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Evaluation of ecosystem services loss due to urban sprawl on agricultural land in the context of sustainable development

Doctoral dissertation

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I hereby declare that I have written this dissertation for the purposes of finalizing the International Development Studies at the Department of Development Studies of the Faculty of Science of Palacký University in Olomouc independently and under the supervision of Doc. Ing. Ivo Machar, Ph. D.

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14th March 2019, Brussels

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2 ABSTRACT

This dissertation focuses on the ecosystem services which are provided by agriculture land and urban sprawl in the study area of municipality with extended powers Třebíč. The main focus of the dissertation is to evaluate what ecosystem services are provided to Czech society by the agricultural land and assess their financial value and also evaluate which ecosystem services disappear or are limited due to urban sprawl on agricultural land.

The practical output of this dissertation will comprise of better insight on function and value of land under agriculture use which is lost due to urban development and raising the awareness amongst the society on the fast-growing trend of unsustainable urban sprawl.

The main outcomes of this dissertation show that in most cases and for most of the typical arable crops in the Czech Republic, agriculture provides a disservice to the ecosystems rather than a service. The one notable exception is the provision of food, which is indeed the vital and primary function of agriculture land. The results also show that much can be done for a better provision of ecosystem services through sustainable management of land and through implementation of different practices and measures.

As for the urban sprawl, the research shows that the area of agricultural land is indeed steadily decreasing and some if it can be attributed to urban sprawl. The analysis of possible future trends also showed that this development will continue. It can be concluded that even if agriculture land does not provide all ecosystem services, it is still our main resource of food. Some of the ecosystem services can be reinstated in urban ecosystems, yet the provision of food is hardly replaceable on a scale that would matter.

As for the policies which impact all the elements included in this research, the Common Agricultural Policy influences the management of agricultural land, the spatial planning is controlled through Building Act and the agriculture land is also protected against urban development through Act on Protection of Agriculture Land Resources. The CAP can shape the agriculture towards a more sustainable management of land and better protection of environment, while the Building Act can be formulated to protect against uncontrolled urban sprawl and better preservation of rural areas and communities. The methodology used in the Act on Protection of Agriculture Land Resources to calculate the fees to change the landuse can also be updated with the ecosystem services evaluation to better reflect the evolving notions of ecosystem functioning and biodiversity protection.

As the wide notion of sustainable development suggests, the underlying issue of ecosystem disservice provision, land degradation, ownership fragmentation and urban sprawl can be targeted through a policy mix aiming at the three pillars of sustainability – economic, environmental and social.

Key words: ecosystem services evaluation, urban sprawl, land degradation, biodiversity, carbon sequestration, nutrient run-off, soil erosion

Tato disertační práce se zaměřuje na ekosystémové služby, které jsou poskytovány zemědělskou půdou a zástavbě této zemědělské půdy v zájmové oblasti obce s rozšířenou působností Třebíč. Hlavním cílem disertační práce je zhodnotit, jaké ekosystémové služby jsou české společnosti poskytovány zemědělskou půdou a posoudit jejich finanční hodnotu a také zhodnotit, které ekosystémové služby zanikají nebo jsou omezeny v důsledku zástavby zemědělské půdy.

Praktickým výstupem této disertační práce bude lepší pochopení hodnoty zemědělsky využívané půdy, které je ztracena v důsledku rozvoje měst a take zvyšování povědomí společnosti o rychle rostoucím trendu neudržitelné zástavby zemědělské půdy.

Hlavní výsledky této disertační práce ukazují, že ve většině případů poskytuje zemědělství pro okolní ekosystémy spíše zátěž než službu. Jednou z důležitých výjimek je poskytování potravin, což je skutečně zásadní a primární funkce zemědělské půdy. Výsledky také ukazují, že mnoho lze udělat pro lepší poskytování ekosystémových služeb prostřednictvím udržitelného hospodaření s půdou a prostřednictvím implementace různých přírodě blízkých postupů a opatření.

Pokud jde o zástavbu zemědělské půdy, výzkum ukazuje, že procento zemědělské půdy se neustále snižuje a částečně to lze připsat rozrůstání měst a obcí. Analýza možných budoucích trendů také ukázala, že tento vývoj bude pokračovat. Lze konstatovat, že i když zemědělská půda neposkytuje všechny ekosystémové služby, je stále naším hlavním zdrojem potravin. Některé z ekosystémových služeb mohou být obnoveny v městských ekosystémech, ale poskytování potravin je těžko nahraditelné v takové kapacitě, jakou poskytuje zemědělská půda.

Pokud jde o politiku, které má vliv na všechny prvky tohoto výzkumu, společná zemědělská politika ovlivňuje hospodaření na zemědělské půdě, územní plánování je řízeno stavebním zákonem a zemědělská půda je chráněna před rozvojem měst prostřednictvím zákona o ochraně zemědělské půdního fondu. SZP může formovat zemědělství směrem k udržitelnému zacházení s půdou a lepší ochraně životního prostředí, zatímco stavební zákon může být formulován tak, aby chránil před nekontrolovaným rozrůstáním měst a lepší ochranou venkovských oblastí. Metodika použitá v zákoně o ochraně zemědělských půdy pro výpočet poplatků za vynětí ze zemědělského půdního fondu může být také aktualizována hodnocením ekosystémových služeb, aby tak lépe odrážela rozvíjející se představy o fungování ekosystémů a ochraně biodiverzity.

Základní představa o udržitelném rozvoji naznačuje, že problém poskytování ekosystémových služeb, degradace půdy, roztříštěnosti vlastnictví zemědělské půdy a rozrůstání měst a obcí může být řešen prostřednictvím kombinace politik zaměřených na tři pilíře udržitelnosti - ekonomický, environmentální a sociální.

Klíčová slova: hodnocení ekosystémových služeb, zástavba zemědělské půdy, degradace půdy, biodiverzita, sekvestrace uhlíku, odtok živin, eroze půdy

3 INTRODUCTION

Ecosystem services and their evaluation is a concept which has been long gaining steam amongst scientists. The idea behind this concept is to assess the value of those services that nature provides to us (e.g. provision of oxygen through photosynthesis, climate regulation, carbon sequestration, food production, recreation etc.). It also became self-evident that we do need to put forward this concept and raise the awareness just as the value of these ecosystems is declining and we face a severe biodiversity loss in span of just a couple of decades. Through the ecosystem services evaluation we help to transform these values into a concept that every citizen would understand – into monetary value. This aims to bring the attention to severe ecosystem services loss and bring this closer to everyday discourse, outside of the scope of purely scientific bodies.

The idea of ecosystem services also closely links to sustainability and the strive to make our lives and our everyday practices and development more sustainable. The concept of sustainability came into broader knowledge in the 90's and it is also connected to the idea of halting biodiversity loss and adjust our actions in order to achieve a sustainable development. In this sense, all these concepts are still rather new and aim to educate the wider population that our current way of life has its consequences and we need to make radical changes in order to sustain this planet for the future generation.

One of the ways of how the landscape and ecosystems around us are dramatically changing is urban sprawl, which means transforming the area from its natural way in order to fit our needs, in most cases permanently and without the possibility to reverse it. This is one of the most prolific cases when human settlements shape the area we inhabit in a permanent manner. In order to address this issue, we should in the best-case scenario aim to the point in which this urban sprawl takes place in a manner which is sustainable and takes into consideration also the provision of ecosystem services.

Most of the area which is now being urbanized in Europe is agriculture land. This is due to the nature of colonisation in Europe where urban settlement has been proceeding for many centuries and therefore most of the landscape is cultural, with agriculture and forestry being the most prevalent type of land use. In this regard, most of the land which is being transformed is being now used for agriculture. If we would therefore want to address how might the urban sprawl impact on the sustainability and ecosystem services, we would need to assess what values are we losing through the development on agriculture land.

This will be indeed the main goal of this dissertation - to evaluate what ecosystem services are provided to Czech society by the agricultural land and assess their financial value and also evaluate which ecosystem services disappear or are limited due to urban sprawl on agricultural land. The outcome of this dissertation will be a note of recommendation to policy makers. Ecosystem services are today one of the main indicators of what financial value does each ecosystem have and their calculation will lead to specification of its overall value in the Czech Republic.

The practical output of this dissertation will comprise of better insight on function and value of land under agriculture use which is lost due to urban development and raising the awareness amongst the society on the fast-growing trend of unsustainable urban sprawl. By including the evaluation of ecosystem services into policy making a better protection of land might be achieved. It would also strengthen the pursuit of sustainable development of cities and villages without the uncontrolled urban sprawl. There are currently about 6100 hectares of agriculture land that disappear every year. In order for this area loss to resonate even louder, we need to put a price tag on the services which have been lost and stand for a more balanced approach in future policy making.

4 LITERATURE REVIEW

This literature review will aim to collect the main ideas and concepts behind the driving topics of this dissertation – ecosystem services, urban sprawl and sustainable development.

4.1. Ecosystem services

4.1.1. Definition of ecosystem services

The notion of naming and systematizing services provided by nature and environment to the human population began to take shape in the 1970´s with the term “environmental services”. The term was introduced in the 1970 report of the Study of Critical Environmental Problems (SCEP, 1970) and the definition and classification of environment services goes as follows:

“Environmental services refer to qualitative functions of natural non—produced assets of land, water and air (including related ecosystem) and their biota.” (Glossary of Environment Statistics, 1997)

They are classified as:

(a) disposal services which reflect the functions of the natural environment as an absorptive sink for residuals,

(b) productive services which reflect the economic functions of providing natural resource inputs and space for production and consumption, and

(c) consumer or consumption services which provide for physiological as well as recreational and related needs of human beings. (Glossary of Environment Statistics, 1997)

Moving on in time, in 1977, Westman (1977) presented the idea that the social value of the benefits that ecosystems provide could potentially be enumerated so that society can make more informed policy and management decisions and he named these social benefits ‘nature’s services.

Later the term “ecosystem services” was coined and it has been used in the scientific circles ever since. The term itself was first used by Ehrlich and Ehrlich (1981). Then the ecosystem services came into wider knowledge in the 1997 following among other things the publication of the article “The value of the world’s ecosystem services and natural capital” (Costanza, 1997) and the book Nature´s services: Societal dependence on natural ecosystems (Daily, 1997). Costanza defines ecosystem services as: *“benefits human populations derive, directly or indirectly, from ecosystem functions”* (Costanza, 1997) while Daily describes them as: *"conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfil human life"* (Daily, 1997). These definitions were later expanded in the Millennium Ecosystem Assessment into: "*benefits people obtain from ecosystems. These include provisioning services such as food and water; regulating services such as regulation of floods, drought, land degradation, and disease; supporting services such as soil formation and nutrient cycling; and cultural services such as recreational, spiritual, religious and other non-material benefits."* (MEA, 2005) Yet this concept is under scrutiny and several lead authors have acknowledged the need to keep this as an evolving concept (see Carpenter et al., 2006; Sachs and Reid, 2006).

Important is the notion that ecosystem services are linked to human well-being. Indeed naming the functions provided by the nature and by the environment as "services" provides a clear link to the terminology used in economics (even as it might seem as a degradation of ecosystem functions, in a sense that they supposedly only exist in order to fulfil human needs) and gives an opportunity to value these services.

4.1.2. Classification of ecosystem services

As the knowledge on ecosystem services expanded, so has the need to classify and name these services became more urgent. In his 1997 work, Costanza lists 17 ecosystem services, without any further classification into categories. De Groot (2002) expands on this list by adding six more services and classifies them into four categories: regulation functions, habitat functions, production functions and information functions. The list is following:

Regulation functions:

- Gas regulation
- Climate regulation
- Disturbance prevention
- Water regulation
- Water supply
- Soil retention
- Soil formation
- Nutrient regulation
- Waste treatment
- Pollination
- Biological control

Habitat functions:

- Refugium function
- Nursery function

Production functions:

- Food
- Raw materials
- Genetic resources
- Medicinal resources
- Ornamental resources

Information functions:

- Aesthetic information
- Recreation
- Cultural and artistic information
- Spiritual and historic information
- Science and education (Costanza et al. 1997, De Groot 1992, De Groot et al. 2000, De Groot 2002)

The methodology to classify ecosystem services has been changing throughout the years meaning that also the Millennium Ecosystem Assessment brought a slightly different categorization. It listed four main categories of ecosystem services, which are provisioning, regulating, cultural and supporting services (mostly renaming production function to provisioning services and information function to cultural services) with subcategories that slightly alternate with the categories by de Groot (2002). It needs to be noted that this classification is not meant to fit all purposes, and this has been pointed out for contexts regarding environmental accounting, landscape management and valuation, for which alternative classifications have been proposed (Boyd and Banzhaf, 2007; Wallace, 2007; Fisher and Turner, 2008). For the more contemporary initiatives for evaluation of ecosystem services and the categorization they use, The Economics of Ecosystems and Biodiversity (TEEB), a global initiative for mainstreaming the values of ecosystems and biodiversity, uses roughly the same list as the MEA (with slight alternations in the subcategories).

The most current classification is provided by the initiative of the Common International Classification of Ecosystem Services (CICES) which was developed from the work on environmental accounting done by the European Environment Agency (EEA). They saw it as particularly important to come up with a common classification. As the ecosystem accounting methods will continue to be developed, comparisons will have to be made between the different methods for which a standardized classification is needed. The first version of CICES was published in 2013 and the structure and scope has since then expanded, with versions being published regularly (the most recent one in March 2018). According to CICES, ecosystem services can be classified into three main categories – provisioning, regulation and maintenance and cultural, with many subcategories, divided also by the fact of being biotic and abiotic (see Annex I).

In the overview presented, we can see that ecosystem services are being promoted as a tool to assess the value humans place on these ecosystems and describe the benefits derived from natural resources (Costanza et al., 1997; De Groot et al., 2002; Abel et al., 2003; Chee, 2004; Groffman et al., 2004; Eamus et al., 2005; Kremen, 2005; Millennium Ecosystem Assessment, 2005; Farber et al., 2006). Indeed, if a wider use of ecosystem services is to be promoted, an effective framework for decision making needs to be presented, which would also assume a classification to allow comparisons and trade-offs amongst the relevant set of potential benefits (Wallace, 2007). Yet the current classifications tend to mix processes (means) for achieving services and the services themselves (ends) within the same classification category. Similar problem can be found in general texts and applied uses of ecosystem services and similar valuations (for example, Abel et al., 2003; Groffman et al., 2004; Anielski and Wilson, 2005; Kremen, 2005; Naiman et al., 2005). In order to provide a comprehensive classification useful for policymaking purposes, a set of key characteristics needs to be included:

- A minimum set of sharply defined terms that effectively encompass the topic.
- Clarity concerning the terms used to characterise services.
- Specification of the point at which linked processes deliver a service (Wallace, 2007).

Following this logic, a workable classification can be developed.

4.1.3. Concept of ecosystem services

When speaking about the concept of ecosystem services, there needs to be a clear distinction in terminology. In research, the term ecosystem comes together usually with the terms structure, function and finally the service. However, this does not mean that they are identical or synonymous. Ecosystem structure and function have been identified and studied for years without making any reference to the services to humans, which they also provide. Even as most ecosystem structures and processes do provide services they are not the same thing. Indeed, as mentioned above, the ecosystem services are only relevant when speaking about the benefits they provide to humans; otherwise the concept would not exist (Fisher, 2009).

