management, especially for the East-European countries, represents the era of collectivization, closely related to the agricultural policies linked to the communist centralisation. In the Czech Republic until 1990, up to 1.5 million ha of arable land had been drained, frequently in areas of natural accumulation of surface water and in mountain areas. By 1998 drained land still represented 25% of the total area (Sysel, 1999). The drainage of the land has a negative impact for its retention capability and directly affects levels of ground water and water cycle in general. Mankind cannot transform and drain the land without also having impact on precipitation and thermal regime (Kravčík et al., 2008).

Deforestation is one of the causes which is being connected with ongoing shortage of water resources (Kravčík et al., 2012). Forests help in storing rainfall water and therefore have an important role on hydrology (Bond et al., 2008). Trees can also mitigate negative effects of agriculture such as water erosion and a threat of water quality.

2.2.3 Biodiversity

Our current preoccupation with climate and global warming is often bypassed by the most important aspects of on-going global change. The cumulative impact of human activities on biosphere over the last 200 years has been greater than those resulting from climate change (Oldield, 2005).

According to Macák (2006), biodiversity is a heterogeneity of life and its processes. It embraces all living forms from a single cell, to complex organisms and processes and cycles that bond living organisms into populations, ecosystems and landscape models.

Another definition comes from Demo et al. (2011) - biodiversity represents diversity of organisms and their environment. It can be understood as a variety of living organisms and natural resources within ecosystems. The expression *biological diversity* contains ecosystems, species, genes and their relative quantity. Species and ecosystem variety both define biodiversity as well.

The elimination of important ecosystems together with species diversity reduction are main factors of most of Planet Earth's biodiversity loss and mass species extinction (Kováč et al., 2008). Around 44% of the known biodiversity of plants and 35% of all non-fish vertebrates are endemic to 25 biodiversity hotspots covering 12% of Earth's surface (Kitching, 2000). These areas are threatened through land-cover change, e.g. forest clearance (Oldfield, 2005). Decrease of biodiversity leads to chain reaction on the basis of synecological processes and ecological interconnection of various organisms. This considerably contributes to land cover disruption and desertification of landscape (Růžička, 2000). Diversity at the landscape scale is linked with species biodiversity and can be retained only through maintenance (or establishment) of mosaic of suitable habitats with necessary linkages (spatial and functional) (Waldhardt, 2003).

2.2.3.1 Agrobiodiversity

Current biodiversity loss significantly affects food production, since our crops are dependent on natural pollinators and predators. In addition, higher level of biodiversity represents important condition for healthy and functional landscapes, therefore pesticide and herbicide usage should be lowered (Kováč et al., 2008).

According to Moudrý, Moudrý jr. (2014), factors driving agrobiodiversity are widening of crop range, supply of organic matter into soil, optimal fertilization, plant nutrition and protection, soil conservation, and creation of landscape feature creation (cops, alleys, strip planting, land division). Meanwhile organic farming provides more diverse areas.

Annually 21 million ha of arable land became infertile and 6 million ha is turned into desert. Main cause of this process is agricultural intensification, excessive grazing and deforestation (Růžička, 2000).

Deforestation is dangerous phenomenon since according to Ozanne et al. (2003), forest canopies are among the most threatened habitats in the world and at the same time they are the most important for biodiversity, because 22 of 25 global diversity hotspots include forest habitats. Loss of biodiversity raises many questions about whether future and large-scale monitoring will be necessary (Oldfield, 2005).

Trees can considerably increase biological diversity of agricultural landscape, because they create habitats for various species. According to Kalda et al. (2014), homogenization of agricultural landscape driven by the intensification practices led to loss of biodiversity and to degradation of ecosystems because it often underestimates functions of scattered tree vegetation. Lack of such features may also lead to creation of migration barriers for animals (Anděl et al., 2010).

2.2.4 Soil

Our relation to soil goes very far into history of the human race. Agriculture itself is as old as what we could call human civilization. Once agriculture had been invented, our life became dependent on soil. Soil provided us with food for millennia. However, our relationship with soil has been much more than a production of food.

According to the research of the anthropologist George Armelagos taking place in remote Sudan, the bones of our predecessors from 350-550 AC contain a natural antibiotics produced by the bacteria called *Strepotomyces*, living naturally in soil (Cílek, 2015). It means that soil had also had a significant influence on our immunity and health. To achieve a healthy humanity, we need a healthy soil.

Soil is a key component for agriculture and is one of the most important natural resources. Healthy soil is not just essential for the proper growth of plants, which can be classified as the production function, but its other functions are also very important. Those functions include filtering, buffering, transformation, (etc.). Last but not least, soil represents the environment for living micro-organisms (Moudrý, Moudrý jr., 2014).

Soil is viewed as a non-renewable resource for its very slow creation. The top layer of soil is created with a speed of 10 mm in many hundreds of years (Macák, 2006). A large-scale degradation of soil started thousands of years ago with its cultivation and intensive farming. An invention of a plow and deep tillage, later enhanced by power of tractors, led to 30% loss of topsoil over last 40 years worldwide (Berner et al., 2012).

Therefore, soil has to be protected and its quality maintained for future generations. An important factor in soil organic matter protection is minimum soil cultivation (Moudrý, Moudrý jr., 2014).

2.1.1 Soil functions and properties

2.1.1.1 Soil fertility

Fertility of soil is the most important aspect for a great part of agricultural activities. Ecologically healthy soil is able to refresh its yield potential, but if we do not replenish its needs sufficiently, soil suffers and loses its vitality while becoming vulnerable to erosion and other negative impacts (Berner et al., 2012).

During the 20^{th} century our vision and understanding of soil fertility was influenced by the introduction of artificial fertilizers. Fertility has been simplified to mathematical equations between the most important chemicals contained in soil such as carbon and nitrogen and their relation with yields. Such limited interpretation can be dangerous, because it does not take a soil edaphon into account. The chemical relations are important to understand soil fertility, but they cannot represent complex understanding of the way in which soil functions. Biological relations are important as well, because soil is not just a mixture of organic matter and minerals, it can be understood as a living substance. Soil cannot be healthy without a natural balance of organisms living inside. According to Moudrý, Moudrý jr. (2014), the positive role of such organisms is mainly in decomposition of organic matter and transformation of inorganic substances. In soil abundant with these organisms, nutrients are easier to access by plants, and symbiotic relationships of bacteria and plants within the rhizosphere can take place.

One gram of soil contains hundreds of millions of bacteria and hundreds of meters of fungi fibers. These organisms are able to decompose organic material to elementary components and to regulate cycles of nutrients (Berner et al., 2012).

Moudrý, Moudrý jr. (2014) refer that soil deterioration caused by intensive cultivation through the use of mineral fertilizers and pesticides leads to reduction of soil biodiversity, while soil with low humus content and light soils are relatively more sensitive.

2.1.1.2 Soil erosion

We distinguish two main types of soil erosion - caused by wind or caused by water. These two elements directly affect the soil in the sense of negative displacement of little particles.

Agriculture is the main user of arable land and it considerably affects run off ratios and loss of soil particles from it. Availability of soil and water are elementary for function of agriculture (Kováč et al., 2008).

According to Macák (2006), erosion is the greatest threat to soil caused by agricultural activities, such that the scale of displacement of soil particles can lead to degradation of quality and even irreversible devastation of the land (Kravčík et al., 2008).

Erosion of topsoil removes nutrients stored in the surface layers of the soil, especially those retained within the organic matter generated by the decomposition processes. This leads to moisture-holding capacity reduction. Soil degradation can be understood as the negative shift of an ecosystem, when nutrient recycling and availability are lowered. This happens if the depletion rate of soil nutrients exceeds the rate of their renewal (Oldfield, 2005).

2.1.1.3 Wind erosion

Wind erosion is affected mainly by three factors: erosion effects of weather, erosion resistance of the soil and roughness of the surface. The effect of erosion increases with wind velocity and decreases with air humidity. The content of clay particles and organic matter are important as well (Macák, 2006). There is substantial importance of physical barriers slowing wind currents. These barriers can be formed by vegetation (trees, windbreaks, vegetation cover) or by the relief of the landscape (orographic barriers).

Trees can serve as a barrier in prevention of both water and wind erosion (Demo et al, 2011). The sustainability of agriculture is dependent on the presence of such natural features like forest remnants, hedgerows, tree lines and so on.