The logic behind ecosystem services could be represented by the cascade in Figure 1. This diagram (making also the relationships and connections more simple and linear as opposed to real world) makes a distinction between the primary structure which creates a potential for ecosystem service (ecological structure, e.g. woodlands or wetlands) and the benefits people derive from these structures – which are indeed the ecosystem services. (Haines-Young et al., 2010)

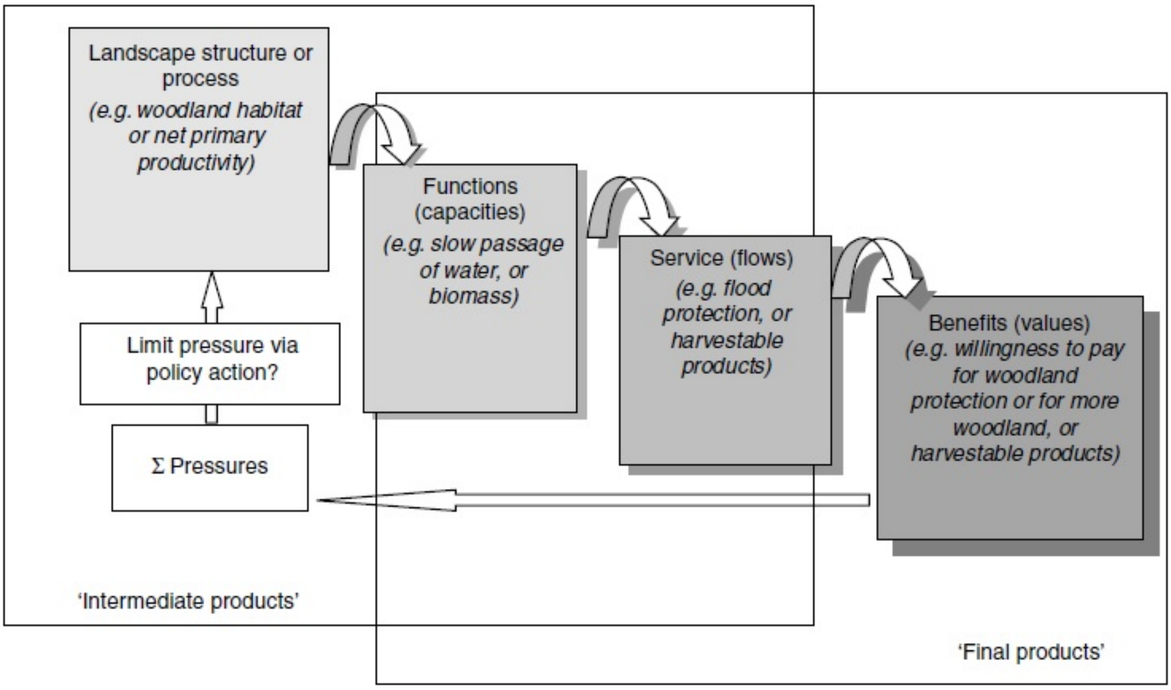


Figure 1 The relationship between biodiversity, ecosystem function and human well-being (Haines-Young et al., 2010)

It is important to say that the capacity or function (from which the ecosystem service is derived) of the primary structure is only taken into consideration when it is deemed useful for humans – therefore separating it from other fundamental capabilities or functions. Indeed for this we also need to find a specific benefit or beneficiary in order to distinguish clearly what is an ecosystem service and what is not. The observation that ecosystem services are defined by human activities and needs comes with an implication that due to the contingent nature of these services, a simple, generic checklist of services might never be devised. This links to the fact that categorization of ecosystem services is constantly evolving to incorporate new knowledge and new findings. (Haines-Young et al., 2010)

This cascade model can serve as a basis for developing conceptual models used for a wide assessment of ecosystem services. For example the conceptual framework developed as part of the Mapping and Assessment of Ecosystems and their Services was based on this cascade model together with the TEEB framework (de Groot et al.,2010) and the UK National Ecosystem Assessment (UKNEA, 2011) as well as some elements from the DPSIR framework shown in Figure 2 (Drivers-Pressures-State-Impact-Response) (Kandziora et al.,2013). The DPSIR approach has traditionally been used in the conception and implementation of environmental legislation in Europe (Niemeijer and de Groot,2008). All together a working conceptualisation is needed for a viable approach to assess and value ecosystem services.

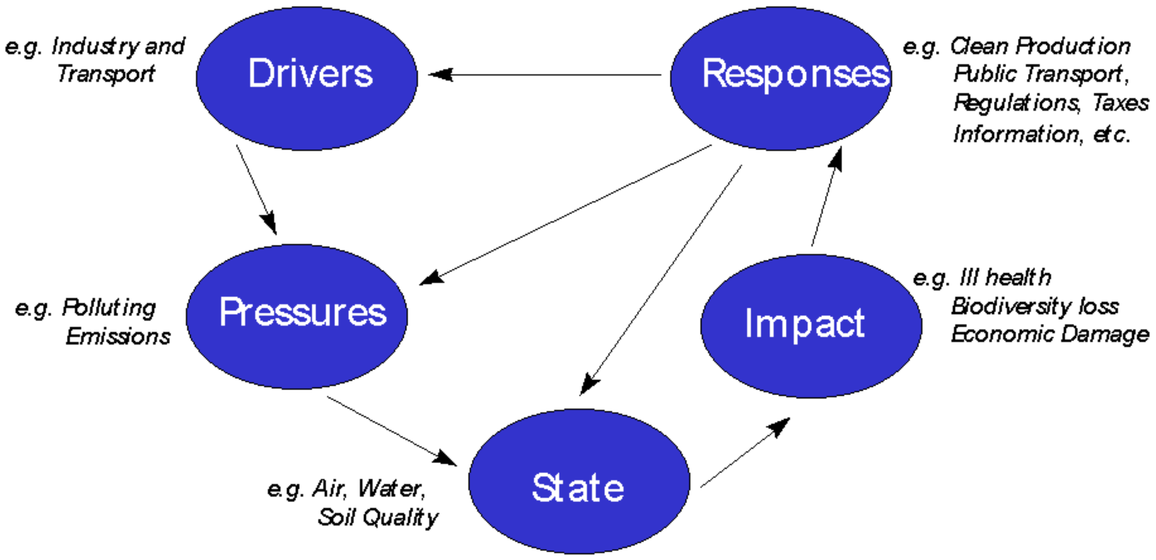


Figure 2 The DPSIR Framework. Source EEA, 2016

4.1.4. Methods for evaluating ecosystem services

Methods for evaluating ecosystem services have been outlined ever since the concept of ecosystem service came into popular view. The concept of valuation goes hand in hand with the idea that ecosystem services provide for human well-being and are thus linked to the production of added value in our daily lives. Otherwise the idea of putting a value on something as intangible as environmental aesthetics would be rather unwise or outright impossible (Costanza, 1997). Even though we can argue that we should protect ecosystems purely for moral or aesthetics reasons and do not need a valuation for this purpose, it is sometimes important to outline the value in terms every human understands (meaning in monetary terms) to win an argument for example when making a policy regarding nature conservation.

Many of ecosystem services valuation methods are based on the willingness to pay concept – stipulating that if for example if ecosystem functions in a well-managed forest leads up to 50 EUR/ha increment to the timber productivity, then beneficiaries of this service are expected to provide for this additional cost (Costanza, 1997). Moreover, we can usually distinct three different types of values – 1) actual or direct use values, 2) potential or indirect use values and 3) non-use or intrinsic values. To calculate monetary value, two methods are usually used – market pricing and shadow pricing. Note that market prices are mostly linked to active use values. (de Groot, 2000).

The measurement, modelling and monitoring of ecosystem functions are the foundation for ecosystem service valuation and are thus the basis for the sustainable use of biodiversity, ecosystems and natural resources in general (Carpenter et al. 2009). These different methods are discussed in detail through a variety of reviews and guidelines - for example, Barbier (2007), Bateman (2007), Bateman et al. (2002a), Champ et al. (2003), Freeman (2003), Hanley and Barbier (2009), Heal et al. (2005), Kanninen (2006) and Pagiola et al. (2004). The evaluation of ecosystem services in economic terms became an increasingly popular approach not only to assess alternative land use strategies but also to demonstrate and justify the need for the conservation of biodiversity (Bayon and Jenkins, 2010; Chan et al., 2007; Costanza et al., 1997; de Groot et al., 2002; Fisher et al., 2009; Ghazoul, 2007a, 2007b; Ridder, 2008; Wallace, 2007).

Following basic overview list of methods for evaluating ecosystem services is presented as stated in the introductory guide on valuing ecosystem services (DEFRA, 2007).

4.1.4.1. Revealed preference methods

Market prices – this method can be used to capture the value of goods and services which are traded (market value of timber). These market prices however need to be adjusted to take into account possible distortions, for example subsidies, and they also do not capture the non-use value. The market price is a minimum expression of willingness to pay.

Averting behavior – this method evaluates the price paid by individuals to mitigate against environmental impacts, for example using the cost of water filtration as a proxy for value of water filtration damages.

Production function approach – this method examines the relationship between particular ecosystem services and the production of market good. Environmental goods and services are considered as inputs to the production process and their value is inferred by considering the changes that would have to made in the production process. This method is valuable for capturing indirect use value.

Hedonic pricing – this method looks at environmental characteristics (for example pleasant view from the window) and the impact they have on property prices. The value of the environmental component in the property price can therefore be captured through modelling all the possible influencing factors in the price. Hedonic pricing can be used to capture direct and indirect use value.

Travel cost method – this is a survey-based technique based on costs incurred by individuals taking a trip to a recreation site (travel costs, entry fees etc.) which serves as a proxy for the recreational price of that site. This method only captures use value.

Random utility models – this method is an extension of the travel cost method and can be used to test the effect of changing the quality and quantity of environmental characteristics in particular site. (DEFRA, 2007).

4.1.4.2. Stated preference methods

Contingent valuation – this method is a survey-style approach which constructs hypothetical markets through a questionnaire, where respondents answer questions regarding what they are willing to pay for a particular environmental change. In theory, it can capture all elements of the total economic value.

Choice modelling – this method is again a survey-style approach that zooms in on the individual attributes of the ecosystem. Participants are presented with different combinations of attributes (e.g. in connection with a lake – water quality, number of species) and are asked to choose their preferred combination or rank the different combinations. Each combination has a price associated with them and again this method is able to capture all elements of the total economic value. (DEFRA, 2007).

4.1.4.3. Cost based approaches

These approaches consider costs incurred in relation to provision of environmental goods and services and provide only proxy values. These approaches calculate a value of natural resources by how much it would cost to replace or restore it after it has been damaged.

Opportunity costs – this method works with a value forgone when protecting, enhancing or creating a particular environmental asset (for example opportunity costs of agriculture production lost if an area is reinstituted as forest).

Cost of alternatives/substitute goods – this method takes into account provision of a substitute good which has similar function to the environmental good. Giving an example, wetlands providing flood protection can be valued on the basis of cost of building artificial flood protection defences. However, given to the range of ecosystem services provided by the wetlands, this method only estimates minimum estimate value of the wetland.

Replacement cost method – this method looks at costs of replacing or restoring a damaged good to its original state and uses this cost as a measure of the benefit of restoration. (DEFRA, 2007).

4.1.4.4. Methods of eliciting non-economic values

Focus groups, in-depth groups – focus groups try to discover the position of participants on an issue of set of related issues. In-depth groups are similar in some respect but are much less closely facilitated with a great emphasis on how the group creates discourse on the topic.

Citizen’s jury – a sample of citizens is given an opportunity to consider evidence from experts and other stakeholders and provide with a carefully considered public opinion on a particular issue.

Health-based value approaches – this approach measures health-related outputs in terms of the combined effect on the length and quality of life.

Q-methodology – this approach focuses on identification of typical ways in which people think about environmental or other issues. It mostly concerns the way people understand, think and feel about environmental problems and their solutions.

Delphi surveys, systematic reviews – this approach aims to produce summary of expert opinion or scientific evidence relating to particular questions. On one hand, Delphi relies mostly on expert opinion while on the other hand, systematic review attempts to maximise reliance on objective data. Both of these methods are rather means of summarizing knowledge then full-on methods. (DEFRA, 2007).

Farber et al., 2006 also highlights what methods can be best used for what ecosystem service (see Figure 3)

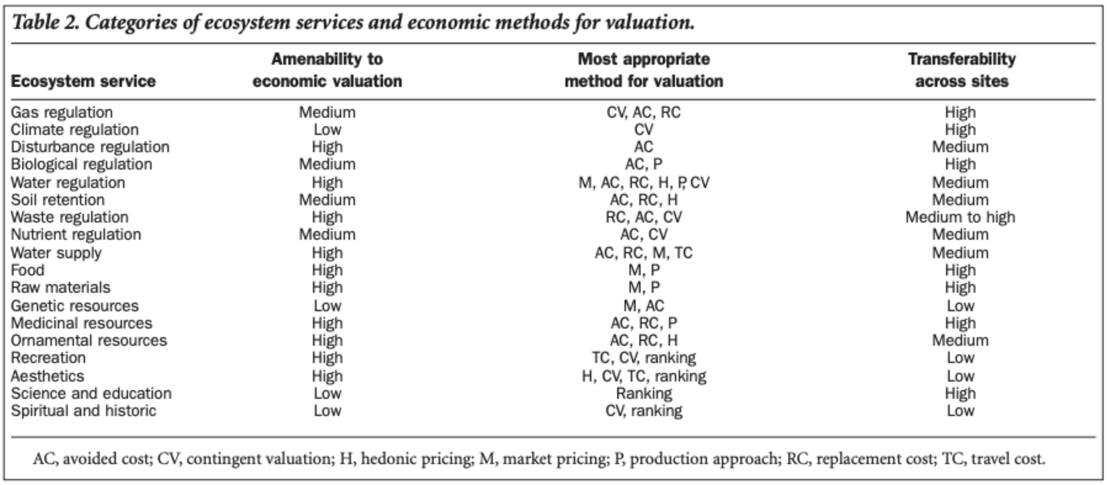


Table 2. Categories of ecosystem services and economic methods for valuation.

Ecosystem service	Amenability to economic valuation	Most appropriate method for valuation	Transferability across sites
Gas regulation	Medium	CV, AC, RC	High
Climate regulation	Low	CV	High
Disturbance regulation	High	AC	Medium
Biological regulation	Medium	AC, P	High
Water regulation	High	M, AC, RC, H, P, CV	Medium
Soil retention	Medium	AC, RC, H	Medium
Waste regulation	High	RC, AC, CV	Medium to high
Nutrient regulation	Medium	AC, CV	Medium
Water supply	High	AC, RC, M, TC	Medium
Food	High	M, P	High
Raw materials	High	M, P	High
Genetic resources	Low	M, AC	Low
Medicinal resources	High	AC, RC, P	High
Ornamental resources	High	AC, RC, H	Medium
Recreation	High	TC, CV, ranking	Low
Aesthetics	High	H, CV, TC, ranking	Low
Science and education	Low	Ranking	High
Spiritual and historic	Low	CV, ranking	Low

AC, avoided cost; CV, contingent valuation; H, hedonic pricing; M, market pricing; P, production approach; RC, replacement cost; TC, travel cost.

Figure 3 Categories of ecosystem services and economic methods for valuation. Source: Farber et al., 2006

4.1.5. The relationship between ecosystem services and biodiversity

When talking about ecosystem services, one cannot leave behind biodiversity. Indeed these two concepts are closely linked together. The evaluation of ecosystem services came to rise with the broader knowledge of universal biodiversity loss and the need to further understand the linkages and reasons behind this loss. The loss of biodiversity is also an effect of ecosystem changes as well as a cause of further changes and a decline in human benefits (Diaz et al., 2006). The positive correlation between biodiversity and ecosystem services is undeniable and many researchers have confirmed the effect of biodiversity on ecosystem functions (Hooper et al., 2005; Diaz et al., 2006). Ecosystem properties depend greatly on biodiversity in terms of the functional characteristics of the organisms present in these ecosystems and many hypotheses, based on diversity in relation to functional compensation and resilience, are formulated (Bengtsson et al., 2003; Hector and Bagchi, 2007; Naeem, 1998; Tilman et al., 1998; Walker, 1992). The increase in spatial and temporal variability and a large number of species with different functional characteristics act as insurance which buffers ecosystem processes and their services and makes the ecosystem more resilient.

Even as these links might seem unquestionable, there is some contest to this notion in the literature. For example, only limited field experimental proof is found on the importance of species richness for ecosystem services (Diaz et al., 2006; Hector and Bagchi, 2007; Hooper et al., 2002). A direct link to biodiversity, especially to species richness and species diversity, can be made only for some cultural services like ecotourism, resources for medicines and ethical or aesthetical reasons and for some regulating services executed by keystone species (Begossi, 1996; Elmqvist et al., 2010; Hooper et al., 2005; Swift et al., 2004; Thomas et al., 2008). Many studies also revealed only weak linkages (either positive or negative) between priority areas for biodiversity conservation and different ecosystem services (Bennett et al., 2009; Chan et al., 2006; Naidoo et al., 2008). Yet again, due to the complexity of ecosystem functioning, the role of many species might be unknown to us. In this regard, a precautionary principle is often presented as an argument to protect all species and to avert catastrophes (Daily, 2000; Ridder, 2008).

Yet even with this rather limited knowledge, local ecosystem management projects focused both on delivering on both biodiversity and ecosystem services can be found (TEEB, 2010; http://www.eea.europa.eu/atlas) and especially in densely populated areas the ecosystem services framework can be used to advocate for biodiversity conservation (Ghazoul, 2007b). This practice might imply that both concepts could simply be interchangeable, but this assumption does not hold as the scoring systems for both concepts are quite different. Due to the rareness of some key species valuable in terms of biodiversity (often placed on the UN Red list) the scores cannot be used in all areas. Moreover, ecosystem services are usually not provided by rare or endangered species. Key species for the delivery of ecosystem services are usually those that are common and tolerant, species that are resilient in the face of change or a specific group of species fulfilling certain functional criteria (Schneiders et al., 2011). Therefore, together with biodiversity indicators, other indicators highlighting the key structural and functional variables of the ecosystems should be developed as using common metrics and methodology to measure and value both biodiversity and ecosystem services will help to find a better alignment of both concepts (Schneiders et al., 2011).

4.1.6. Ecosystem services and the concept of sustainability

As the notion of ecosystem services gained its popularity through raising awareness on biodiversity loss and habitat destruction, this also suggests that the ecosystem services evaluation should aim to a sustainable use of these ecosystems. It is clear that any economic analysis of ecosystem services has to appraise the impact of potential stock depletions in order to assess its sustainability. In past, literature has focused on assessing historic development paths through adjustments of national income accounts (Bartelmus 2001, 2008; United Nations 2003; Hamilton and Ruta 2009), yet in future some alternative options should be evaluated. Impact on sustainability could be incorporated into appraisals such as: (i) assessment of how future depletion of ecosystem stocks might increase the marginal shadow value of corresponding services; (ii) incorporation of the insurance value of maintaining ecosystem resilience and; (iii) the use of safe minimum standards as a means of preserving stocks of ecosystem assets (Bateman et al. 2014).

The first proposed method depends on the the concept of discounting, which is the process of converting benefits and costs occurring at some future date into their present day value. Yet this preliminary idea on this concept is not simple and there are many factors which need to be considered such as the empirical relationship between asset stocks, the flow of services and the way in which these services are valued at different stock levels (Pascal et al. 2009). However, there is a general assumption which should play a role in the evaluation and that is that ecosystem services are difficult to replace (i.e. the natural asset is characterised by limited substitution possibilities). In this regard, the marginal shadow value of these services is likely to rise all the more rapidly as the asset is increasingly degraded or converted (see, for example, Gerlagh and van der Zwaan (2002), Hoel and Sterner (2007) and Sterner and Persson (2008). Another approach, taking into consideration the resilience of ecosystems, is proposed by Mäler et al. (2009) and Mäler (2008) who considers the ability of an ecosystem to withstand stresses and shocks and so continue to provide services. They propose to treat this ecological resilience as a stock with a distinct asset value which can be degraded or enhanced over time. The last approach, one that considers the safe minimum standards, can be thought of as a precautionary approach to the management of a natural asset (Ciriacy-Wantrup 1952; Bishop 1978). In this approach, a conventional economic decision making prevails until a threshold is reached at which the primary objective becomes conservation, unless the sacrifice (i.e. the opportunity costs) that it entails is intolerably high. Farmer and Randall (1998) and Randall (2007) argue that the popularity of this safe minimum standard lies in it being an approach that entails a broad moral consensus for making decisions. The safe minimum standard approach might have influenced conservation policy worldwide (Berrens 2001; Pearce 2004), including in the US (e.g. the Endangered Species Act, ESA), Europe (e.g. the EU Birds and Habitats Directives, the Marine Strategy Directive, the Water Framework Directive, the European Landscape Convention, etc.) and the UK (e.g. Public Service Agreement 28, the Environmental Protection Act, Integrated Pollution Prevention and Control, Water Resources and Water Acts, Natural Environment and Rural Communities Act, Wildlife and Countryside Act, Forestry Act and others). All in all, the notion of ecosystem services and its evaluation certainly has a positive impact on the general awareness about the sustainable use of ecosystem functions.

4.1.7. Ecosystem services and agriculture

As the topic of this dissertation focuses on the ecosystem services provided by agriculture, this notion needs to be brought forward as well. When referring to the ecosystem services, the ecosystems we tend to focus in many cases on those that are endangered or rare. Yet the land-use type which takes up a large share of Earth´s land area (between 24% and 38%) is agriculture crop and pasture land (Millennium Ecosystem Assessment, 2005; Wood et al., 2001). As a managed ecosystem, agriculture has a unique position in both supplying and demanding other ecosystem services. Agriculture provides all three major categories of ecosystem services — provisioning, regulating and cultural services — while it also requires supporting services to ensure productivity (Swinton et al, 2007). Even as the conversion of native ecosystems to agriculture use often results in profound environmental impacts, agricultural ecosystems still manage to preserve many features common to native ecosystems, and therefore the consideration of ecosystem services provided by agriculture has to be observed in the context of what they replace, and what they might be replaced with. As an example, conversion of agricultural land to urban areas may diminish certain ecosystem services that may have functioned as well in the agricultural ecosystem as in the native one it replaced (Swinton et al, 2007). As for the ecosystem services provided by agriculture, unquestionably the most important service is the provision of food, fuel, and fiber. Amongst other service agriculture provides is the maintenance of soil fertility, carbon sequestration, pollination, pest control, nutrient management, reduction of runoff or different cultural services, such as recreational hunting (Swinton et al, 2007). On the other hand, there are also disservices of agriculture, or the ecosystem service agriculture depletes in order to remain its function. Among these disservices belong competition for resources and crop pests (see also Figure 4) (Stoller et al., 1987, Zhang et al. 2007). In this sense, the agriculture should not be disregarded as the source of ecosystem services, yet a careful balance needs to be set so that they would not deplete all provisioning services.

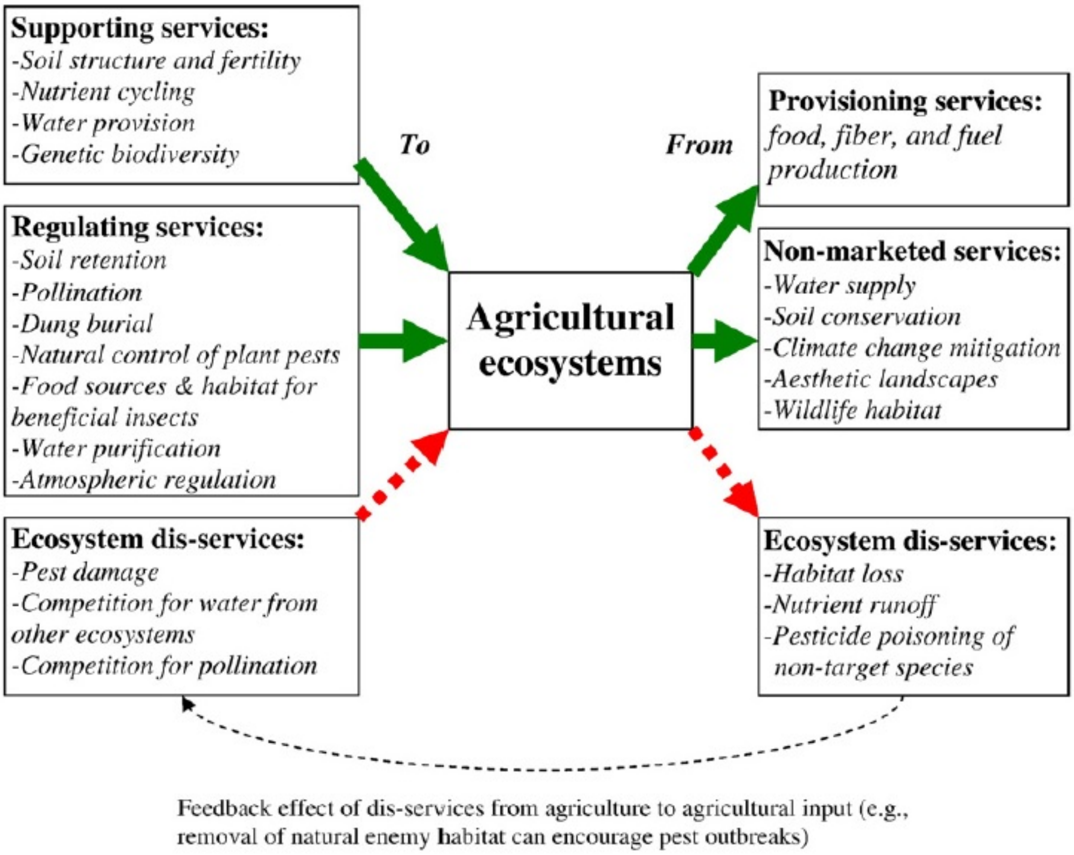


Figure 4 Ecosystem services and dis-services to and from agriculture. Solid arrows indicate services, whereas dashed arrows indicate dis-services (Zhang et al. 2007)

4.1.8. Initiatives for global assessment of ecosystem services

As mentioned in the previous chapters, there are several initiatives which work with ecosystem services evaluation and aim to assess the global value of ecosystem in order to point out the natural riches. The Millennium Ecosystem Assessment was the first one to do so, and from 2001 to 2005, the MA involved the work of more than 1,360 experts worldwide. Their findings provide a scientific appraisal of the condition and trends in the world’s ecosystems and the services they provide, as well as the scientific basis for action to conserve and use them sustainably. This was followed by the global initiative on the Economics of Ecosystems and Biodiversity (TEEB) which is a global initiative focused on “making nature’s values visible”. In March 2007, environment ministers from the G8+5 countries meeting in Potsdam, Germany proposed to initiate the process of analysing the global economic benefit of biological diversity, the costs of the loss of biodiversity and the failure to take protective measures versus the costs of effective conservation. Its outcome was then this initiative for mainstreaming the values of biodiversity and ecosystem services into decision-making at all levels. European Union has also came up with its own initiative, grounded in the EU Biodiversity Strategy to 2020. The Mapping and Assessment of Ecosystems and their Services (MAES) should give guidance for mapping and assessing urban ecosystems and includes an indicator framework to assess the condition of urban ecosystems and services, which is used at European, Member State and local level.

4.1.9. Shortcomings of the ecosystem services evaluation approaches

As the notion of ecosystem services and their evaluation has gained steam and has become more widely used, a certain level of cautiousness needs to be applied with these concepts. As there are several approaches to the ecosystem services evaluation being developed worldwide simultaneously, there might be some coherence missing in the overall tendency. A quantitative review of these approaches (Seppelt et al., 2011) has identified four key characteristics that any holistic approach to ecosystem services research should have. These are: (i) biophysical realism of ecosystem data and models; (ii) consideration of local trade-offs; (iii) recognition of off-site effects; and (iv) comprehensive but critical involvement of stakeholders within assessment studies.

Even as the concept of ecosystem services has been mainstreamed, a fully operational method to implement the concept, which would assist policy makers and provide policy-oriented researchers with sufficient tools for taking provisioning of natural goods and services into account is currently still missing (Armsworth et al. 2007). The ecosystem services are now translated into a wide array of different research projects. This variation proves difficult for the policymakers who would want to use this tool as it makes it difficult to assess the credibility of assessment results and reduces the comparability of studies. If the political relevance of the concept is to be strengthened, we need to improve the scientific basis for its implementation (Ash et al. 2010).

The biophysical basis for the ecosystem services research and translating ecosystem functioning to indicators has been addressed in a number of methodological approaches. These should be able to explain the non-monotonous, non-linear and time-variant relationships that all require data, maps, monitoring (Lautenbach et al. 2010), fieldwork or experiments (e.g. Greenleaf & Kremen 2006; Sandhu et al. 2008) and ⁄ or models (Boumans et al. 2002; Schröter et al. 2005). The other vital part of a sound ecosystem services research, trade-offs, emerge when ecosystem services respond differently to change. According to Rodriguez et al. (2006), trade-offs occur due to feedback in ecological processes resulting in temporal and spatial patterns (Steffan-Dewenter et al. 2007) when gains and losses do not occur in the same region (Egoh et al. 2009). The off-site effects, identified to be also one of the vital components of research, occurs when local decisions affect the delivery of distant ecosystem services.

This is either due to causal links on the global scale or human-induced effects, such as international trade in goods, which can also involve a trade in ecological damage (Scharlemann & Laurance 2008). The last essential component, stakeholder involvement, should be used to relate ecosystem function to human well-being. Stakeholders should be able to identify the relevant ecosystem services, should be able to evaluate and re-evaluate the key indicators and they also provide ground for different management options (Ananda&Herath 2009). If all these components are considered, only then can we have operational indicators which translate the functioning of the ecosystems.

4.2. Urban sprawl

As this dissertation focuses on how much does the urban sprawl impact the provision of ecosystem services provided by agriculture land, it is important to recall this phenomenon and its implications in spatial planning.

Urban sprawl is known to us as the spatial dispersion of settlements. With the developing urbanization in most of Europe, this has become one of the major policy concerns. Even as the term itself is quite well known and might mean different things to different people, little is known about the phenomenon itself, how urban sprawl varies country to country, what are the determinants of the spatial variation and how do the institutional settings determine the urban sprawl outcomes. What we might learn is that the land use policies and local fiscal incentives are the crucial factors explaining urban sprawl. This phenomenon is also more prevalent in Central and Eastern Europe. (Ehrlich et al. 2018)

Yet this is not an issue critical only for Europe – urban systems are expanding at fast rates all over the world. Forecasts indicate that this expansion rate will dramatically increase the size of cities – by threefold by the middle of century. (Angel et al., 2011; Seto et al., 2012; Inostroza et al., 2013). This rapid development is a challenge to spatial planning framework and will require integrated approaches to tackle the negative environmental, social and economic effects of urban development. Yet this expansion is an unavoidable fact of economic development, growth of GDP, motorization rates and population growth. (Haase et al., 2013; Inostroza et al., 2013). We need to however draw a line between urban expansion and urban sprawl. While urban expansion is an overall physical process resulting from the reproduction of the urban material structure as the fundamental urban function, urban sprawl is one specific type of this expansion, a scattered development (Inostroza et al., 2013, Burchfield et al., 2006; Schneider and Woodcock, 2008). There is widely accepted need to manage urban sprawl and consequences through the promotion of compact urban development and urban reutilization. The underlying dilemma of reducing the negative impact of urban sprawl (such as loss of fertile soil, reduction or loss of ecosystem services) through fostering urban development on one hand

and increasing environmental quality in cities through densification on the other hand is called the “compact city paradox” (De Roo, 2000; Neuman, 2005).