2.3 History of agricultural landscape formation with focus on Czech lands

It is possible to divide the history of the landscape formation into two different periods: natural period and anthropogenic period.

2.3.1 Natural formation of the landscape

During the period of natural formation of the landscape, which took place between last glacial period and the Neolithic revolution, climatic oscillations and natural succession were the main drivers of the change in vegetation cover (Neühauslová et al., 1998).

The potential natural climax of the most of the land areas of the globe, which today support high human populations, would be some type of forest ecosystem (White et al., 1992). However, the present area of the Czech Republic that is covered by forests is only 33%. This is the long-term consequence of continuous deforestation and the influence it has had on natural evolution of biota (Úřadníček, 2010). It is important to highlight, that quantity does not reflect the issue of quality. According to Neühauslová et al. (1998), the original climax forests have been modified by plantation of timber and pine monocultures, and also by the recent on-going succession of nitrophilous plants thanks to eutrophication.

2.4 Anthropogenic formation of landscape and influence of agriculture

Originally, humans as hunter-gatherers were an integrated part of a dynamic balance of a climax ecosystem (White et al., 1992). That started to change around mid-Holocene (7000 years ago), when the Neolithic agriculture reached central Europe, and semi-permanent settlements emerged (Neühauslová et al., 1998). People switched from an intuitive way of resource utilisation to more organised forms of farming (Supuka et al., 2008).

Although the density of settlements and the technical level of dwellers didn't allow great damage to be caused to the ecosystems (Neühauslová et al., 1998), the Neolithic revolution can be considered an important milestone in the landscape formation (Ložek, 1973). The fire-stick farming has been used for obtaining new land and it affected the mosaic of the landscape (Löw and Míchal, 2003). These land-management practices had profound effect on the landscape vegetation pattern and biodiversity (Pausas and Keeley, 2009). The spatial changes in vegetation allowed the secondary migration of light-requiring plants, originally succeeding on sporadic and extreme habitats. The stability of these newly developed habitats were conditioned by human presence and action (Neühauslová et al, 1998).

During Eneolithic (3200 -2000 BC), the next significant revolution of the landscape character started with invention of the hook plough (Löw and Míchal, 2003). Additional large-scale deforestation happened, and locally the original vegetation was transformed into fields and meadows, and poor land was usually used for pasture (Neühauslová et al., 1998).

Deforestation was intensified during the iron age with the need for fire wood to manufacture iron (Löw and Míchal, 2003), with discovery of iron tools, the scythe finds its utilization in maintenance of meadows, which provides twenty times more biomass than forests (Gojda, 2000).

With Roman Empire expansion around 0 AD the roman settlements in Europe emerged and future towns developed on their foundations (Dark, K., Dark, P., 1998). Numerous roads were built and the first triangulation occurred (Sklenička, 2003). That was the very beginning of structured landscape in our lands (Gojda, 2000).

During early Middle Ages the lowland deforestation was being finished (Neühauslová, 1998). According to Lipský (1999), it is estimated that arable land already represented about 10-15% of total area of the Czech lands. A new long field pattern developed with more advanced tillage methods (Sklenička, 2003).

The important change in landscape was a foundation of pond networks in the late middle ages (Löw and Míchal, 1993). That caused further alteration of natural vegetation (Neühauslová et al., 1998). During that period the total area of forestation was so low, that agricultural land became locally the prevalent culture (Sklenička, 2003). The on-going period of the Little Ice Age caused also raising pressure on European forests (Fagan, 2001).

The Modern Age together with the Industrial Revolution brought an important shift. In the 17th and 18th century the colonization of highland areas came to an end and a need for timber in border forests increased (Gojda, 2000). In the 19th century the total area of forestation was at the historical minimum (Sýkora, 1998). Science contributed to the improvement of the agricultural methods and helped to create intensification trends (Sklenička, 2003) and the four-course crop rotation started to spread through Europe (Löw and Míchal, 1993).

The Red Revolution and the collectivisation had a massive impact on our landscape. The small fields were united into large plots of hundreds of hectares of land (Kravčík et al., 2008). With only short-term vision and planning, an abundance of chemicals were utilised in agriculture that caused an irreversible damage to the ecosystems (Kender, 2004). One of the most radical landscape interventions was the process of melioration and the water course regulations, which both developed during second half of the 20th century and causing great damage to water regime of the landscape (Sklenička, 2003). Because of the agricultural-technical modification taking place up until 1990, 450 000 ha of meadows, 50 000 ha of scattered vegetation, and 240 000 ha of copses were cut and ploughed (Simon, Sucharda, 2004).

Although according to Verschuur et al. (2003), the intensification of the agriculture, boosted by some donation programs of the EU (e.g. CAP), had similar effects as actions described above. In general, the Velvet Revolution in 1989 brought a positive shift to both theoretical and practical behaviours towards landscape ecology and improvement of the environment (Kender, 2004).

2.5 Function of trees in agricultural landscape

2.5.1 Trees and the atmosphere

2.5.1.1 Trees produce oxygen

According to Nowak et al. (2007), trees produce oxygen with help of photosynthesis, and sequester atmospheric CO_2 into biomass. He points out the fact that trees change the concentration of CO_2 more noticeably than the O_2 concentration, because some of the O_2 is consumed through the process of transpiration. Nevertheless, one matured tree can produce oxygen for approximately 10 people (Korytář, 2012).

2.5.1.2 The air pollution mitigation

Trees present a natural filter of various harmful substances from air. They are very efficient in dealing with pollutants such as ozone, particulate matter, sulfur dioxide, nitrogen dioxide, carbon monoxide, and lead (Nowak et al., 2007). During transpiration the moistening effect takes place and helps with air quality (from the standpoint of human health) (Korytář, 2012). Moreover, some woody plants release essential oils, which kill dangerous pathogens (Wohlleben, 2016).

2.5.1.3 Tree as an air conditioner

Of all vegetation, trees have the most important effect on the thermal regime of plant Earth. Also, locally they are able to affect the microclimate via evapo-transpiration (Jackie and Toensmeier, 2005). Vegetation protects the ground from overheating or drying out, and optimizes evaporation through transpiration via stomata on leaves (Kravčík et al., 2008). Stomata regulate transpiration to ensure that losses do not exceed the supply capacity of water (Bond et al., 2008)

Vegetation well stocked with water has a significant cooling effect and air-conditioning capability. A single tree can evaporate up to 400 litres of water, draining up to 280kWh of thermal energy from air (Korytář, 2012). If solar radiation falls on a surface with disrupted vegetation, it quickly dries out and radiation is changed into heat (Kravčík et al., 2008).

Evaporation off trees during hot day cools air, while at night the condensation of water on leaves warms the surrounding air (Mollison, 1988). Through these processes trees are able to mitigate the effects of thermal extremes.

2.5.1.4 Trees as a sink for sequestration of atmospherical CO2

Nitrogen, oxygen and argon account for up to 99,88% of the Earth's atmosphere. However, these gases have very low absorption of long-wave radiation. Opposite properties have gases as carbon dioxide, water vapour, methane, nitrogen oxides, freons and ozone. Although their concentration in the atmosphere is minor, their effect on the long-wave radiation absorption is major (Nátr, 2000).

Since 1750, atmospheric carbon dioxide (CO_2) concentration has risen by 30%, with a steep increase observed over the last 50 years. With an annual increase of 0,5%, atmospheric concentration is expected to double until the mid to late 21th century, which may cause a rise in temperature between 1,5°C and 4,5°C (Peichl et al., 2004). The current speed of deforestation is about 1% per year, and is the cause of 1.7Gt emission of C annually (Nátr, 2000). Therefore deforestation significantly contributes to rising levels of atmospheric CO_2. One of the most important ecological services performed by functional ecosystems is climate regulation. Carbon dioxide is removed from the atmosphere and sequestered in the biomass (Ward et al., 2014).

The majority of carbon stored in global vegetation is in forests. The growth of trees and the preservation of old forests are critical in regulating the size of the terrestrial carbon sink (Heath, 2005).

European forest vegetation is an important sink of atmospheric CO^2 (Nátr, 2000). In the context of the fact that potential natural vegetation in most of Europe would be a forest (Neühasulová and col, 1998), the European C sink provided by trees should be protected. Additionally, temperate and boreal forest soil stores four times the amount of carbon in comparison to vegetation, and 33% higher than total carbon storage in tropical forests (IPCC, 2001). According to Nátr (2000), it is possible that with the reduction of deforestation and the increase in afforestation,

CO^2 emission could be lowered. Conserving and restoring existing C stocks can lessen the impact of climate change (Ward et al., 2014).

Within anthropogenic emission sources, agricultural practices may account for one quarter of the contribution to the effect of global warming (Duxbury et al. 1993). Afforestation of agricultural land provides an important opportunity to mitigate climate change by storing carbon in both plant biomass and the soil (Hoogmoed et al., 2014). Trees in agricultural landscapes play an important role in the global carbon cycle as sinks for carbon (Kuyah et al., 2012). Soil contains approximately 1500Pg of organic carbon. That is twice the amount of carbon stored in the atmosphere, and roughly three times the C stored in terrestrial vegetation (Raich et al., 1995). Roots hold more than 20% of total tree biomass, which is mostly held in coarse roots. Roots directly transfer carbon into soil upon decomposition, where it may be stored (Kuyah et al., 2012).

2.5.1.5 Tree intercropping

A potential solution for the issue of increasing concentration of atmospheric CO2 could be intercropping involving trees. According to Peichl et al. (2006), integration of trees into such systems results in greater CO_2 sequestration from the atmosphere, and within the temperate zone, agroforestry land use has been estimated to potentially sequester 10-208t C/ha. The case study developed by Mr. Peichl mentioned above used *poplar/barley* and *norway spruce/barley* as the intercropping combination. The canopies of trees dominate photosythesis and biomass creation and also influence the soil environment (Jackie and Toensmeier, 2005). Therefore, not only were trees able to sequester C to biomass, but also soil C concentration of intercropping system was slightly higher than for sole cropping system (Peichl et al., 2006).

However, to generate significant contributions, intercropping systems will need to be established on large areas of land, which poses several problems including labour intensity, and the incentives for farmers to adopt temperate intercropping systems in general (Dabbert, 1995).

2.5.2 Trees and hydrology

2.5.2.1 The global relation of forests with changes in hydrology

Forests occupy approximately one-third of the Earth's land area, accounting for over two-thirds of the leaf area of land plants, and thus play a very important role in terrestrial hydrology (Bond et al., 2008). A healthy forest works to a large extent like a sponge - it is able to soak moisture during rainfall and then slowly release it, moderating differences between the periods of water shortage and excess (Kravčík, et al., 2012). Global climate changes may mean that precipitation will become less reliable; there are strong links between deforestation and climate change (Roberts, 2009). The drying of the continents is caused by urbanization, agricultural activities and by the deforestation of large areas of the Earth's surface. All of these actions cause rapid sluicing of water to the seas and oceans (Kravčík et al., 2008). Sapwood of large trees serves as a storage reservoir for water as well as a conduit (Bond et al., 2008). Moreover, deeper rooted forests (or single trees) acquire water from lower soil horizons in times of limited rainfall and close stomata in response to air humidity deficit (Roberts, 2009). Also, when roots are in contact with soils that vary spatially in moisture content, they may act as conduits for water redistribution through the soil, driven by gradients in soil water potential (Bond et al., 2008). The process of water transport from deep to shallow soil layers through roots is called hydraulic lift (or 'hydraulic redistribution'). The amount of water moved by hydraulic lift is relatively small - less than 0.5 mm m^{-1} soil depth day^{-1} (Brooks et al., 2006), however, there is significant effect on water regime. In general the balance between forest evaporation, soil moisture, and moisture flow from the ocean is essential because it is simply a product of the evolution of forest communities over hundreds of millions of years (Kravčík et al., 2012).

2.5.2.2 Trees make rain - The biotic pump phenomenon and nucleii for rain

Little attention is given to a phenomenon called the *biotic pump,* presented by Russian scientists, V. G. Gorshkov and A. M. Makarieva, who described how forest vegetation draws in moist air from the ocean to inland (Kravčík et al., 2012).

When water vapour condensates in the air its phase changes which results in a pressure decrease. Tree crowns with abundant leaves have larger evaporation than water surface, therefore, condensation above the forests has a potential to cause a greater decrease in pressure than the condensation above the ocean. The circulation of moist air from ocean areas takes place and water vapour condensates above forest areas. According to Makarieva and Gorshkov (2012), rainfall above forested areas remains constant, and vice versa, on the non-forested continental areas, the landscape is dependent on hardly predictable precipitation.

There is another way in which trees may affect local climate. According to Mollison (1998), the upward spirals of humid air coming up from forest carry little particles of pollen and bacteria which can create the nucleii for rain.

2.5.2.3 Trees and cloud water deposition

The major differences between forests and shorter vegetation are in the lower solar reflection coefficient (albedo) and higher aerodynamic roughness, both related to large vertical distribution of tall canopies. The higher roughness is important in increasing rainfall interception. According to Roberts (2009), the presence of forest (tree) canopy as an obstacle causes water particles (r=10 μm) to coalescence and be deposited as precipitation. This phenomenon is called *cloud water deposition* or termed as *fog drip*. Deposition of fog water can be important to local hydrology. In some areas interception and condensation of fog by mature conifer canopies can actually increase the amount of moisture reaching the soil (Dawson, 1998).

2.5.2.4 Trees and water retention in floods prevention

Human alteration of natural processes through urbanisation, agricultural activities and deforestation change run-off ratios from land and largely affects catchment areas. Such alteration of water regime threatens flood areas (Kravčík et al., 2012).

Forests have important functions in water retention, but with the focus on economical profits, the majority of forests have been changed to high-production woody plants. Water regime is usually not the priority (Simon and Sucharda, 2004). Vegetation has an important role in water retention. Not only tillage method and crop rotation but also the presence of tree elements in agricultural landscape have influence on run-off, emphasizes Kravčík et al. (2012), therefore little plots of field separated by infiltration trenches combined with woody plant vegetation (shrubs, trees) should be integrated into the landscape.

The important way to mitigate flood wave aftermath is the revitalization of river and stream banks (Kravčík et al., 2008). Flooding can be slowed and the amount of sediment lowered in alluvial plains. The material is then partially captured by forest (or shrub) vegetation and sedimented afterward. Alluvial plains are well adapted for such processes and they positively affect the water quality as well. (Simon and Sucharda, 2004).

2.5.3 Trees and biodiversity

2.5.3.1 Trees and landscape heterogeneity

During the last century, agricultural landscape has gone through a process of homogenization. The leading factor has been the land use intensification which led to biodiversity loss and degradation of ecosystem services such as biological pest control (Kalda et al., 2014). This happens mainly in the industrialized countries. Even though we have relatively strong environmental concerns, we usually design landscapes without the preference for ecological health (Jackie and Toensmeier, 2005). A high level of biodiversity can be supported via spatially heterogeneous agricultural landscapes (Gaigher et al., 2016).

Heterogeneous landscape is a mosaic of various habitats which supports species diversity in plants and animals. The quality of habitats is often characterised by a large structural richness and heterogeneous vegetation (Birrer et al., 2014). The linear vegetation features (shelterbelts, riparian strips, road side plantings, double-tree lines and woodland patches) provide essential habitat for a range of taxa (Kalda et al., 2014; Welsch et al., 2013). The preservation of the eco-stabilisation elements in agricultural landscape is crucial in protection of biotopes and rookeries of bird species which are dependent on their environment (Kováč et al., 2008).

The keystone structures that may have important value in farmland biodiversity are scattered trees (Rivest, 2012). Solitaires have many functions in landscape. They create habitat for various species such as birds and invertebrates (Matějková et al., 2009). According to Kalda et al. (2014), the mosaic of solitaire trees represents important habitats for bat species, who significantly contribute to pest regulation. However, numbers of scattered trees in agricultural landscapes have declined due to intensive land use (Rivest, 2012), moreover in suburban areas, they are frequently cut because of the fear from fall, even if trees are healthy (Matějková et al., 2009).

2.5.3.2 What happens after death?

For dead wood the term *Coarse Woody Debris* may be used. It has great importance in various ecosystems (Horák et al., 2007). A living tree sheds its waste to soil when its branches and roots are dying and later decomposing (Mollison, 1988). Even if a tree falls and dies, its purpose is not yet over. A dead and decaying tree may have many functions in a landscape. If possible, we should allow a tree to die naturally because many forms of wildlife depend directly or indirectly on dead wood (Mattheck and Breloer, 1996). Insects especially use trees as habitat during all phases of decay and even after death (Matějíčková et al., 2009). Therefore, dead wood has an important role in biodiversity preservation in landscape.