Urban expansion is an inevitable part of the future development. Not understanding the most essential ways for the cities to grow without upending the environment and provision of ecosystem services is a key challenge to reach sustainable development goals. Much of the endeavour has been put towards limiting the urban sprawl yet the trade offs and the way to reach a balance in this development has not been discovered. Yet urban sprawl has been shown to compromise key ecosystem services, most notably the climate regulation and the ability of landscape to infiltrate and purify water. (Barnes, Morgan III, Roberge, & Lowe, 2001; Beach, 2003; Mentens, Raes, & Hermy, 2006; Otto et al., 2002). There are some urban sprawl alternatives which have been introduced, such as the UK Compact City and US Smart Growth. (Breheny, 1992, Duany, Speck, & Lydon, 2010) These aim to limit the impacts of urban sprawl with patterns that concentrate urban amenities and infrastructure to reduce land consumption and travel costs. These alternatives have been shown to be effective in shaping neighbourhood design but much less is known about the impacts of these alternatives on the ecosystem services. (Song, 2005, Gómez-Baggethun & Barton, 2013; Preuss & Vemuri, 2004). The study run by Shoemaker, 2018 to compare different growth scenarios and development patterns concluded that all alternative futures with urban sprawl resulted in more pollution, losses of carbon and irreparable changes to habitats. On the opposite hand, landowners will probably enjoy increased revenues.

The key challenge is therefore to meet the growing demand for urban land use on one hand while also accommodating natural ecosystems on other hand. There is now a movement to support the transition to sustainable urban planning (Anguluri and Narayanan, 2017; Liu and Jensen, 2018). Urban green areas, which are an undeniable part of such plans, have many positive impacts on human well-being (Lee et al., 2015). Amongst those are the enjoyment of aesthetic environment, sense of community identity and provision of habitat for biodiversity (Dearborn and Kark, 2010). Unused industrial sites like brownfields are a perfect example of space which could be used for conversion to green areas which could provide ecosystem services and contribute to enhancing the liveability in cities (Mathey et al., 2015). These ecosystem services provided by semi urban land or conversed urban land are urban ecosystem services (Bolund and Hunhammar, 1999; Gómez-Baggethun and Barton, 2013; Gómez-Baggethun et al., 2013; Larondelle and Haase, 2013). Amongst the most common urban ecosystem services are local climate regulation, local air filtration and ventilation, recreation, carbon sequestration and storage and avoided runoff (de Valck et al., 2019). The level of brownfield regeneration and therefore the level of provision of these urban ecosystem services reflects the sustainable development strategies of cities and regions (Wedding & Crawford-Brown, 2007).

From this short overview we can see that this part of research focus is well under way and most of the studies are quite recent, as the review shows. Anyhow, it is quite clear that urban sprawl has implications both on provision of ecosystem services and sustainable development.

4.3. Sustainable development

As an underlying topic of the previous two chapters, sustainable development is indeed an overarching subject which is being reflected in many research areas and policy making efforts of today.

Sustainable development is defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." (WCED, 1987: 43). It is generally conceived to be resting on three pillars of sustainability – economic development, social development and environmental protection. Continuing policy discourse on the international level has put the world on notice that achieving sustainable development in this century is not an option but an imperative. (Shah, 2008)

The term came into wider knowledge in 1987 when the United Nations Commission on Environment and Development issued the Bruntland report. This report argued that equity, growth, and environmental maintenance are simultaneously possible and that every country is capable of achieving its full economic potential while at the same time enhancing its resource base. Then in 1992, the Earth Summit brought together the world leaders to negotiate an agenda for environment and development which would fit the twenty first century. This was the Agenda 21, which spelled out actions towards sustainable development, including goals and responsibilities. Another accomplishment of this Summit was the Rio Declaration, a statement on guiding principles when it comes to environment protection, climate change adaptation and mitigation and biodiversity protection. The Rio Declaration also firmly stated that humans are the centre of concern for sustainable development. It also highlighted the polluter pays principle and precautionary principle when it comes to environment protection. (Shah, 2008)

Next step was setting up real targets in relation to priority challenges, such as sustainable development, namely, poverty, hunger, education, gender, health, environmental sustainability, and a global partnership for development. This materialized in the form of Millennium Development Goals, put in place in 2000. (Shah, 2008) Seeing those as successful predeterminant for global action, these goals were translated and expanded in 2012 into Sustainable Development Goals (SDG). Those were aimed mostly at the end of poverty and hunger, better standards of education and healthcare - particularly as it pertains to water quality and better sanitation, achievement of gender equality, sustainable economic growth while promoting jobs and stronger economies and sustainability to include health of the land, air, and sea. The SDG contain 17 global goals, which are:

- Goal 1: No poverty
- Goal 2: Zero hunger
- Goal 3: Good health and well-being for people
- Goal 4: Quality education
- Goal 5: Gender equality
- Goal 6: Clean water and sanitation
- Goal 7: Affordable and clean energy
- Goal 8: Decent work and economic growth
- Goal 9: Industry, Innovation, and Infrastructure
- Goal 10: Reducing inequalities
- Goal 11: Sustainable cities and communities
- Goal 12: Responsible consumption and production
- Goal 13: Climate action
- Goal 14: Life below water
- Goal 15: Life on land
- Goal 16: Peace, justice and strong institutions
- Goal 17: Partnerships for the goals

The Sustainable Development Goals have put people at the forefront of solving this global issue, acknowledging that nature has certain rights and that we have the stewardship of the world. Sustainable development stresses that growth must be both inclusive and environmentally sound in order to reduce poverty and build a shared prosperity for today population while also continuing to meet the needs of the future generations. (Iyyanki, Manickam, 2017)

The SDGs have been translated to many policies which touch different areas. The European Union as one of the signatories of this agreement agreed to translate the commitments of SDG to their legislation. One of the most important policy line which touches the agriculture sector is the Common Agricultural Policy (CAP). As this policy is now in process of being reformed, there is a call to include the sustainability goals even further and adapt the sector to the rising challenges of climate change and biodiversity loss.

5 METHODOLOGY

5.1. Definition of terms

There are several concepts this dissertation will be working with. Here are the established definitions for the scope of this work.

Ecosystem services - *"benefits people obtain from ecosystems. These include provisioning services such as food and water; regulating services such as regulation of floods, drought, land degradation, and disease; supporting services such as soil formation and nutrient cycling; and cultural services such as recreational, spiritual, religious and other non-material benefits."* (MEA, 2005)

Biodiversity - *the variability among living organisms from all sources, including terrestrial, marine, and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species, and of ecosystems* (MEA, 2005)

Sustainable development - *development that meets the needs of the present without compromising the ability of future generations to meet their own needs* (UN, 1987)

Urban sprawl - the spread of an urban area into what used to be countryside (Collin English Dictionary, 2019)

Municipality with extended powers – designation of area for the use of spatial planning and delegation of administration competences, the connecting level between regions and local districts. Municipalities with extended powers were established in 2002 through legislative act n. 388/2002 Sb.

District – designation of area for the use of spatial planning and delegation of administration competences. A historic reference, the competences of district office were taken over by the municipalities with extended powers in 2002.

Soil erosion - displacement of the upper layer of soil, one form of soil degradation. Erosion is sometimes divided into water erosion, glacial erosion, snow erosion, wind (aeolean) erosion, zoogenic erosion, and anthropogenic erosion. Soil erosion may be a slow process that continues relatively unnoticed, or it may occur at an alarming rate causing a serious loss of topsoil. The loss of soil from farmland may be reflected in reduced crop production potential, lower surface water quality and damaged drainage networks.

Carbon sequestration - the long-term storage of carbon in plants, soils, geologic formations, and the ocean. Carbon sequestration occurs both naturally and as a result of anthropogenic activities and typically refers to the storage of carbon that has the immediate potential to become carbon dioxide gas. (Encyclopaedia Britannica, 2019)

Nutrient run-off – a surface run-off is water, from rain, snowmelt, or other sources, that flows over the land surface, and is a major component of the water cycle. In the case of nutrient run-off, there is excess of nutrients included in this run-off, mostly nitrogen and phosphorus. These are added to bodies of water and can act like fertilizer, causing excessive growth of algae and acting as nutrient pollution.

Brownfield - brownfield is a site that has been affected by the former uses of the site or surrounding land, is derelict or underused, mainly in fully or partly developed urban areas, requires intervention to bring it back to beneficial use, and may have real or perceived contamination problems (CEN, 2014).

5.2. Research objective, hypothesis and main research question

The objective of this research is to determine the value of ecosystem services provided by agriculture land which is lost due to urban sprawl. As many hectares of agriculture land a year are lost due to urban development, this valuation would serve as an argument for preserving agriculture land and preventing urban sprawl. The study area dedicated for this research is the municipality with extended powers Třebíč. This research aims to collect the data on the amount of agriculture land lost to urbanization in Třebíč and evaluate the ecosystem services that could no longer be provided by this land.

This topic was chosen in the light of the ever-growing rate of urban sprawl in Czech lands without sufficient policy and argumentation tool to address this trend. Hopefully the notion of ecosystem services evaluation might help to scale back this negative development.

The default hypothesis which is basis for this research is as follows: *“The value of ecosystem services provided by agriculture land in the municipality with extended powers Třebíč has decreased due to urban sprawl.”*

From this hypothesis stems the main research question:

What is the value of ecosystem services provided by agriculture land which has been lost due to urban sprawl in the region of Třebíč?

This main research question will be divided into three more specific research question:

- Research question 1: What are the different ecosystem services provided by agriculture land?

- Research question 2: What is the value of these ecosystem services?
- Research question 3: What amount of agriculture land has been lost due to urban sprawl?

The structure of the research and of this dissertation shall be based on these research questions and conclusions shall be drawn accordingly.

5.3. Methods

5.3.1. Research question 1 – ecosystem services provided by agriculture land

To determine answer to research question one desk research will be used to conclude which ecosystem services are provided by agriculture land and more importantly for which of these ecosystem services can we determine their value. The preliminary research has identified these ecosystem services which can be remunerated in terms of this study: carbon sequestration, prevention of erosion, prevention of water contamination, production function. To determine the ecosystem service of prevention of water contamination, the nutrient run-off needs to be established first.

5.3.2. Research question 2 – evaluation of ecosystem services provided by agriculture land

Nutrient run-off (prevention of water contamination) and carbon sequestration

To determine the nutrient runoff and carbon sequestration (both methodologies shall be described together, as the collection of data for both of them was done simultaneously) on agriculture land and evaluate the belonging ecosystem services will involve several steps. The first step would be to collect data on different samples of agriculture land with different type of management through case studies. Case studies were chosen in the municipality with extended powers Třebíč and to provide multiple samples, farms with different type of management were chosen, ranging from small ecological farms with prevalent permanent grassland to big farms with cereal production and animal production. As this research was conducted as part of the study commissioned by the Ministry of Agriculture on the provision of public goods and ecosystem services through agro-envi-climate measures, all farms had part of their land designated as grassland on arable land under this scheme. Farms were chosen through the database provided by the Ministry and to provide anonymity for the responders, no names were included in the published outcomes. To collect the data, qualitative semi-structured questionnaire (mixing closed and open question) was prepared to get all the needed data to feed into the models used for this exercise. The questions in the questionnaire were divided into several blocks, which were:

- General information about the farm (type of farm, number of hectares/animals, climate)
- Information about the agriculture production (types of plants, date of planting/collecting, final yield in tones, by-products)
- Information about the soil (soil structure, organic matter, moisture, pH)
- Information about fertilizers (types of fertilizers, amount of tones used, method for fertilizing)
- Information about pesticides (types of pesticides, amount of tones used)
- Information about the by-product (type of by-product, amount, management)
- Land use (changes in land use over last couple of years, use of cover crops/catch crops)
- Types of machinery used (yearly consumption of fuel, machinery output)
- Operations in the field (number of operations in the field during the agriculture year)
- Transport to and from farm

The complete survey with all questions included can be found in Annex II. The interviews were conducted with the owners at their farm; each interview took overall 2 hours. The interviews took place in autumn 2017.

The overview of the selected farm types:

- **Farm 1** – Mixed medium sized privately-owned ecological farm (81 pieces of cattle, 23 horses, 6 sheep), grassland on arable land, permanent grassland and pastures, 130.47 ha in total
- **Farm 2** – Large conventional farm (wheat, maize, rapeseed, alfalfa, low percentage of grassland), 579.98 ha in total
- **Farm 3** – Large conventional mixed farm (wheat, maize, rapeseed, permanent grassland, 1000 pieces of cattle, biofuel station), 1172.56 ha in total
- **Farm 4** – Large conventional mixed farm (wheat, rapeseed, maize, barley, permanent grassland, 30 000 chicken, 420 dairy cows), 3487.45 ha in total
- **Farm 5** – Small privately-owned ecological farm with cattle, horses, sheep and pigs, 25.41 ha in total
- **Farm 6** – Small privately-owned mixed farm (wheat, barley, permanent grassland, 35 pieces of cattle), 94.30 ha in total

The data collected through the interviews were then used to feed into the model computing and visualizing processes in soil. Namely the models Cool Farm Tool, model on the flow of nutrients and model on nitrate leaching were used.

The data input for the model on nutrient flow shown in Table 1 was structured as such:

Table 1 Data input for the model on nutrient flow

			Main product		**By-product**		**Application of manure**		**Nutrient consumption in mineral fertilizers**		
n.	**Type of crop**	**Area sown (ha)**	**Total yield (t)**	**Average yield**	**Taken away (ha)**	**Left in field (ha)**	**Appli-cation**	**Of which on arable land**	**Tones N**	**Tones P2o5**	**Tones K20**
1	Alfalfa	6,0	16,2	2,7		6,0	2618,0	2618,0			
	Oats	7,0	11,2	1,6	7,0	0,0					
	Temporary grassland	87,5	236,3	2,7		87,5					
	Permanent grassland	35,5	95,9	2,7		35,5					
2	Wheat	250,0	1500,0	6,0	229,0	21,0	1000,0	1000,0	50,6	4,5	4,5
	Rapeseed	100,0	300,0	3,0		100,0					
	Silage maize	100,0	4000,0	40,0		100,0					
	Alfalfa	124,0	1240,0	10,0		124,0					
	Temporary grassland	6,0	30,0	5,0		6,0					
3	Wheat	250,0	1125,0	4,5	150,0	100,0	31228,0	31228,0	87,6	24,8	24,8
	Rapeseed	200,0	620,0	3,1		200,0					
	Silage maize	300,0	7200,0	24,0		300,0					
	Alfalfa	100,0	800,0	8,0		100,0					
	Temporary grassland	148,6	1040,2	7,0		148,6					
4	Wheat	692,5	5193,8	7,5	461,6	230,9	17499,0	15459,0	272,5	38,6	38,6
	Rapeseed	550,4	1981,4	3,6		550,4					
	Silage maize	237,9	11419,2	48,0		237,9					
	Temporary grassland	32,6	166,3	5,1		32,6					

			Main product		By-product		Application of manure		Nutrient consumption in mineral fertilizers		
n.	Type of crop	Area sown (ha)	Total yield (t)	Average yield	Taken away (ha)	Left in field (ha)	Application	Of which on arable land	Tones N	Tones P2o5	Tones K20
	Permanent grassland	875,8	4466,6	5,1		875,8					
5	Temporary grassland	15,5	83,5	5,4		15,5					
	Permanent grassland	2,7	14,9	5,5		2,7					
6	Wheat	10,0	35,0	3,5		10,0	150,0	150,0	0,8	0,3	0,3
	Barley	7,0	24,5	3,5		7,0					
	Grass with clover	4,0	17,2	4,3		4,0					
	Fescue	18,0	12,6	0,7	18,0	0,0					
	Temporary grassland	33,0	141,9	4,3		33,0					
	Permanent grassland	23,0	98,9	4,3		23,0					

The model on nitrogen required different set of data, which were structured as follows:

Field water capacity

- 0,31 cm^3/cm^3 value for loamy soils

Harvest index

- Rapeseed 0,4 (Prof. Ing. Andrej Fábry, DrSc., Česká zemědělská univerzita v Praze, 2001)
- Wheat 0,4-0,6 (Chloupek, 1995)
- PG 0,9 (value for modelling 0,6)
- Silage maize 0,9 (value for modelling 0,6)

Depth of roots (Svoboda, P., Haberle, J., 2014)

- Wheat 90-140 cm
- Spring wheat 80-115 cm
- Maize 90-145 cm

- Rapeseed 95-135 cm
- Poaceae grasses – 1,5m (ZF JČU)