Indirect connection of dead wood to biodiversity is thanks to wood in water courses. Such wood effectively retains organic material, which is then food for various invertebrates. The invertebrates are a part of the food cycle of fish species. Von Siemens et al. (2005) warns that the lack of dead wood in watercourse limits the size of fish populations, because such wood also functions as a shelter for reproduction. He additionally points out that fish populations usually prosper well among beaver communities.

2.5.3.3 The Territorial System of Ecological Stability

Ecosystem biodiversity is directly connected with ecosystem stability. The spatial net of interconnected areas of ecological stability creates the TSES with its primary components - biocorridors and biocentres.

According to Anděl et al. (2010), large areas of agricultural land without sufficient amount of adjacent forest remnants or scattered vegetation (trees, shrubs) creates migration barriers for large mammals and other animals. Moreover, current trends of landscape management tend to increase landscape fragmentation and contribute to decrease of connectivity of habitats.

2.5.4 Trees and soil protection

Soil erosion and degradation are in fact, the loss of production and affects both plants and animals (Mollison, 1988).

2.5.4.1 Soil erosion caused by water

Trees help with soil erosion in the form of scattered vegetation and therefore their function in soil protection should not be underestimated. Soil erosion affected the oldest known civilizations; it consumed large amounts of wood, caused loss of productivity of the land and contributed to the fall of the famous Roman Empire (Kravčík et al., 2012).

According to Sklenička (2003), main factors accelerating erosion are: deforestation, climate conditions, morphological conditions (slope characteristics and length), soil conditions and landuse management. Erosion is a powerful force which degrades biodiversity values, ecological goods, and services provided to local communities (Ward et al., 2014). The importance of anti-erosion protection is coming more into awareness, because negative effects of the erosion processes on agriculture are nowadays well known. These are: threat to hydrosphere, harm of urban areas, and damage to line structures (Demo et al., 2011). Agricultural land is threatened by erosion when anti-erosion steps are not followed, such as removal of vegetation (country lanes, shrubs, hedgerows) (Sklenička, 2003). Demo et al. (2011) suggests that protective forestation is one of the answers for water-caused erosion and according to Kravčík et al. (2012) it is needed to prevent further soil loss from slopes where the land is already desolated. Mountain vegetation on steep slopes plays a critical role in the control of soil erosion caused by water (Ward et al., 2014). A healthy forest has a vegetation cover with very high anti-erosion effect, thus forestation is a very effective method for dealing with soil erosion (Sklenička, 2003).

2.5.4.2 Erosion caused by wind

Holý (1994) distinguish two types of wind erosion, first, so called *deflation* (direct transport of soil particles) and *corrasion* (abrasion of soil particles which are then carried by deflation). Wind erosion affects land surface. Factors influencing its extent are climate conditions, soil conditions, land use and land cover (Sklenička, 2003).

Tree line vegetation can serve as a wind-break shield and slow the wind currents causing loss of little particles from the soil surface. Positive effects of such trees are, improving microclimate, creation of habitats for bioregulators (predators), and they may provide shielding for livestock (Demo et al., 2011).

Anti-erosion steps with an application of tree vegetation have several advantages. First of all, they are independent of market demands influencing decisions in crop rotation (Sklenička, 2003); moreover they can be understood as a permanent multi-functional element in agricultural landscapes.

2.5.4.3 Roots and landslide protection

Trees also protect soil from landslides with help of root systems. This feature can be used to strengthen slopes, river banks and dams (Korytář, 2012).

2.5.5 Other ecological functions of trees

2.5.5.1 The symbiosis

An interesting function of trees is their ability to cooperate with some fungi. Their relationship is symbiotic (Jackie and Toensmeier, 2005). Trees produce carbohydrates via photosynthesis and store them in roots. On the other hand, fungi are able to obtain minerals which they offer to the trees in exchange for carbohydrates fungi cannot create. They may ask for up to one third of sugar production of the tree (Wohlleben, 2016).

2.5.5.2 Trees as partners of pollinators

Trees are supporters of pollinators, which are very important for agriculture. According to Haragsim (2013), scattered tree vegetation is very important in landscape, because the area of non-forest woody vegetation in agricultural landscape is frequently not sufficient. An example of an important tree for bees is Scots pine (Pinus Sylvestris L.)

2.5.5.3 The noise mitigation

Trees in urban and suburban areas can serve as noise absorbers, while with higher density of vegetation the effect is more noticeable (Korytář, 2012). According to Samara and Tsitsony (2010), the foliage of trees mitigates traffic noise by partially transforming the acoustic energy into kinetic energy (through motion of leaves or needles). A forested area (minimal width of 20m) can lower the noise level by up to 6dB in comparison with a grass-covered area.

2.5.6 Esthetical functions of trees

2.5.6.1 Landscape character and memorable trees

Old trees from the esthetical view are elements of cultural landscapes (Hyt'ha et al., 2007). Such trees also improve the mosaic and variety of the landscape, and for inhabitants serve as a connection with the previous generations who planted them (Korytář, 2012). According to Gojda (2000), the value of the landscape may be viewed also like a memory of and connection to "home" for people. Therefore, trees as the oldest green elements of the landscape carry a very important role in the landscape character. Memorable trees have been planted for special occasion (feast, birth, construction of buildings, etc.) and may have historical and cultural meaning for the local area (Hyt'ha et al., 2007).

2.5.6.2 Alleys

Since long ago roads and pathways were planted with alleys of trees to provide shade to travelers (Korytář, 2012). Old alleys are being cut because they are often understood as dangerous elements on roads. However, alleys are an important part of the landscape character and besides their ecological function, they are an irreplaceable esthetical component of our landscape which could also represent a kind of historical legacy (Hyt'ha et al., 2007). The woody vegetation may serve as a spatial border of roadways and may also help with mitigation of drivers' tiredness (Supuka et al., 2008).

2.6 Groups of non-forest woody vegetation in agricultural landscape

The term *Non-forest woody vegetation* is being used for all types of woody vegetation in landscape that are not registered in Forestland Fund. It contains vegetation elements or vegetation covers of woody plants with small spatial or line demarcations and various shares of trees and shrubs (Hrnčiarová et al., 2000).

A more general term is *scattered vegetation*, which is being used for non-forest vegetation with the exemption of agricultural plants (Sláviková, 1984).

The non-forest woody vegetation is important for its positive effect on biodiversity on boundaries of arable land and it also differentiates the matrix of the landscape (Sklenička, 2003).

2.6.1 Classification of groups of non-forest woody vegetation

The classification of groups of non-forest woody vegetation by area characteristics according to Demo et al. (2011)

- Point vegetation (randomly and irregular dislocated solitaires)
- Line vegetation (coherent or disrupted strips of vegetation, e.g. along rivers, communications, plots of land)
- Square vegetation (groups a covers of woody plants in mainly agriculturally utilized lands)

The classification of groups of non-forest woody elements according to Supuka et al. (2008) (Modified for demands of this thesis)

Point vegetation

- Solitaires (One to three individual trees which are not connected, without internal underbrush and with no clear border line)

Line vegetation

Strips of vegetation with one or more rows, optionally without visible rows. Maximal width is 30% of the length. Line vegetation represents important connecting element between forest biotopes (Anděl et al., 2010).

- Tree-lined avenue (one line of trees)
- Belt of trees (Two or three lines of trees with average crown width 5-10 m)
- Strip of trees (several lines of trees, strip width is 10-30 m)
- Hedge (compact formation of shrubs up to 2m tall with width of 1-3 m)
- Hedgerow (compact formation of trees more than 2m tall with width of 3-5 m, common in England as boundary of fields)
- Protective vegetation belt (combination of strips or belts with character of windbreaks, also may provide shade for livestock)

Square vegetation

- Cluster of trees (area of 50 - 100 m^2)
- Copse (area of 100 - 500 m^2)
- Niche (500 m^2 - 2,0 ha, frequently called a *grove*)
- Forest (area larger than 2,0 ha with minimal width of 50 m)

2.6.1.1 Solitaires

Solitaires are usually native woody plants that grow independently. Frequently with significant historical and cultural value - some may be called *memorable trees*. They are preserved on land boundaries, along pathways and by memorable places, where they have aesthetic and landmark functions (Demo, 2011). The term *scattered trees* also can be used. Scattered trees represent the last remaining relicts of large woodlands and forests in agricultural landscape, and they are considered to be keystone structures because their effect on ecosystems is believed to be disproportionate relative to the small space that an individual tree occupies (Fischer et al., 2010)

2.6.1.2 Tree-lined avenues

Tree lined avenues is a line of trees with consistent gaps and regular spatial displacement (Demo et al., 2011).

They are usually found as a borderline of plots of land or along rivers, roads etc. Tree-lined avenues can serve as a windbreak (Sklenička, 2003) or to reinforce riverbanks and dams (Supuka et al., 2008). An additional function of tree-lined avenues is the influence on microclimate, because they can moderate intensity and affect direction of freezing winds (Kováč et al., 2008; Mollison, 1988). Special types of tree-lined avenues represent an alley. An alley can be found mainly along roads and pathways.

2.6.1.3 Belt of trees and strip of trees

Belts and strips are similar elements with common features. They represent a line vegetation of trees that differ mainly in width (Supulka et al., 2008). They can be founded artificially as an integrated part of TSES, to reinforce eroded slopes or as a part of anti-erosion solutions in agricultural landscape (Demo et al., 2011). However they can also be natural as the consequence of succession. The important function is high water retention potential (Supuka et al., 2008). According to Demo et al. (2011), the higher the level of vegetation density and species diversity is, the more effective is the retention ability.

2.6.1.4 Hedges and hedgerow

Hedges are not as common in the Czech Republic as in the United Kingdom, but they can be found in suburban areas (gardens, parks etc.) as a natural fence made of shrubs (Supuka et al., 2008). The level of ecological value is higher if the hedge is formed with the use of native species (Maděra, Zímová, 2005). Their main function is aesthetic but also can be important as a shelter for smaller birds. Hedgerow is a line vegetation element that consists of shrubs and trees. Hedgerows are usually more heterogeneous in specie composition and therefore they are more valuable in terms of biodiversity. Both hedges and hedgerow elements are frequently used as noise barriers along roads and other infrastructure (Samara and Tsitsoni, 2011; Supuka et al., 2008).

2.6.1.5 Protective vegetation belt

Protective vegetation belt is usually a combination of strips, belts, hedges and hedgerows. It can have the character of windbreaks or it can facilitate water retention and interception (Demo et al., 2011). A multifunctional solution is the most optimal one. Besides these ecological functions it frequently serves as a protection in areas for temporary stabled livestock, where it provides shade (Supuka et al., 2008).

2.6.1.6 Cluster of trees

Cluster is little area of trees up to 100 m^2. Area is usually of an irregular shape (Demo, et al., 2011). It is frequently result of natural succession.

2.6.1.7 Copse

A copse is larger (up to 500 m^2) in comparison to a cluster and its shape can be more regular (Supuka et al., 2008). It is a remnant of the deforestation of agricultural landscape. It finds its place on slopes or tops of hills, where it may serve as reinforcement against landslide and erosion.

2.6.1.8 Niche (grove)

A niche or a grove is larger (up to 0,5 ha) in comparison to a copse (Demo et al., 2011). It may be functionally very close to a forest. The typical feature is rich underbrush. Underbrush takes advantage of the abundance of light.

2.6.1.9 Forest

Forest is a vegetation of woody plants typical for forests. Important features are distinctive borders, crown cover, and internal microclimate. Herb underbrush together with tree vegetation form a single auto regulated ecosystem (Supuka et al., 2008). The effect of forest is beyond its site. Moreover, it has a complex ecological and biological influence on surrounding areas of the landscape (Demo et al., 2011).

2.6.2 Foundation of non-forest woody vegetation

2.6.2.1 Windbreaks

Windbreaks find utilization mostly in arid areas with an abundance of winds. Their foundation is supposed to help with microclimate and soil moisture (Zachar et al., 1984). The most effective way of soil protection is vegetation cover (Kravčík et al., 2008). However, the seasonal way of cultivation puts stress on the soil, because for a substantial part of the year the soil is bare and threatened by erosion.

Porosity of windbreaks is an important feature. Porosity represents perceptual ratio of gaps in the surface of windbreak, and it is dependent on the structure of vegetation (Demo et al., 2011). The optimal porosity may vary according to the way of application. Zachar (1984) recommends 30% porosity, but according to Gabriš et al. (1998) it can be up to 70%.

The density of vegetation should not be lower than 20% and not much higher than 60%. If the density is too low, the effect of vegetation is not sufficient. On the other hand, high density limits the area of positive windbreak effect. The frame of windbreak is supposed to be made of long-living native trees. It is important to choose woody species with various biological attributes (Demo et al., 2011).

Mezera (1950) distinguishes three categories of woody species used for windbreak foundation.

- *Primary woody vegetation* (the base of the vegetation, with slow growth)
- *Temporary woody vegetation* (fast-growing species which are functional until the primary vegetation is full-grown)
- *Shrub vegetation* (complementary vegetation in the form of underbrush)

2.6.2.2 Interception belts

Interception belts represent important elements in agricultural landscape. They are being used in the form of the line vegetation, which may be called *protective forest vegetation*. These elements help with water retention and against water erosion (Demo et al., 2011). Interception belts are supposed to be oriented perpendicularly to fall lines where their efficiency is the highest. The maximum tolerable divergence is about 20° (Zachar et al., 1994). The width and the density of vegetation have the most important role in the level of interception. The optimal width is 15-30 m (Demo et al., 2011) and the belt should not represent more than 10% of the protected area (Zachar et al., 1994). On large plots of land a system of belts may be used. Distance between plots and their width is conditioned by the gradient of the site (Demo et al., 2011).

It is important to mention that some woody species may be associated with pest issues; therefore some kinds of species are less suitable for plantation in agricultural landscape. It may create friction between protection of the environment and interests of farmers, because farmers are economically dependent on their yields. This fact has a role in their decision making about woody vegetation elements on their fields. An interesting survey was carried out by Sklenička et al. (2002). In this survey, 168 land owners were polled and asked if they would agree to the establishment of the elements of scattered vegetation on or near to their plots of land. The following chart explains further.

Poll	Yes (%)	No (%)	Not sure (%)
Do you think, that amount of scattered vegetation is sufficient for you cadastre?	56	22	22
Would you agree to financially participate on foundation of new elements of scattered vegetation on your land?	0	100	0
Would you accept a presence of a new copse (remíz) with size of 500m2 on your land?	4	96	0
Would you accept a presence of a new solitaire tree on your land?	12	80	8
Would you accept a presence of a new copse on your neighbours land, if it would shadow a part of your land?	24	66	10
Would you accept a presence of a new solitaire tree on your neighbours land, if it would shadow a part of your land?	38	52	10

Table number 1 - Poll table (Sklenička et al., 2002)

According to Sklenička (2003), the farmer's unwillingness to accept shared responsibility for the development of the landscape is the consequence of lost relationships with the environment and nature among farmers. Additionally, he points out that Land Consolidations have a high potential in dealing with ownership issues. Land Consolidations allow owners to exchange land and to build up a land reserve for an application of changes (design of TSES and anti-erosion steps) necessary for a proper function of the landscape.

2.6.3 The European Ecological Network and the Territorial System of Ecological Stability

2.6.3.1 The European Ecological Network

The goal of the European Ecological Network (EECONET) is a functional net of selected areas with high levels of landscape management supported by scientific justification. Functional capability is conditioned through an international interconnection of selected areas (Sklenička, 2003).

The components of EECONET are *core areas*, *corridors* which connect the landscape, *buffer zones* and *nature development areas* (Löw a Míchal, 2003).

2.6.3.2 The Territorial System of Ecological Stability

The Territorial System of Ecological Stability (TSES) is defined by Czech act No. 114/1992 Sb. as a mutually interconnected complex of both natural and near-natural altered ecosystems that maintain natural balance. Its main purpose is to reinforce ecological stability of the landscape by conservation or restoration of ecosystems and their mutual interconnection.

According to Sklenička (2003), TSES can be understood as an ecological minimum necessary for a landscape to sustain its ecological stability.

Structural elements of TSES according to (Sklenička, 2003)

Biocentre

Biocentre is the basic component of TSES which allows permanent (or long-term) existence of target species and communities from the landscape's natural gene pool. The Functional state of biocentre is the state in which the level of ecological stability is the highest and it contains native and natural communities. Biocentres represent various biotops for numerous species. In an intensively cultivated agricultural landscape, biocentres increase ecological stability and biodiversity (Kosejk et al., 2009).