Average yield according to agriculture norms

- Wheat 6t
- Barley 5t
- Rapeseed 3,2t
- Maize 40t (value for modelling 10t)
- Grassland on arable land 5,2t (2014, VURV), PG 3,8t

The need for nitrogen (Klír, 2007)

- Wheat 24,3 kg/t --- 145,8 kg/ha
- Barley 20,1 kg/t --- 100,5 kg/ha
- Rapeseed 48,0 kg/t --- 153,6 kg/ha
- Maize 3,7 kg/t --- 148 kg/ha (for 10t yield)
- Grassland on arable land 26,8 kg/t, PG 19,9 kg/t --- 139,4 kg/ha, 75,6 kg/ha

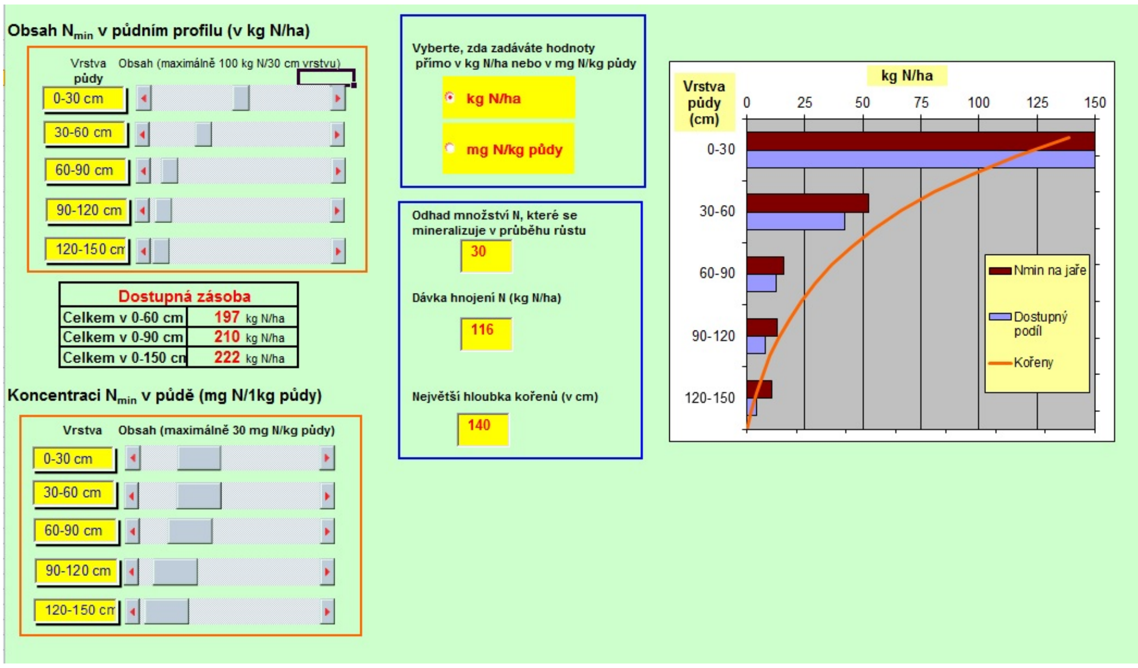
Estimation of mineralized nitrogen

- 30 kg/ha for HPJ 12 (Klír, 2007)

Effective rainfall (surface runoff)

- Referential value 10cm used for all crops

The data was then put in the nutrient run off model as shown in Figure 5.



Obsah N_{min} v půdním profilu (v kg N/ha)

Vrstva půdy — Obsah (maximálně 100 kg N/30 cm vrstvu)

0-30 cm

30-60 cm

60-90 cm

90-120 cm

120-150 cm

Dostupná zásoba	
Celkem v 0-60 cm	197 kg N/ha
Celkem v 0-90 cm	210 kg N/ha
Celkem v 0-150 cm	222 kg N/ha

Koncentraci N_{min} v půdě (mg N/1kg půdy)

Vrstva — Obsah (maximálně 30 mg N/kg půdy)

0-30 cm

30-60 cm

60-90 cm

90-120 cm

120-150 cm

Vyberte, zda zadáváte hodnoty přímo v kg N/ha nebo v mg N/kg půdy

● kg N/ha

○ mg N/kg půdy

Odhad množství N, které se mineralizuje v průběhu růstu: 30

Dávka hnojení N (kg N/ha): 116

Největší hloubka kořenů (v cm): 140

Figure 5 Preview of the model, data for wheat.

The data input for the Cool Farm Tool, the model destined to determine the carbon sequestration, was structured in a slightly different manner:

- Yields per hectare were determined based on agriculture norms
- Soil characteristics: medium (this was the prevailing soil type, according to the data it represents around 56,9% of arable land in Czech Republic, the area with both fine and coarse soil type is around 20%)
- Amount of organic matter in soil between 1,72% to 5,16%, a dry spell during the year, good water capacity and pH between 5,5 to 7,3
- The percentage amount of land with no tillage during the year: 30% (according to the data acquired from case studies), the period for land use change is 5 years
- Cover crop (the use of cover crop decreases the carbon footprint) – no input
- Fuel consumption for transport and field operations” the consumption was calculated based on agrotechnical operations (the mechanization used and a number of operations per crop). Information about the average agrotechnical procedure was transcribed from the agriculture norms and they were revised as according to the information from the case studies and consulted with agronomists
- Electric energy consumption and other type of energy consumption in buildings adhering to the farm were not included in the model

- Fuel consumption for transport outside of the farm: according to the data acquired from the case studies, weight of the cargo and the average transport distance was used. The strive to cut down the costs can be reflected by the relatively short transport distances (around 30km)
- The amount of straw left on the field was determined to be 2 tonnes per hectare, for permanent grasslands this is 0,5 tonnes per hectare
- The price for one tonne of hay was established to be 1038 CZK

Sensitivity analysis

Some parameters have a more significant impact on the carbon footprint. These are:

- Change of land use from arable land to permanent grassland
- Lowering tillage intensity (for example when a tilled area goes under low tillage management) on larger scale
- Long-term fertilization with farm manure (the model then indicates a lower carbon footprint)
- With a more frequent use of mineral fertilizers, pesticides and number of field operations including transport the carbon footprint increases
- Management of crop residues has an impact on the greenhouse gas emission

Determining the price for carbon sequestration

There are several ways how to determine the costs related to carbon emissions. The so-called Social Cost of Carbon (SSC) might be used for assessing the value of carbon sequestration in ecosystems, since those very ecosystems contribute to climate change mitigation. Social cost of carbon is the cost of each tonne of carbon dioxide which is being emitted as a consequence of climate change. This social cost is evaluated according to the integrated models for economics of climate change.

In terms of this dissertation, the assessment for SSC which is recommended by the US Environmental Protection Agency (EPA) shall be used. This assessment is regularily used in science studies focusing on the role of ecosystems in carbon sequestration and climate change mitigation. It is also used for the purposes of the Regulation Impact Assessment in the US.

For determining the social cost of carbon, the values presented in the study on the evaluation of the ecosystem of permanent grassland biodiversity and its role in carbon sequestration shall be used (Hungate et al., 2017). The values used in the study derive from the EPA recommended values based on carbon dioxide emission and the molecular weight of carbon. The final values determine the social cost of carbon for one tonne of carbon emitted.

The calculation from the US based methodology was done by using the exchange rate and determining the difference in purchasing power parity as according to OECD indexation.

Production function

The production function of agricultural land shall be determined through a simple method of direct market value. Therefore, for each selected crop a total average yield per hectare shall be established together with a determination of the average market value for given year. The combination of the two elements should give the desired value. After the application of weighting factors, an average value for production function in the Czech Republic could also be established.

Soil erosion

The assessment of yearly soil loss due to soil erosion shall be done with the help of ArcGIS software. The soil erosion shall be calculated per crop type to evaluate the differences in crop management. For these purposes, the data from LPIS (Land Parcel Identification System) shall be used – in this system, all farmers have to put in the information on what type of crop they are growing on which part of the land. This will help to assess the average soil erosion per crop type in the municipality with extended powers Třebíč. The ecosystem service associated with soil will be determined based on the costs for cleaning the soil run-off from water bodies.

The average annual loss of soil due to erosion was calculated for those blocks with selected crops based on the data received from LPIS. The data was requested from the paying agency under the Czech Ministry of Agriculture. The entry values for the annual yearly loss were calculated based on the data from 2017, so therefore in this regard data from this year are the most relevant. To assess the trends the soil erosion was calculated also for years 2015, 2016 and 2018 – the placement of soil blocks with type of crop is unique for each year yet the entry data for erosion remain the same.

Based on the nature of the data provided (tables and not shapefiles), a corrective calculation had to be done for those soil blocks where more than one crop was grown. On these blocks, an average soil erosion was calculated for the whole block and not only for the part designated to the crops in question. Yet this correction only represents 5% of the data between the four years and therefore does not affect the final average value.

The ArcGIS software was used for the calculation and the primary tool was the zonal statistics for the vector shapefiles of LPIS and the soil loss was assessed based on the raster data for water erosion G.

Costs connected to soil erosion

When determining the ecosystem service (or in this case the obvious disservice) for prevention of soil erosion, one has to consider all the costs related to this service. Average soil loss determines the amount of fertile land which is lost. The next thing that happens is that this soil contaminates the water and is being swept away in the river flow. By default, the nutrients which are embedded in the soil are lost. Therefore, we first need to determine the price of these nutrients. Next is the price of the soil itself. As the soil which has been run off from the field contaminates the water and builds up in the nearest water body, the costs for clearing up the water body have to be considered together with the costs for transporting the soil and storing it in a landfill.

The price of nutrients can be assessed from the average volume of nutrients in a tonne of soil, as shown in Table 2, and the market value of these nutrients.

Table 2 Volume of nutrients in one tonne of soil

Nutrient	**Volume of nutrient (Kg/t soil)**		
	Low volume	**High volume**	**Average volume**
Nitrogen	6,7	26,6	16,7
Potassium	17,8	88,8	53,3
Phosphorus	6,7	28,9	17,8
Magnesium	13,3	68,8	41,1

Source: Kapler et al. 2008

The price of nutrients was determined from the market value of fertilizers found online on the websites of agriculture resellers. For the purposes of this research, the price for 1 kg of nitrogen, phosphorus and potassium is 58 CZK/kg, magnesium 31,2 CZK/kg (as according to http://www.agrozetaservis.cz/aktualni-cenik-zemedelskych-hnojiv and http://www.compo-agroefekt.cz/images/cenik2017.pdf). This means that in one tonne of soil the overall price of nutrients is as follows: Nitrogen 968,6 CZK, Phosphorus 1032,4 CZK, Potassium 3091,4 CZK and magnesium 1282,3 CZK which is altogether 6374,7 CZK.

Since the soil that has run off the field builds up in the nearest water body down the stream, we need to take into consideration the costs for the clearing up the water body and draining up the mud. In this model example, we will consider that the soil cannot be returned to the field but will be moved to a landfill. Therefore we will consider the costs for moving the drained mud to the landfill and also the cost of buying new soil to be returned to the field.

According to the official overview from the Nature Conservation Agency of the Czech Republic, to clear up 1 square meter of mud costs 300 CZK (http://www.dotace.nature.cz/informujeme-vas/naklady-obvyklych-opatreni-mzp-na-rok-2019.html). To move the material to a landfill which would be one kilometre away would cost additional 70 CZK per square meter, which is therefore altogether 370 CZK per square meter. According to the norms, moist soil has the density of 2000 [Kg/m3] which means that one square meter of soil weighs two tonnes (http://www.agronormativy.cz/docs/rpttab5020001.pdf). Therefore to clear up and move one tonne of soil costs 185 CZK. The price of soil itself can be deduced from the offer on the market. After comparing several offers on different websites, the average price of one tonne of soil was established to be 158 CZK.

When regarding the overall costs for the nutrients, clearing up water bodies and new soil, the final established cost is 6832,4 CZK per tonne.

Analysis of land parcel size

For a significant part of the degradation processes on soil the size of a land parcel is a significant element (as it also indicates the slope length) and therefore it is important to assess how large land parcels are in the municipality with extended powers Třebíč. The LPIS was used to evaluate the size land parcels of arable land. The following analysis was performed with LPIS data on soil for the municipality with extended powers. Only those land parcels, which at least partially fall into the relevant area, were selected and of those only those with cultivated arable land were included in the final selection. Subsequently, a value of 95% quantile of land parcel size was determined, indicating the 5% of the largest land parcels in the study area.

For comparison purposes, an analysis was made for the whole Czech Republic district by district. For the whole CR the limit of 5% for the largest land parcels with arable land is 41.7 ha (a total of 235 125 land parcels were analysed).

5.3.3. Research question 3 – agricultural land lost due to urban sprawl

The answer to research question three, the number of hectares of agriculture land lost due to urban sprawl were determined via a collection of data from the Czech Statistical Office and from the State Administration of Land Surveying and Cadastre. As the data provided by the Czech Statistical Office only comes per district, while the data from the State Administration of Land Surveying and Cadastre is defined for the municipality with extended powers, an extrapolation was made and these two sets of data were compared. For the analysis of the future situation, the data from spatial plans of all individual villages are used in order to determine what rate of area is designated for construction and what the current land use of these areas is. This analysis was be executed in ArcGIS.

5.4. Study area

The research is conducted for the area of the municipality with extended powers Třebíč. The total area of this municipality is 83 773 ha and comprises of 93 villages and their cadastral areas. Agriculture land in this municipality makes up for 64,1% of the total area.

5.4.1. Description of study area

The study area in question is the territory of the administrative district of the municipality with extended powers Třebíč.

The total area is 83 773 ha.

Basic data on the population, the size of individual municipalities as well as the proportion of non-urbanized areas in the area of Třebíč is shown in Table 3 below.

Table 3 Description of study area

Name of municipality	N. of inhabitants	Area (ha)	Rate of non-urbanized area (%)[1]
Bačice	202	532,5	94,73
Benetice	191	491,0	92,44
Biskupice-Pulkov	268	1184,3	94,69
Bochovice	154	584,7	94,33
Bransouze	236	515,3	81,19
Budišov	1204	1330,4	92,40
Čáslavice	544	1019,6	91,62
Čechočovice	294	393,9	88,60
Čechtín	310	634,2	94,02
Červená Lhota	187	739,9	90,91
Číhalín	204	634,0	94,56
Číchov	232	956,5	91,39
Číměř	197	434,1	90,77
Dalešice	604	1137,8	94,79
Dolní Vilémovice	393	990,8	94,78
Dukovany	862	2036,7	90,66
Heraltice	363	702,4	95,49
Hodov	305	1021,5	94,82
Horní Heřmanice	139	494,1	95,04
Horní Smrčné	49	332,7	93,04

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[1] The rate of non-urbanized area is the reversed ratio of all urbanized area against all other area in the SO ORP

Name of municipality	N. of inhabitants	Area (ha)	Rate of non-urbanized area (%)[1]
Horní Újezd	268	716,5	93,33
Horní Vilémovice	80	976,3	95,47
Hrotovice	1770	2091,5	95,03
Hroznatín	109	390,7	91,33
Hvězdoňovice	102	259,8	91,89
Chlístov	290	377,0	88,48
Chlum	157	692,7	93,55
Jaroměřice nad Rokytnou	4181	5137,1	93,12
Kamenná	209	610,7	92,68
Klučov	173	728,1	95,62
Kojatín	80	448,2	94,94
Kojetice	446	465,0	89,41
Koněšín	513	1124,2	93,20
Kouty	382	833,5	94,68
Kozlany	142	312,1	92,23
Kožichovice	409	1064,5	90,59
Krahulov	272	488,1	87,97
Krhov	193	660,2	96,37
Lesůňky	83	348,7	94,66
Lipník	390	514,1	91,01
Litovany	131	664,5	95,82
Loukovice	113	347,8	95,05
Markvartice	269	320,3	88,15
Mastník	240	529,8	93,88
Mikulovice	220	418,2	93,82
Myslibořice	722	1122,3	94,45
Náraměč	348	785,9	94,68
Nová Ves	243	434,8	89,30
Nový Telečkov	103	367,5	93,87
Odunec	92	598,4	96,34
Okřešice	184	581,6	95,01
Okříšky	2058	656,7	83,53
Opatov	769	1900,7	93,54
Ostašov	135	213,3	94,43
Petrovice	422	618,7	93,23
Petrůvky	121	386,5	91,82
Pokojovice	102	178,4	93,50
Pozďatín	157	572,4	93,04
Přeckov	67	460,5	91,07
Předín	699	1510,6	95,75
Přešovice	141	675,2	95,62
Přibyslavice	815	614,6	86,70
Příštpo	269	1442,5	94,32
Pyšel	473	1177,2	92,22
Račice	81	360,8	95,74
Radkovice u Hrotovic	316	1529,9	96,82

Name of municipality	N. of inhabitants	Area (ha)	Rate of non-urbanized area (%)[1]
Radonín	77	398,3	95,41
Radošov	168	640,7	94,95
Rohy	115	639,4	95,55
Rokytnice nad Rokytnou	862	807,5	92,38
Rouchovany	1187	2477,0	92,08
Rudíkov	708	706,6	91,02
Římov	414	915,6	94,46
Slavětice	238	950,4	91,34
Slavičky	267	905,3	92,50
Smrk	271	679,8	93,73
Stařeč	1636	1541,5	91,65
Stropešín	123	689,5	96,28
Střítež	523	757,3	93,34
Studnice	141	389,8	95,45
Svatoslav	248	1929,0	96,44
Šebkovice	474	1073,1	94,12
Štěměchy	303	996,2	95,81
Trnava	689	1238,7	89,49
Třebenice	445	1167,3	95,17
Třebíč	36330	5759,1	82,33
Valdíkov	112	584,1	93,88
Valeč	787	1069,6	94,61
Vladislav	1181	1849,8	91,69
Vlčatín	138	476,7	94,97
Výčapy	866	1333,3	94,08
Zárubice	116	552,2	96,49
Zašovice	119	340,3	90,11

Source: Czech Statistical Office, 2018

5.4.2. Basic physical features of the study area

From the view of primary landscape structure, the area of the municipality with extended powers Třebíč can be divided in two different areas very different in their characteristics – the south and the north. The north can be characterized by colder and wet climate, a highland character, larger share of forests, typical structure characteristic for the Czech-Moravian highlands of villages placed by small river basins and valley ends. On the other hand, the south part of the area can be characterized by a drier and hotter climate and a different topography which is closer to the South Moravia.

5.4.2.1. Climate conditions

The municipality with extended powers Třebíč falls under the mildly war climatic area (Quitt, 1977). It can be characterized by a steady transition from wetter and rougher climate (MT3) to climate units MT5 and MT9 all to the way to the most dry and warm climate unit MT11 in the southeast of the area. Important part in this climate division is played by the valley of Jihlava river, which serves as a way for the warmer climate to transmit itself to the rougher climate in the west. The coldest part of the area is represented by the west of the Brtnice highlands around Předín, Opatov a Štěměchy in the middle west part of the area and the surroundings of Svatoslav a Čechtín in the northern part of the area. A considerable part of Jaroměřice basin which is connected to higher parts of Jevišovice highlands in the south and Bíteš highlands in the north falls under the climate unit MT5. The lowest parts of the geomorphological regions in the south and northeast border of the area falls under climate unit MT9. Climate unit MT11 comprises of northern part of the Znojmo highlands and covers the southern part of the area in the direction of river Jihlava all the way to the western border of the city Třebíč.

The average yearly temperature depends on the geomorphological region and varies between 6,5°C in the Brtnice region, 7°C in Bíteš highlands, 7,5° in Znojmo highlands and 8,0° on the borders with the Znojmo region. The coldest month is January while the warmest one is July. The average yearly precipitations are around 550-575 mm in the Znojmo highlands and Jaroměřice basin while in the Bíteš highlands and Jemnice basin it can be around 600 mm and in the highest part of Brtnice highlands even 650 mm. The month with most rainfall is July with an average of 80-90 mm of precipitation and the driest month is usually March with 25-35 mm of precipitation. The area is specific with cold winds from autumn to spring connected also to local and regional inversions in deep river valleys and river basins. The predominant flow of winds is west to northwest while in the winter the flow is mostly east to south east.

5.4.2.2. Hydrological characteristic of the area

The municipality with extended powers Třebíč belongs to the drainage area of the Black sea. The main water course in the area is the Jihlava river which with its tributaries Oslava and Rokytná river drains most of the area. The Jihlava river flows into the area close to the village Bransouze and leaves it around the Mohelno dam. The southernmost part of the area and the Želetavka and Jevišovka rivers belong to the catchment area of the Dyje river. The area is made up mostly by small springs which flow to the Jihlava, Oslava and Rokytná rivers and subsequently to the Danube.

Most of the area of municipality with extended powers Třebíč falls under the catchement area of Jihlava, Rokytna and Oslava rivers. The total number of water sources flowing through the area is 783 and the largest concentration of water surfaces can be found in lower altitudes and in the western part of the Znojmo highlands. The region of Třebíč also lies in the rain shadow of the Czech-Moravian highlands and this influences the water levels of rivers as well. It also creates shortages of groundwater and influences the fish breeding production.

There are two major dams in the area of Třebíč, which are the Dalešice and Mohelno dams. They serve for recreational purposes but mostly feed the Dukovany nuclear power plant.

The municipality with extended powers Třebíč also has a number of local sources of groundwater, for example in the Heraltice-Hvězdoňovice. The dams Lubí and Nový rybník serve as sources of surface water while drinking water is brought in from neighbouring areas, from the Vranov dam and Mostiště dam. There are two sources of mineral water in the area as well - hydrogen sulphide mineral water in Okrašovice and sparsely used mineral water spring of the same type in Pozďátky. The valley of the Brtnice River also carries witness to medieval panning and gold mining.

5.4.2.3. Geology and geomorphology

In the municipality with extended powers Třebíč there are two main geological units, the so-called moldanubicum, made up of heavily converted rocks, and the Třebíč massif with deep rock falls. These are, to varying degrees, covered by unpaved deposits of Tertiary and Quaternary ages. There are no known deposits of mineral resources in the area except of stone. Dominant is the relatively old Třebíč massif, which originated in the Paleozoic and breaks through the surrounding crystalline slate, forming its rocks formed by the melt (magma) at a depth of about 12 km. The Třebíč massif is formed by characteristic gulosyenites, which also represent the main rock form of the Třebíč massif. There are outcrops of the Třebíč massif on the left bank of Jihlava in the northern part of the territory. Characteristic for this part of the area are boulders and small rocks, which are the cause of the characteristic structure and texture of the agricultural landscape and the cause of the picturesque expression of the northern part of the territory. The massif in the valley of the Jihlava River in Třebíč is in the east-west direction called the Třebíč shift.

The gulosyenite of the Třebíč massif represented a valuable building stone (the so-called Trnava or Třebíč granite) during history, from which a whole number of objects were built – for example some farms or the basilica of St. Prokop in Třebíč. The Třebíč massif is also characterized by high natural radioactivity due to the content of uranium, thorium and radioactive isotope of potassium.

Tertiary rocks represent the remains of tropical weathered rocks, corresponding to then-location of Třebíč near to the equator. These are mainly colourful clay with opals, quartzite residue or iron sand sediments. The remains of the shallow sea can be found in the territory, as a reminder of the younger Tertiary, as well as the sediments of freshwater origin with the well-known natural glasses - moldavites. Unlike the quaternary quarries in the area, clay is represented by clay-stony sediments on slopes and loess with calcareous stones (so-called cysts). The bones of wild horses, rhinoceroses, mammoths, etc. were found in the loess. The Jihlava an Oslava valley are filled with young clay and clay fillings. Small anthropogenic sediments, such as pond dams, road embankments, have been created by humans.

In terms of geomorphology, the area belongs to the Czech-Moravian System and the Czech-Moravian Highlands sub-system. It has typical features of the georelief on the old transformed and burnt rocks of the Hercyn base of the Czech Highlands. The basic feature is the difference between the platforms and the rounded ridges on the one hand and the recessed river valleys on the other side. The hilly and highland georelief is predominant.

Two geomorphological units, the higher Křižanov highlands in the west and the north, and the lower Jevišovice highlands in the middle, east and south, interfere with the area.

Jevišovice highlands is represented by:

- Jaroměřice basin and its districts:

o Moravskobudějovice basin

o Old highlands

o Třebíč basin

- The Znojmo highlands and its districts:

o Hrotovická hora

Mohelen Highlands

o Myslibořice spine

o Náměšť lowlands

o Tavíkovice highlands

Křižanov highlands is represented in the area by:

- Brtnice Highlands and its districts:

o Čechtin highlands

o Markvartice highlands

o Puklice highlands

o Zašovice ridge

- Bíteš Highlands and its districts:

o Velké Meziříčí highlands

o Jinošov highlands

o Pyšel ridge

The area is dominated by hills, only in the northern part predominates the character of the highlands. The difference in the landscape of the northern part and the southern part of the territory is well visible, influencing the arrangement of the landscape and its overall character. The valleys of watercourses are higher in the upper parts, the corridors are noticeably smaller and the relief is also the reason for the settlements in the landscape. Relief in the northern part in many places affects the possible development of settlements. The southern part of the territory, with the exception of the closed valleys, allowed for more intensive forms of agriculture on large areas, typical of which are large blocks of arable land, which completely deny the original historical arrangement of the plow. The countryside in the southern part is afforested much less.

5.4.2.4. Pedology and pedogeography

In the municipality with extended powers Třebíč, the most represented soil type is brown soil. In the northern part of the territory, cambisol prevails on acidic and neutral rocks. They are alternately the dominant or accompanying component of the luvisol and brown soil on the agricultural land. In mildly humid places under the permanent grasslands there is a pseudogley cambisol, which turns in wet places into pseudogley. The loess in the eastern and south-eastern parts of the territory predominate in Illimeric soils, typical of brown soils, loess, loess and polygenetic soils.

Hydromorphic soils in the area represent pseudogley on polygenetic soils. The largest number is visible in the south-east and south-west of Třebíč, further in the area towards Moravské Budějovice. Permanently wet locations around the streams and smaller rivers (Bihanka, Olešná, upper stretches of Rokytná, Zeletavka, Jevišovka etc.) and around numerous ponds (Vidlák, Dubovec, Netušil, Pyšelák etc.) are covered with a typical gley. The valleys of Jihlava, Rokytna, Rouchovanka and Oslava rivers are accompanied by fluvizem and glanded soils created on carbonated sediment. Arable land occupies a total of two thirds of total deforestation.

5.4.2.5. Biogeography

The municipality with extended powers Třebíč is divided into two bioregions of Jevišovický and Velkomeziříčský. Jevišský bioregion forms the marginal hillside of Hercynik in the west of South Moravia. It includes mainly the southern part of the territory. The bioregion is characterized by a relatively warm and dry hillside with rocky valleys. There are oak-horn groves here, in the valleys is the mosaic of oak-horn groves, acidophilous oak forests, sub-oerophilous oak forests and relict pines, lesser oyster oak forests and rocky forest steeples. The edges form the higher parts of the islands of flowering beech trees and the absence of sub-oerophilic oak forests, which make up the transition to the Velkomeziříč bioregion in the northern part of the area.

The large-scale bioregion is characterized by a small ragged, raised, planar surface, without the occurrence of a thermophilous biota, with uneven surfaces of beech beeches, on more rugged places with bee-flowing islands. The transition edge of the bioregion forms a lower, warmer, drier, territory with predominantly acidophilic oak woods, in valleys of larger streams and with oak-horn groves.

In the territory of municipality with extended powers Třebíč, following habitats can be found:

In the 2nd vegetation level in dry areas:

- Pronounced valleys with serpentinites
- Eroded platforms on acid metamorphites
- Eroded platforms on bright metamorphites
- Pronounced valleys on acid metamorphites
- Loft platforms in dry areas

In the 3rd vegetation level in humid areas

- Wet platforms on acidic rocks
- Eroded platforms on serpentinite
- Erosion platforms on acidic plutonite
- Submerged lowlands on acidic rocks

In the 3rd vegetation level in dry areas

- Pronounced valleys in acid metamorphites

- Eroded platforms on acid metamorphites
- Pronounced valleys in bright metamorphites
- Platforms on loess
- Eroded platforms on bright metamorphites
- Platforms on acid metamorphites
- Pronounced valleys in neutral plutoniums
- Eroded platforms on neutral plutonites

In the 4th vegetation stage in the humid area

- Highlands on acidic metamorphites
- Uplands on neutral plutoniums
- Uplands on acid plutonite
- Uplands on acidic metamorphites
- Eroded platforms on neutral plutonites
- Eroded platforms on acid metamorphites
- Eroded platforms on bright metamorphites
- Submerged lowlands on acidic rocks
- Slopes on acidic metamorphites

In the 4th vegetation stage in dry areas

- Pronounced valleys on acid metamorphites
- Pronounced valleys on neutral plutoniums
- Eroded platforms on neutral plutonites
- Eroded platforms on acid metamorphites
- Uplands on acidic metamorphites
- Uplands on neutral plutoniums
- Uplands on bright metamorphites

In the 5th vegetation level in wet areas

- Eroded platforms on acid metamorphites
- Uplands on neutral plutoniums
- Submerged lowlands on acidic rocks
- Ridges on acidic metamorphites

5.4.2.6. Agriculture

Agriculture plays an important role in the countryside, as farmers are often the only people who actively work with the landscape and live in rural areas. The agricultural nature of the landscape is determined mainly by the structure of cultivated crops (depending on whether standard arable land, permanent grassland or permanent crops such as vineyards and orchards dominate), the structure of land parcels (whether there is a mosaic of smaller land parcels or larger ones) and structure of agricultural holdings (a bigger number of small owners vs. smaller number of large agricultural cooperatives). The conditions for agriculture are also given by less favored areas (LFA). Otherwise, in the municipality with extended powers Třebíč the overall agricultural conditions are close to the average in the CZ with the potato-growing agricultural production area prevailing (Křižanov highlands, Jevišovice highlands) while in the southeast there is also a more fertile beet area.

The current structure of the municipality with extended powers Třebíč in terms of land-use is described in the following Table 4. The agricultural land (according to www.risy.cz) represents 64.1% of the total area of SO ORP and consists of predominantly arable land (85.4%) and permanent grassland (13.5%) as recorded in the LPIS database. Other cultures are represented only marginally. However, all agricultural land is not recorded in the LPIS database, for example, small fields for small trees, small vineyards, orchards and gardens, so the total area of agricultural land according to LPIS as shown in Table 5 differs from that listed in the database which can be found at risy.cz. Forest play an important role as they cover about 26.8% of the area.

Table 4 Land-use in the municipality with extended powers Třebíč

	area (ha)	**% of area**
Agriculture land	53 660	*64,1*
Forest	22 404	*26,8*
Urban area	1 161	*1,4*
Water flows and surfaces	1 424	*1,7*

	area (ha)	**% of area**
Other	5 093	*6,1*
SO ORP Třebíč	**83 743**	***100,0***

Sourcej: www.risy.cz

Table 5 Type of agriculture land in the municipality with extended powers Třebíč according to LPIS database

Type of landuse - LPIS	**area (ha)**	**% of area**	**N. of land parcels**
Arable land	41 509	85,4	4 570
Permanent grassland	6 549	13,5	2 727
Grassland on arable land	366	0,8	283
Other permanent crops	52	0,1	50
Afforested area	49	0,1	67
Nursery	44	0,1	24
Short rotation coppice	17	0,0	23
Land lying fallow	12	0,0	9
Vineyard	5	0,0	8
Orchard	5	0,0	4
Sum	**48 607**	**100,0**	**7 765**

Source: LPIS on 22.7.2017 (MZe ČR)

Evolution since 2003 shows that there is a slight but systematic decline in agricultural land (at about 10% per year).