Biocorridor

Biocorridor is the basic component of TSES which allows interconnection of biocentres. It allows migration of organisms and helps to prevent their isolation. Its spatial and qualitative properties do not have to support conditions for permanent existence of the organisms. Its next important function is a positive effect on ecologically unstable parts of the landscape. Biocorridors may be continuous or interrupted. It is important to mention, that according to Anděl et al. (2010), up to 85% of all corridors is led through forest biotopes.

Interactive components

Interactive components consist of relatively ecologically stable elements that have a positive effect on the surrounding landscape. Interactive components do not have to be connected with other components of TSES. Hedgerows, clusters of trees, copses and all kinds of scattered vegetation may be considered interactive components. According to (Maděra, Zímová, 2005), the important function of interactive components is that it provides habitats for pollinators and predators. The problems are no central methodology and lack of support in legislation.

3 Methodology

The methodology used for this thesis was a combination of a literature research and evaluation of studies and scientific literature. The literature research is supposed to collect information and data from a sufficient amount of scientific sources to create a new coherent output in form of a thesis. The text was structured in topics. The topics were sequenced in term of a logical progression. Readers were first introduced to the general problems then single topics were introduced in detailed way. The goal of the thesis is not only to introduce the chosen problems, but also to provide readers with integral and complex understanding, and additionally to build up their interest in the topic of the thesis. The evaluation of studies and scientific literature is supposed to provide a valuable output, which may be additionally used for further research.

The thesis was divided in two main parts. The text part (literature research) provides a description of problems and issues. The table part (results and discussion) is supposed to sum up the literature in organized summary and answer a question about the importance of various tree functions in agricultural landscape. The summary was structured in categories and subcategories within tables.

The overview table serves for general orientation in results of the evaluation of various tree functions. For each function the number of references is displayed. Functions are classified into subcategories. Categories were classified into subcategories. This overview should provide quick and easy orientation in data.

Category of function	Subcategory	Function of trees	Number of references
Ecological	Subcategory 1	Function 1	**A**
		Function 2	**B**
		Function 3	**C**
		Function 4	**D**
	Subcategory 2	...	**...**
	Subcategory 3		
	...		
Other			

Table 2: Overview table example

The partial tables serve as a list of authors. For each specific function the listing was made. This provides an important evidence for numbers of references in the Overview table. For better representation a column graph for each partial was made.

Subcategory		
Function A	**Function B**	**Function C**
Author 1	Author 3	Author 1
Author 2	Author 4	Author 6
Author 3	Author 5	Author 7
...	...	...

Table 3: Partial table example

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4 Discussion and results

Since the literature research contains not only an analysis of functions of trees, but also a general frame of a broad context of the relationship between agriculture and the environment, the table part, which covers only the tree functions, was made. This should provide easy orientation to the main issues of the thesis.

The results were structured according to subcategories of the functions of trees. For each subcategory a partial table and graph was made. Within each table, the name of the function of trees, and the number of references were displayed. As a summary of the partial tables, an overview table was made. The tables are supposed to represent the degree of importance of individual functions of trees, according to the number of references in the literature used for the thesis.

There are 17 functions of trees divided in 5 subcategories. For each function of trees the number of references was mentioned. Graphs were used to provide easier orientation in data. The literature used for both text and table parts can be found in Bibliography. The analysis covers 62 sources (mainly monographs and articles from the Web of Science).

4.1 Ecological functions

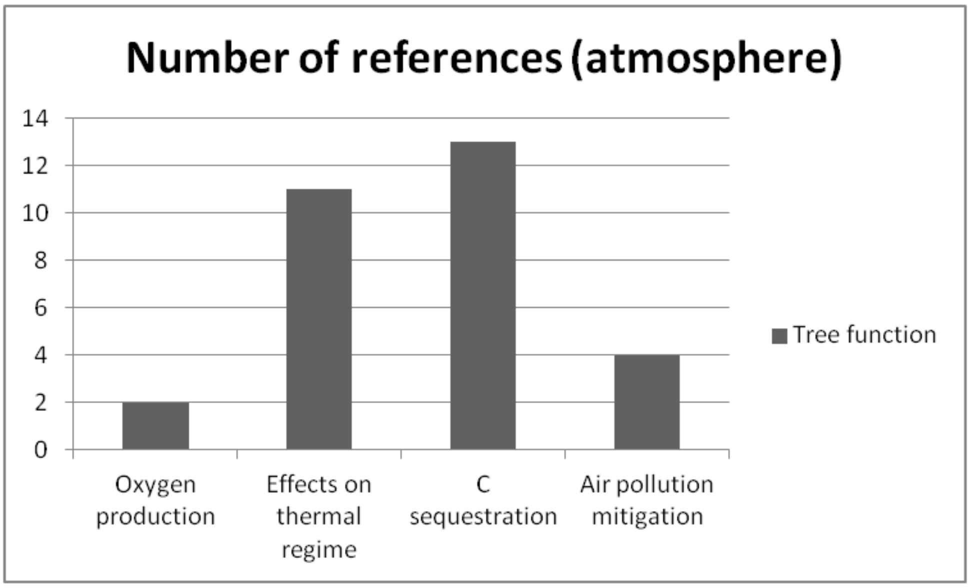
Ecological functions of trees in agricultural landscape were differentiated in subcategories according to four main spheres of their impact: atmosphere, water, impacts on biology and soil. For the purpose of clearly organized graphical interpretation, each subcategory has its own colour scheme.

4.1.1 Atmosphere

The most discussed functions of trees were the sequestration of atmospheric carbon and the impact of trees on thermal regime. The change of land cover is a key driver of changes in atmospheric composition (Oldfield, 2005). Agriculture has a large impact on various ecosystems and their ability to sequester carbon dioxide from atmosphere to biomass (Ward et al., 2014). With reduction of deforestation and increase of afforestation, the rate of rising CO_2 levels could be lessened (Nátr, 2000). With the increasing awareness of rising CO_2 concentration and the Global Warming, it is reasoned that the relation between these two phenomena and trees are frequently mentioned. Afforestation of agricultural land provides an important opportunity to mitigate climate change by storing carbon in both plant biomass and the soil (Hoogmoed et al., 2014). What may be surprising is that oxygen production was merely mentioned. The possible reason is that this function of trees is generally well-known and it does not need further explanations.

Atmosphere			
Oxygen production	**Effects on thermal regime**	**C sequestration**	**Air polution mitigation**
Korytář, 2012	Behringer, 2007	Dabbert, 1995	Korytář, 2012
Nowak et al., 2007	Bond et al., 2008	Heath, 2005	Nowak et al., 2007
	Demo et al., 2010	Hoogmoed et al., 2014	Supuka et al., 2008
	Jackie and Toesmeier, 2005	IPCC, 2001	Wohlleben, 2016
	Korytář, 2012	Jackie and Toesmeier, 2005	
	Kravčík et al., 2008	Kuyah et al., 2012	
	Kravčík et al., 2012	Moudrý, Moudrý jr., 2014	
	Mollison, 1998	Nátr, 2000	
	Oldfield, 2005	Nowak et al., 2007	
	Ozanne et al., 2003	Oldfield, 2005	
	White et al., 1992	Peichl et al., 2006	
		Raich et al., 1995	
		Ward et al., 2014	

Table 4 - Partial table for atmosphere



Graph 1 - Atmosphere

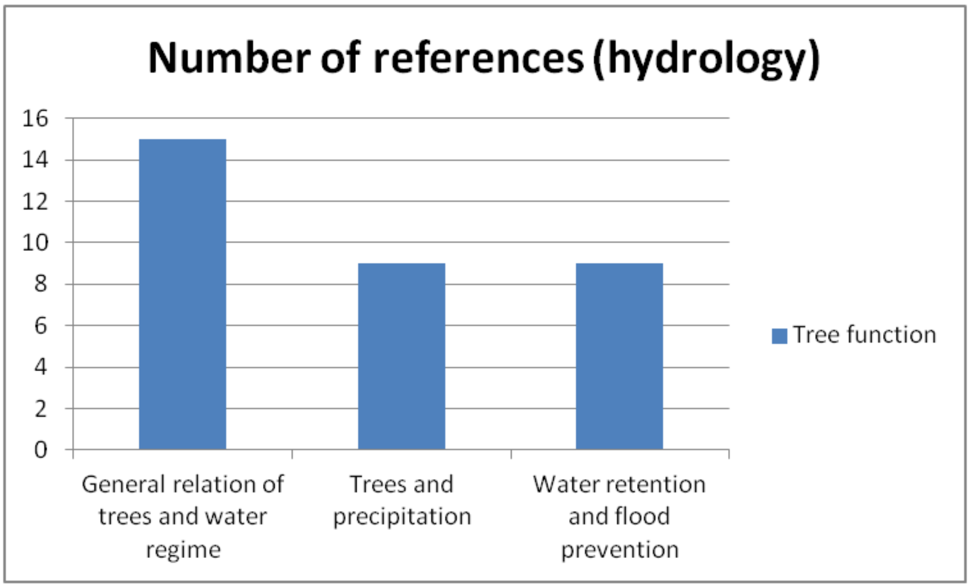
4.1.2 Hydrology

The effects of trees on the general water regime of a site of the planet were frequently discussed. They obviously embrace other functions as well, but for better orientation, two additional functions were qualified.