Agriculture land in terms of ownership

According to the LPIS database as shown in Table 6, there are all together 490 owners of agriculture land in the municipality with extended powers Třebíč. Amongst the largest owners belong: Agriculture cooperative Okříšky, Budišov and Výčapy (each of them farm approximately 5% of land).

Table 6 Agriculture land in terms of ownership

Owner	**Area of registered land parcels**	
	ha	***%***
Agriculture cooperative Okříšky	3 101	*6,4*

Owner	**Area of registered land parcels**	
	ha	***%***
Agriculture cooperative Budišov	2 608	*5,4*
ZD Výčapy, cooperative	2 270	*4,7*
Agriculture cooperative Hrotovice	2 243	*4,6*
Agriculture cooperative Kožichovice	2 115	*4,4*
AGROCHEMA, cooperative	1 870	*3,8*
ZVOZD "Horácko", cooperative	1 631	*3,4*
Agriculture cooperative Kouty	1 495	*3,1*
ZD Klučov - Lhota, cooperative	1 456	*3,0*
Agriculture cooperative Biskupice	1 315	*2,7*
Agriculture cooperative Čáslavice	1 170	*2,4*
SEDUK DUKOVANY, ltd	1 131	*2,3*
KLAS Jaroměřice, ltd	1 107	*2,3*
Agriculture cooperative Stařeč, cooperative	1 103	*2,3*
Liber, cooperative	1 003	*2,1*
Cooperative Ametyst	956	*2,0*
Aleš Neuman	936	*1,9*
ADW FARM, a.s.	935	*1,9*
Agriculture cooperative "Podlesí"	919	*1,9*
DVP, cooperative	739	*1,5*
AGROOS, ltd	591	*1,2*
AgroFarm ltd	577	*1,2*
ZEPAS Rudíkov, ltd	569	*1,2*
Agriculture market cooperative, cooperative	554	*1,1*
Statek Dubinka, ltd	526	*1,1*
Antonín Kovář	467	*1,0*
Agriculture cooperative Slavice	447	*0,9*
LUBÍ ltd	437	*0,9*
MOAGRO, a.s.	418	*0,9*
Agriculture cooperative Šemíkovice	409	*0,8*
AGRO Jevišovice, a.s.	404	*0,8*
Adam Kopeček	398	*0,8*

Owner	Area of registered land parcels	
	ha	***%***
Vítězslav Škoda	384	*0,8*
Luděk Pokorný	369	*0,8*
Radek Vrbka	334	*0,7*
JARI AGRO, ltd	329	*0,7*
ZEPOS, ltd	286	*0,6*
Mgr. Iva Filippiová	263	*0,5*
Vlastimil Ferda	247	*0,5*
Vladimír Chloupek	214	*0,4*
S V P ltd	209	*0,4*
449 owners with less than 200 ha DPB	10 074	*20,7*
490 owners	**48 607**	***100,0***

Source: LPIS database on 22.7.2017 (MZe ČR)

5.5. Research limitations

There are several limitations to this research. As this evaluation is done ex-post after the agriculture land has already changed its land use type, there is no way of saying which crop has been grown on which field and what was the type of management on this land. In order to make up for this only aggregated data will be used to assess each ecosystem service. The valuation of ecosystem services in general does not provide for a targeted specific value but rather a general assessment of the predicted value of the ecosystem. For each method some limitations will be highlighted. The evaluation of land lost due to urban sprawl has also been done on aggregated data and there is no clear link saying which parcel of land has been transferred to what land use. Part of this research has been done with the help of case studies and part was done with data for the whole study area, which might influence the results as well.

6 RESULTS

6.1. Ecosystem services provided by agriculture land in the study area

The answer to this question was determined through desk research as part of the literature review. The four ecosystem services which will be researched in this dissertation are:

- prevention of water contamination,
- carbon sequestration,
- production function,
- prevention of soil erosion.

6.2. Evaluation of ecosystem services provided by agriculture land in the study area

6.2.1. Prevention of water contamination

To determine the ecosystem service for prevention of water contamination, the nutrient run-off which causes this contamination needs to be determined first. This section will present the data gained from the case studies from the two models on nitrogen leaching and nutrient flow. First the outcome from the nutrient flow model shows values for three basic nutrients in agriculture, nitrogen, potassium and phosphorus as shown in Tables 7,8 and 9, respectively.

Table 7 Results from nutrient flow model for the case studies in study area - Nitrogen

	Nitrogen (kg N / ha z.p.)				
Farm n.	**Withdrawal**	**Mineral fertilization**	**Organic fertilization**	**N fixation**	**Balance**
1	53,68	0,00	128,98	10,59	85,88
2	156,62	87,24	9,48	51,30	-8,59
3	114,50	80,43	164,91	22,05	152,88
4	127,11	114,05	42,03	0,00	28,97
5	112,65	0,00	0,00	0,00	-112,65
6	83,18	8,63	10,58	1,05	-62,92

Source: original

From the results on nitrogen balance in the soil it is clear that most nitrogen (152.88 kg N/ha) stays in soil on farm number 3, therefore on a big farm with crop and animal production. Yet the average yearly excess residue of nitrogen in soil should not exceed 60 kg N/ha. In this perspective, the only farm which can be viewed positively is farm number 4. The most negative balance of nitrogen residue in soil is on farm number 5 – small ecological farm only with permanent grassland with no fertilizers. In this case, there is significant shortage of nitrogen in soil.

Table 8 Results from nutrient flow model for the case studies in study area - Phosphorus

	Phosphorus (kg P_2O_5 / ha z.p.)				**tones**
Farm n.	**Withdrawal**	**Mineral fertilization**	**Organic fertilization**	**Balance**	**Balance**
1	15,18	0,00	77,00	61,82	8,41
2	53,20	7,76	7,76	-37,68	-21,85
3	39,54	22,74	67,95	51,14	55,67
4	48,53	16,16	17,22	-15,16	-36,22
5	30,65	0,00	0,00	-30,65	-0,56
6	23,59	2,84	6,32	-14,43	-1,37

Source: original

Table 9 Results from nutrient flow model for the case studies in study area - Potassium

	Potassium (kg K_2O / ha z.p.)				**tones**
Farm n.	**Withdrawal**	**Mineral fertilization**	**Organic fertilization**	**Balance**	**Balance**
1	62,35	0,00	146,30	83,95	11,42
2	119,39	7,76	10,52	-101,12	-58,65
3	98,08	22,74	138,07	62,72	68,28
4	92,36	16,16	35,03	-41,18	-98,39
5	131,28	0,00	0,00	-131,28	-2,38
6	93,46	2,84	12,00	-78,62	-7,47

Source: original

Soils on farm number 2 and 4 are visibly losing potassium and phosphorus every year, on the other hand the biggest input of these nutrients is on farm number 3.

Nitrogen leaching for different types of crops

The model for nitrogen leaching established what amount of nitrogen is leached per hectare per designated crop as shown in Tables 10 till 13.

Table 10 Nitrogen leaching for wheat for the case studies in study area

Amount of nitrogen in soil layer (kg/ha)	N distribution parameter in layer	Field water capacity (cm^3/cm^3)	Effective rainfall (cm)	Rate of N leaching under profile Z	Amount of N leached (kg/ha)
171,8	55	0,31	10	0,18	31,2
52,6	55	0,31	10	0,18	9,6
16	55	0,31	10	0,18	2,9
13	55	0,31	10	0,18	2,4
11	55	0,31	10	0,18	2,0
				Sum	**48,1**

Source: original

Table 11 Nitrogen leaching for barley for the case studies in study area

Amount of nitrogen in soil layer (kg/ha)	N distribution parameter in layer	Field water capacity (cm^3/cm^3)	Effective rainfall (cm)	Rate of N leaching under profile Z	Amount of N leached (kg/ha)
135,4	55	0,31	10	0,18	24,6
48,05	55	0,31	10	0,18	8,7
16	55	0,31	10	0,18	2,9
13	55	0,31	10	0,18	2,4
11	55	0,31	10	0,18	2,0
				Sum	**40,6**

Source: original

Table 12 Nitrogen leaching for rapeseed for the case studies in study area

Amount of nitrogen in soil layer (kg/ha)	**N distribution parameter in layer**	**Field water capacity (cm3/cm3)**	**Effective rainfall (cm)**	**Rate of N leaching under profile Z**	**Amount of N leached (kg/ha)**
177,88	55	0,31	10	0,18	32,3
42,8	55	0,31	10	0,18	7,8
16	55	0,31	10	0,18	2,9
13	55	0,31	10	0,18	2,4
11	55	0,31	10	0,18	2
				Sum	**47,4**

Source: original

Table 13 Nitrogen leaching for grassland for fodder for the case studies in study area

Amount of nitrogen in soil layer (kg/ha)	**N distribution parameter in layer**	**Field water capacity (cm^3/cm^3)**	**Effective rainfall (cm)**	**Rate of N leaching under profile Z**	**Amount of N leached (kg/ha)**
79	55	0,31	10	0,18	14,4
41	55	0,31	10	0,18	7,5
16	55	0,31	10	0,18	2,9
13	55	0,31	10	0,18	2,4
11	55	0,31	10	0,18	2,0
				Sum	**29,1**

Source: original

What needs to be underlined is the notion that the output shows only model values for each crop. To establish the total real value of nitrogen leaching on a farm a field experiment would need to be executed to tell the mineral nitrogen rate in soil layers. Field water capacity would then need to be established as well as the rate of nitrogen which is mineralized during growth period. Values for these inputs were established through desk research and might not reflect the situation on a farm.

Acquired data were used to evaluate what rate of nitrogen is being leached from arable land in the Czech Republic as shown in Table 14 and what is an average value for nitrogen leaching in arable land.

Table 14 Nitrogen leaching in the Czech Republic

Crop	**2016 crop area (ha)**	**Nitrogen leaching kg N/ha**	**Nitrogen leached (t)**
Wheat	839 710,5	48,1	40390,07
Barley	325 725,3	40,6	13224,45
Rapeseed	392 991,3	47,4	18627,79
Maize	241 500,0	29,2	7051,80
Grassland 2017	9 832,93	30,7	301,87
Grassland for fodder	114 093,58	29,1	3320,12
Sum	**1 923 853,56**		**82916,10**

Source: original

An average value for nitrogen leaching on arable land is 43.1 kg N/ha.

Determining the cost for water cleaning

The expenditure on cleaning the leached nitrogen from water was determined according to data obtained from water treatment plant. Detailed data on water treatment methods were acquired from plants of different capacity shown in Table 15 (small, medium and large capacity) from which the rate of water treatment expenditure on nitrogen and phosphorus cleaning was separated. It has to be noted that since these two nutrients are cleaned together in the technological process, the price for their cleaning cannot be separated.

Table 15 Expenditure on nitrogen and phosphorus cleaning per water treatment plant

	Expenditure for water cleaning in 2017 (CZK)	**Expenditure for cleaning nitrogen (CZK)**	**Expenditure for cleaning potassium (CZK)**
1 – Large water treatment plant	336,3	302,4	33,9
2 – Medium water treatment plant	340,6	306,3	34,3

3 – Small water treatment plant	366,6	329,7	36,9
Average		312,8	35,0
Total			**347,8**

Source: calculation according to water treatment plant data and price of water delivery

When combining these two aspects – the amount of nitrogen leeched per hectare and the price for cleaning the nitrogen, the final ecosystem service can be easily determined (see Table 16).

Table 16 Nitrogen leaching per crop

Crop	**Nitrogen leaching kg N/ha**	**The cost of nitrogen leached (CZK/ha)**
Wheat	48,1	16729,18
Barley	40,6	14120,68
Rapeseed	47,4	16485,72
Maize	29,2	10155,76
Fodder	29,1	10120,98

Source: original

As the table shows, when it comes to nutrient run off and especially nitrogen leaching, the agriculture land with the main types of crops provide a disservice. This means that instead of providing the service of prevention of water contamination, they enable it.

6.2.2. Carbon sequestration

The output from the Cool Farm Tool model shows these results, as by case study. The Table 17 shows how much has each of the farms contributed to carbon sequestration through changing the land use on part of the farm from arable land to temporary grassland. This was one part of the research project for the Ministry of agriculture, for which the case studies were executed – to determine, how does land use change from arable land to grassland contribute to carbon sequestration.

Types of farms as indicated in the case study description:

1 - Mixed medium sized privately-owned ecological farm

2 - Large conventional farm

3 - Large conventional mixed farm

4 - Large conventional mixed farm

5 - Small privately-owned ecological farm

6 - Small privately-owned mixed farm

Table 17 Carbon sequestration per case study in the study area

	Change of CO2 emissions after land use change	**CO2 before land use change**	**CO2 after land use change**	**Change of CO2 on the farm**	**CO2 related expenditure before land use change**	**CO2 related expenditure after land use change**	**The amount saved due to land use change**
	tonnes	**t/farm/year**	**t/farm/year**	**tonnes**	**CZK**	**CZK**	**CZK**
1	-1,59	-4,63	-18,73	14,1	-13 135	-53 120	39 985
2	-1,44	1371,75	1342,73	29,01	3 890 276	3 807 990	82 286
3	-0,593	2300,61	2149,49	151,12	6 524 536	6 095 968	428 568
4	-1,99	6947,76	6716,1	231,66	19 703 847	19 046 871	656 975
5	-2,06	-33,81	-49,58	15,76	-95 891	-140 595	44 704
6	-1,69	-80,05	-118,58	38,53	-227 021	-336 297	109 275

Source: original

The results show clear differences between farms when it comes to lowering carbon emission through conversion to grassland. The results vary between -0,59 t CO2 to -2,06 t CO2. The largest amount of carbon sequestrated was achieved by farm number 5. This was mostly due to minimum number of operations in the field, no use of fertilizers, pesticides, minimum mechanization and no transport out of the farm. Farm number 3 fared the worst amongst others and this was due to fertilizers application and larger amount of field operations and transportation.

<u>**Determining the price for carbon sequestration**</u>

The average value of carbon is based on 3% bank rate while estimating a yearly damage as a consequence of climate change until year 2050. The lower estimate for the social cost is based on 5% bank rate and the high estimate on 2,5% bank rate for aggregated impacted based on the current value. The results for these estimates are:

- Low estimate – 867 CZK
- Average estimate – 2836 CZK
- High estimate – 8272 CZK.

For the purposes of this dissertation, the average estimate shall be used.

The factors that play a role when determining how much carbon is sequestrated at a farm is the amount of fuel used or transportation mode – basically the farm management. This is closely linked to crop which is being grown at the farm. With the use of the model, the carbon sequestration per crop was determined and it was linked with the average value for social cost of carbon to establish how much does the crop contribute to the ecosystem service of carbon sequestration (see Table 18).

Table 18 Carbon sequestration per crop for the case studies in the study area

Crop	**CO_2 t/ha**	**The social cost of carbon sequestrated (CZK/ha)**
Wheat	0,82	2325,52
Barley	0,62	1758,32
Rapeseed	2,17	6154,12
Maize	0,74	2098,64
Grassland for fodder	-0,21	-595,56

Source: original

The table clearly shows that the only type of cropland that indeed does sequestrate carbon, are those grassland which are grown for fodder. The other crops only boost carbon emissions, with rapeseed faring the worst. This can be attributed to the farm management connected with the crop, the number of field operations and also the management of residues.

6.2.3. Production function

To determine the production function of each of the selected crops, the total average yield was first determined as according to the agriculture norms.

- Wheat 6t
- Barley 5t
- Rapeseed 3,2t
- Maize 40t

- Grassland on arable land (fodder) 5,2t (2014, VURV),

The average market price for each crop was also determined, for these the data from Czech Statistical Office on agriculture production was used and average was calculated as shown in Table 19.