According to Roberts (2009), there are remarkable links between deforestation and climate change. Moreover, current water shortages are being connected with deforestation (Kravčík et al., 2008). Global climate change may cause changes in the precipitation reliability and therefore affect yields. The presence of tree elements in landscape has influence on run-off from land (Kravčík, et al. 2012). Therefore, scattered vegetation should be protected. Agricultural land is important in water management of the landscape. The agricultural policies should focus on water retention, collaterally with flood prevention. The absorption belts with the utilization of woody vegetation are efficient in mitigation of run-off and prevention of erosion.

Hydrology		
General e. on water regime	**Trees and precipitation**	**E. on Water retention, floods**
Kravčík et al., 2008	Kravčík et al., 2008	Kravčík et al., 2008
Kravčík et al., 2012	Kravčík et al., 2012	Kravčík et al., 2012
Oldfield, 2005	Bond et al., 2008	Simon, Sucharda, 2004
Moudrý, Moudrý jr., 2014	Korytář, 2012	Bond et al., 2008
Bond et al., 2008	Roberts, 2009	Sklenička, 2003
Roberts, 2009	Makarieva, Gorshkov, 2012	Neühauslerová et al., 1998
Brooks et al., 2006	Mollison, 1998	Kender, 2004
Jackie and Toesmeier, 2005	Dawson, 1998	Demo et al., 2011
Mollison, 1998	White et al., 1992	Mollison, 1998
Supuka et al., 2008		
Neühauslerová et al., 1998		
Kováč et al., 2008		
White et al., 1992		
Růžička, 2000		
Ward et al., 2014		

Table 5 - Partial table for Hydrology



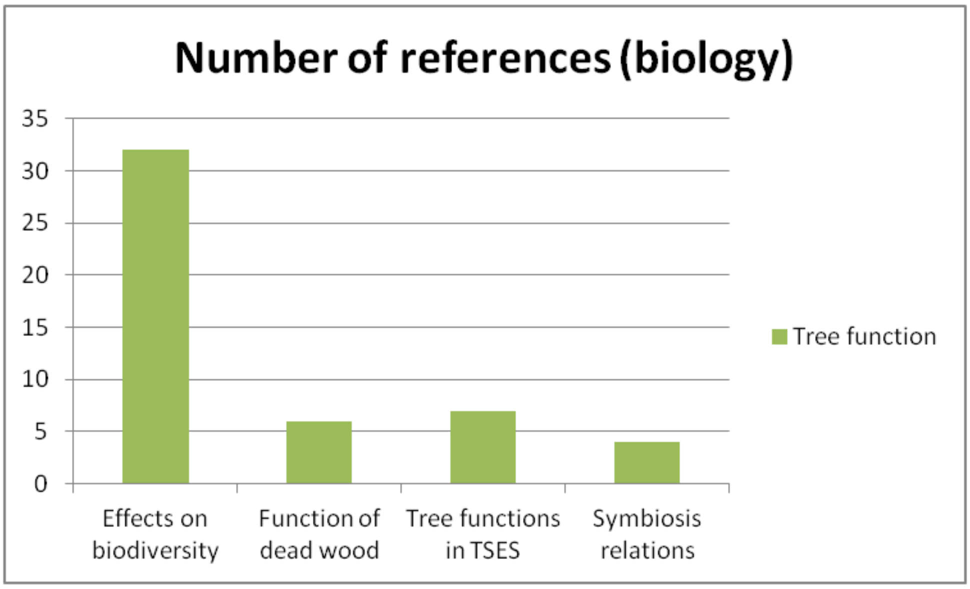
Graph 2 - Hydrology

4.1.3 Biology

The most discussed function of trees was their positive effect on biodiversity. Obviously the effect of trees on biodiversity is frequently mentioned, because increasing areas of cultivated fields and plantations have a huge impact on forests and trees in general. According to Kalda et al. (2014), homogenization of agricultural landscape driven by the intensification practices led to loss of biodiversity and degradation of ecosystems, because the amount of scattered vegetation in agricultural landscapes has declined (Rivest, 2012). Even though we already have certain environmental concerns, we usually design landscapes without the preference for ecological health (Jackie and Toensmeier, 2005). This approach should be changed. Our agriculture cannot be sustainable without a sufficient level of ecological stability. The Territorial System of Ecological Stability represents a basic framework of functional landscape. However, the inclusion of elements of non-forest woody vegetation in agricultural landscape should overreach the scale of TSES. It is interesting, that references about the symbiotic relationship of trees with pollinators or fungi, were rarely mentioned.

Biology				
Effects on biodiversity	**Function of dead wood**	**Functions in TSES**	**Symbiosis relations**	**E. on Pollinators**
Anděl et al., 2010	Horák et al., 2007	Anděl et al., 2010	Berner et al., 2012	Haragsim, 2013
Behringer, 2007	Matějíčková et al., 2009	Czech act No. 114/1992	Jackie and Toensmeier, 2005	Mollison, 1988
Birrer et al., 2014	Mattheck, Breloer, 1996	Kosejk et al., 2009	Mollison, 1988	
Demo et al., 2011	Mollison, 1988	Kováč et al., 2008	Wohlleben, 2016	
Fagan, 2001	Von Siemens et al., 2005	Löw and Míchal, 2003		
Fischer et al., 2010	White et al., 1992	Maděra, Zimová, 2005		
Gaigher et al., 2016		Sklenička, 2003		
Gojda, 2000				
Horák et al., 2007				
Kalda et al., 2014				
Kender, 2004				
Kitching, 2000				
Kováč et al., 2008				
Kováč et al., 2008				
Löw and Míchal, 2003				
Macák, 2006				
Maděra, Zimová, 2005				
Matějková et al., 2009				
Moudrý, Moudrý jr., 2014				
Nátr, 2000				
Neühasulerová et al., 1998				
Oldfield, 2005				
Ozanne et al., 2003				
Pausas and Keeley, 2009				
Rivest, 2014				
Růžička, 2000				
Simon, Sucharda, 2004				
Sklenička, 2003				
Sýkora, 1998				
Waldhardt, 2003				
Welsch et al., 2013				
White et al., 1992				

Table 6 - Partial table for Biology



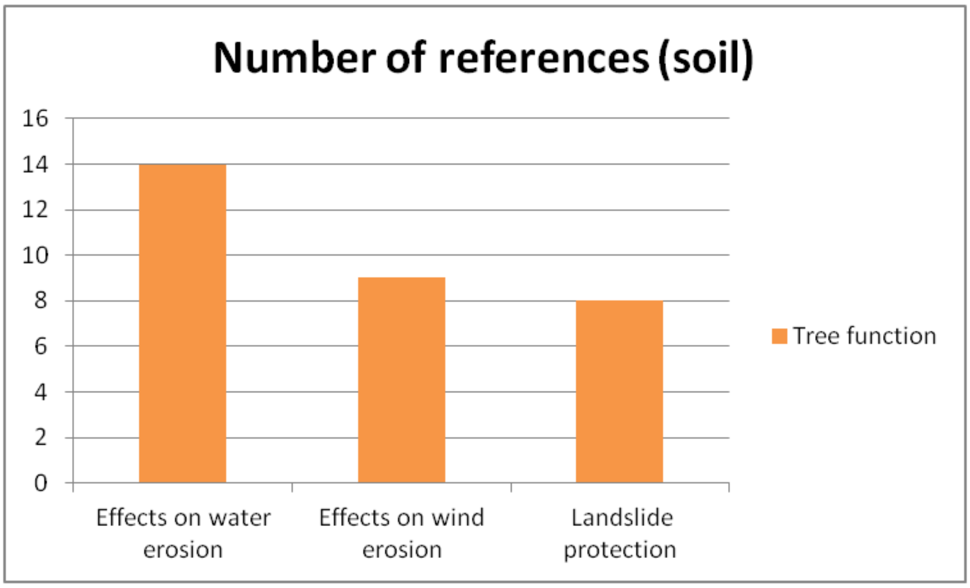
Graph 3 - Biology

4.1.4 Soil

Agricultural intensification, excessive grazing and deforestation cause 21 million ha of arable annually to become infertile worldwide (Růžička, 2000). The disruption of vegetation puts stress on bare soil, and water and wind erosion occur. Agricultural land is threatened by erosion when anti-erosion steps are not followed (Sklenička, 2003). The effect of trees on water erosion was discussed most, but wind erosion and landslide protection relations may be also considered to be common topics as well. According to Demo et al. (2011), trees are the important in prevention of both water and wind erosion. The relation between water management in agricultural landscape and soil jeopardy is evident. Protective forestation may serve as a multifunctional solution for current problems of soil preservation. Soil is the most important input for agriculture. It is not possible to continue in desertification of arable land and simultaneously fill increasing demands for food. The loss of topsoil has to be reduced otherwise soil fertility will decrease irreversibly.

Soil		
Effects on water erosion	**Effects on wind erosion**	**Landslide protection**
Demo et al., 2011	Demo et al., 2011	Demo et al., 2011
Fukuoka, 2009	Holý, 1994	Korytář, 2010
Kender, 2004	Kravčík et al., 2008	Kravčík et al., 2008
Kováč et al., 2008	Macák, 2006	Kravčík et al., 2012
Kravčík et al., 2008	Mollison, 1988	Mollison, 1988
Kravčík et al., 2012	Růžička, 2000	Sklenička, 2003
Löw and Míchal, 2003	Sklenička, 2003	Supuka et al., 2008
Macák, 2006	Sklenička, 2003	Ward et al., 2014
Mollison, 1988	Ward et al., 2014	
Oldfield, 2005		
Růžička, 2000		
Sklenička, 2003		
Supuka et al., 2008		
Ward et al., 2014		

Table 6 -Partial table for Soil



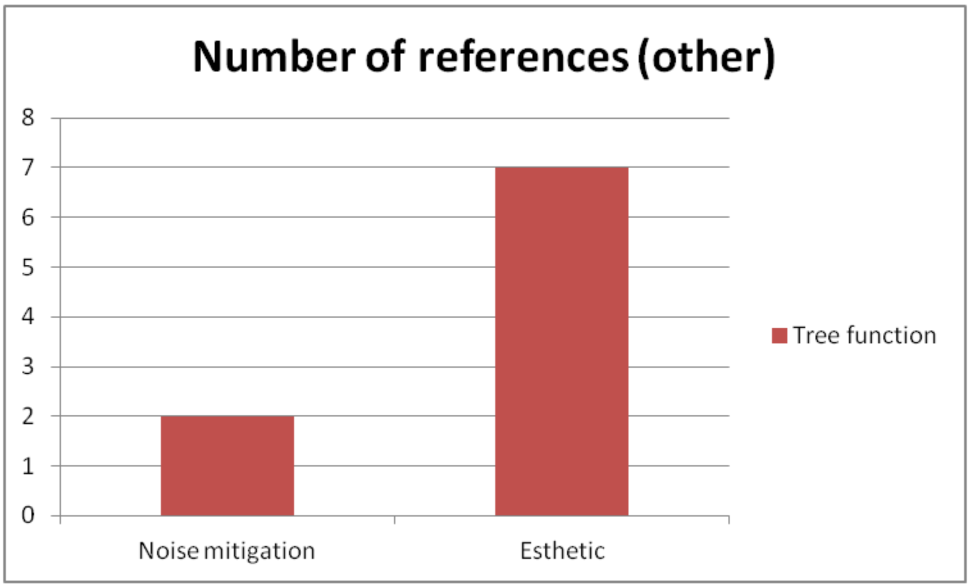
Graph 4 - Soil

4.2 Other

Trees may have other than ecological functions. Esthetical function of trees is also very important. This function cannot be scientifically evaluated nevertheless it is one everyone can relate to. The most mentioned topic was the effect of trees on esthetical value of landscape. Especially old trees from the esthetical view are elements of cultural landscapes (Hyt'ha et al., 2007). We should protect such trees as a legacy of our ancestors. On the other hand, the noise mitigation effect of trees can be rarely found in the literature dealing with agricultural landscape. The cause is that the literature used for the thesis embraced usually only agricultural issues. To find out more about noise mitigation ,the literature about urban vegetation could offer more information. However, such literature may be too vague for the purpose of this thesis.

Other	
Esthetic	**Noise mitigation**
Demo et al., 2011	Korytář, 2012
Gojda, 2000	Samara and Tsitsoni, 2011
Hyt'ha et al, 2007	
Korytář, 2012	
Löw and Míchal, 2003	
Sklenička, 2003	
Supuka et al., 2008	

Table 7 - Partial table for Other functions



Graph 5 - Other functions

4.3 Overview table

Category of function	Subcategory	Function of trees	Number of references
Ecological	Atmosphere	Oxygen production	2
		Effects on thermal regime	11
		C sequestration	13
		Air pollution mitigation	4
	Hydrology	General relation of trees and water regime	15
		Trees and precipitation	9
		Water retention and flood prevention	9
	Biology	Effects on biodiversity	32
		Function of dead wood	6
		Tree functions in TSES	7
		Symbiosis relations	4
		Effects on pollinators	2
	Soil	Effects on water erosion	14
		Effects on wind erosion	9
		Landslide protection	8
Other		Noise mitigation	2
		Esthetic	7

Table 8 - Overview table

5 Conclusion

The reason for massive deforestation in the past was the lack of knowledge about fragile mutual relations in nature. There used to be so-called high civilizations that put their existence in danger, because they underestimated the value of trees for humanity. Now, we have entered the era of science. We already have enough scientific evidence about trees and their functions to know, that deforestation and loss of trees cause serious changes of the environment. Some such changes include: change in atmospheric composition, change of water cycle and water quality, erosion of soil, biodiversity loss, and more. It is not possible to evaluate which phenomenon is the most important one, because they are interconnected. However, if these effects have one mutual cause in disruption of tree vegetation, it is not possible to neglect it. The cause should be solved both locally and globally. The vegetation will become very important in a forthcoming period of unstable climate. Extreme exposure to weather, such as torrential rains and droughts will take place. Moreover, we will have to cope with desertification of land on a global scale. In the Czech Republic we should focus on lowering water stocks and on soil quality preservation. The shift from the industrial agriculture practices to more frugal ecological and sustainable agriculture is vital. Sustainability should be an increasingly common word in our landscape management. In this thesis the relation of trees with agricultural landscape was described to offer a basic framework of the functions of trees. This framework represents the potential of trees as a solution for our current problems. The topic could be developed in a more detailed way, but it would exceed the scope of this thesis. A potential extension of the thesis might be the applications of agroforestry and permaculture to our current agricultural practices. These new solutions for growing food based on scientific research and observation of natural principles represent hope for humankind, and I wish such ideas could become common in the future. However, this will only be possible with significant changes in the values of the general public. We simply cannot give up the responsibility for the condition of our landscape. Consumers can easily create pressure on food producers, but their awareness of the relation between agriculture and landscape is necessary. We cannot improve the health of any landscape if there is no support of the public. Therefore, education should be considered as a powerful tool. If individuals do not change their relationship with nature, we cannot expect meaningful change of the state of the environment and our landscape.

As Albert Einstein stated:

We cannot solve our problems with the same thinking we created them.

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List of abbeviations

EECONET - The European Ecological Network

EUROSTAT - Directorate-General of the European Commission

C - Carbon

CAP - The Common Agricultural Policy

GHG - greenhouse gase(s)

TSES - The Territorial System of Ecological Stability