Table 19 Market price of different crops in 2018

	2018					
Crop	**July**	**August**	**September**	**November**	**December**	**Average value**
	CZK	CZK	CZK	CZK	CZK	CZK
Wheat for food production	3917	4050	4347	4474	4479	4253,4
Wheat for fodder	3736	3813	4038	4210	4187	3996,8
						4125,1
Barley for food production	4516	4457	4710	4836	5116	4727
Barley for fodder	3468	3605	3937	4083	4033	3825,2
						4276,1
Rapeseed	9057	9166	9305	9377	9473	9275,6

Source: CSU, 2019, own calculations

The price for maize (designated for silage) was determined through desk research, the indicated price is 1000 CZK (VURV, 2106) for when the maize is destined to be used in the biogas station. The price for hay is indicated to be 1339 CZK (CSU, 2017).

To introduce a weighting factor, a total cropland in the Czech Republic was determined and the total share of the selected crops in this cropland (see Table 20).

Table 20 Weighting factors according to share of cropland in the Czech Republic

	Cropland in 2018	**Share of land**	**Share of land after extrapolation**
	ha		
Wheat	819 690	33%	41,5%
Barley	324 724	13%	16,5%
Rapeseed	411 802	17%	20,9%
Maize	223 829	9%	11,3%
Fodder	193 199	8%	9,8%
Total cropland for selected crops	1 973 244		

Total cropland in CZ	2 460 939	80%	100%

Source: CSU, 2019, own calculations

Finally, these data were combined to determine the production function per crop and the average production function in the Czech Republic, shown in Table 21.

Table 21 Average production function in the Czech Republic

Crop	**Average yield**	**Average price**	**Total production**	**Weighting factor**	**Final value**
	in t/ha	**in CZK per tonne**	**CZK/ha**		**CZK/ha**
Wheat	6	4125,10	24750,60	0,42	10281,46
Barley	5	4276,10	21380,50	0,16	3518,45
Rapeseed	3,2	9275,60	29681,92	0,21	6194,40
Maize	40	1000,00	40000,00	0,11	4537,27
Fodder	5,2	1393,00	7243,60	0,10	709,22
			Average production in CZK/ha		**5048,16**

Source: Agriculture norms, CSU 2019, own calculations

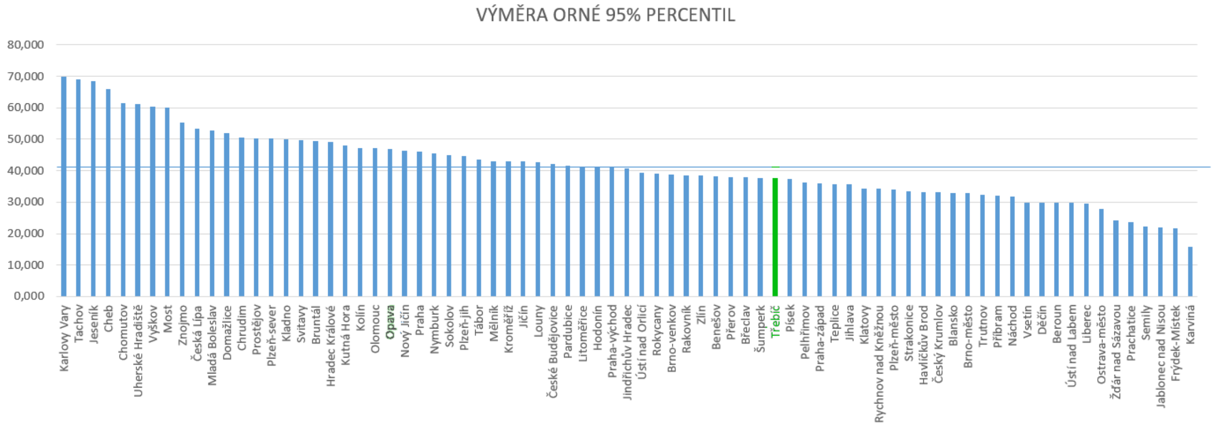
The total production function of arable land in the Czech Republic is therefore 5048 CZK, while the most profitable crop is maize, with rapeseed closely following. The least value is attributed to grasslands. For the purposes of this research, the total production value per hectare per crop shall be used.

6.2.4. Prevention of soil erosion

6.2.4.1. Analysis of land parcel size

As the size of the soil blocks plays an important role in determining the soil erosion, this needs to be addressed first. In municipality with extended powers Třebíč, the limit for large parcels of land is 37.7 ha (slightly below the national average), while the 95 percentile is 36.3 ha (a value slightly lower than the district level) – see Table 21. There are 232 land parcels with an area of more than 36.3 hectares. The largest land parcels are located variously over the entire study area. The largest ones are for example in the eastern part of the study area in Hodov, Rohy, Nárameč, in the southern part of the municipalities Rouchovany, Hrotovice, Bačice, Krhov, Lipník, Ostašov, Jaroměřice, Biskupice, Radkovice, in the western part of Opatov and Předín. The size of the two largest land parcels is 127 ha (in the cadasters of the villages Bačice, Ostašov and Lipník). On the other hand, there are many small land parcels with arable land (there are 868 land parcels of up to 1ha). The average size of land parcel is 9,3 ha, the median is 4,3 ha, the large land parcels (more than 36,3 ha) are situated mainly in lowlands, the maximum slope of these parcels is 6,0% , on average 2.7%.

Table 22 95% quantile of arable land parcel size in different districts of the Czech Republic



Source : original, 2017 based on LPIS data

The analysis shows that in municipality with extended powers Třebíč there are some parcels of arable land, which pose a potential risk for soil and water in terms of soil erosion, especially if they are located on slopes (see also Figure 6). They are also not favourable for biodiversity and can be a negative feature as regards to landscape character.

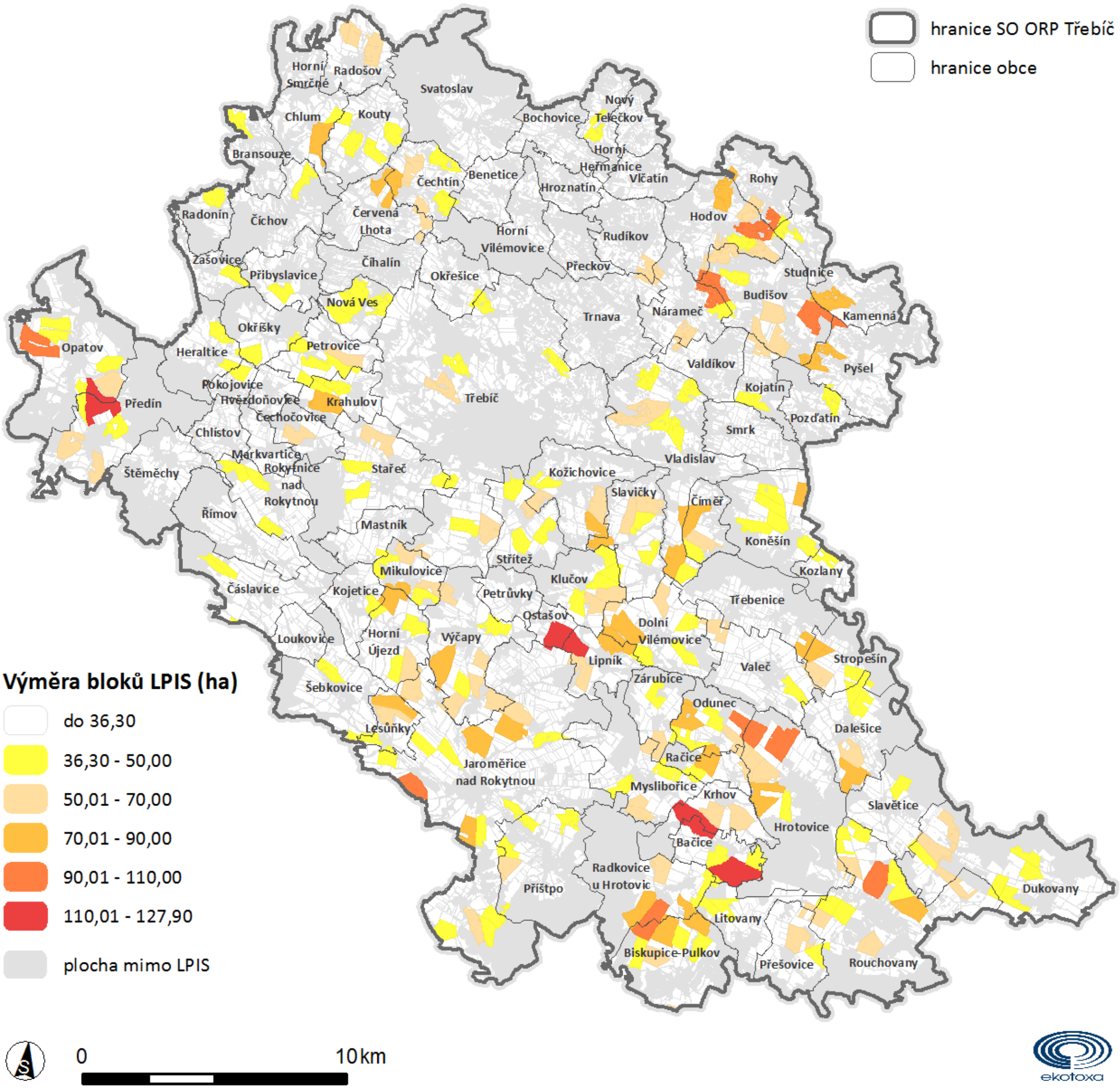


Figure 6 Parcels of arable land with more than 36,3 ha in the study area. Source: original

6.2.4.2. Soil erosion per crop type

Below in Figure 7 is a map overview of the soil erosion in the municipality with extended powers Třebíč. From this overview it is clear that the problem of erosion is not very pronounced in this municipality in comparison to the rest of the republic (the soil erosion could go well beyond 30 t/ha/year in the most endangered sites in the country as according to the Research Institute for Soil and Water Conservation) and therefore also the figures used in this research will be quite low. Table 23 shows the overview of soil erosion per crop type.

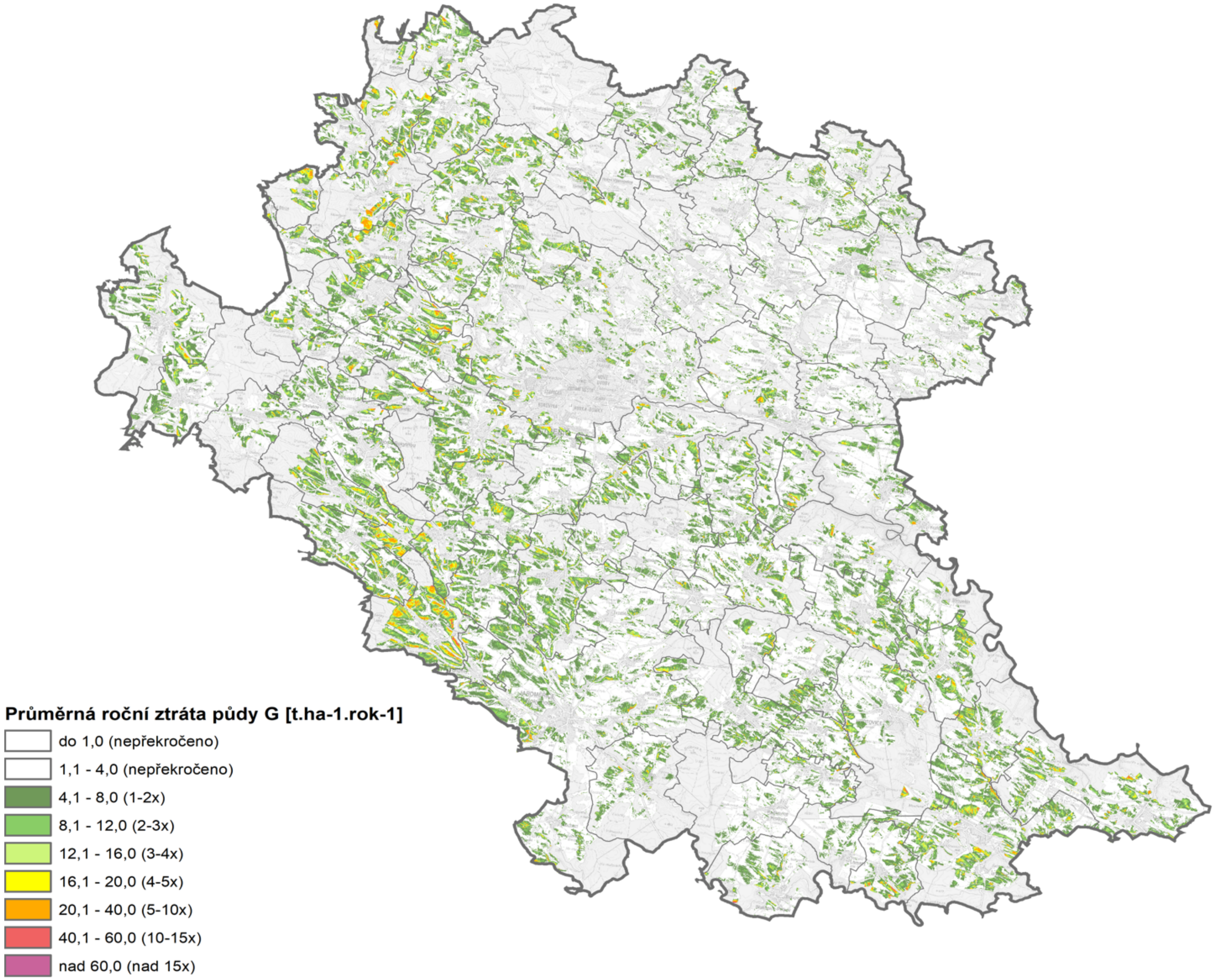


Figure 7 Soil erosion in the municipality with extended powers Třebíč. Source: original

Table 23 Soil erosion per crop type in the study area, 2015 - 2018

		2015		2016		2017		2018	
Crop	**Name of crop or culture**	**Number of soil blocks where the crop/culture is grown**	**Average annual loss of soil G [t.ha-1.year-1] on blocks with the crop/culture**	**Number of soil blocks where the crop/culture is grown**	**Average annual loss of soil G [t.ha-1.year-1] on blocks with the crop/culture**	**Number of soil blocks where the crop/culture is grown**	**Average annual loss of soil G [t.ha-1.year-1] on blocks with the crop/culture**	**Number of soil blocks where the crop/culture is grown**	**Average annual loss of soil G [t.ha-1.year-1] on blocks with the crop/culture**
Arable land	Spring barley	526	4,26	385	4,56	412	4,58	304	4,48
	Winter barley	216	4,43	292	4,04	253	4,32	301	3,9
	Clover	123	4,71	157	4,39	173	4,46	204	4,47
	Clover mixture	145	5,4	136	5,45	159	4,99	152	5,18
	Maize	450	3,94	454	4,03	462	4,09	447	4,18
	Spring wheat	93	4,57	56	5,13	98	4,54	39	3,6
	Winter wheat	1254	4,14	1296	4,29	1202	4,16	1307	4,24
	Spring rapeseed	1	2,27	2	4,88	4	5,66	1	1,79
	Winter rapeseed	564	4,37	547	4,13	664	4,09	652	4,34
	Fodder mix for northern lapwing	2	0,6	1	0,65	1	0,65	1	0,77
	Fodder mix for buffer strip	23	4,57	25	3,36	30	3,39	46	3,4

		2015		2016		2017		2018	
Crop	**Name of crop or culture**	**Number of soil blocks where the crop/culture is grown**	**Average annual loss of soil G [t.ha-1.year-1] on blocks with the crop/culture**	**Number of soil blocks where the crop/culture is grown**	**Average annual loss of soil G [t.ha-1.year-1] on blocks with the crop/culture**	**Number of soil blocks where the crop/culture is grown**	**Average annual loss of soil G [t.ha-1.year-1] on blocks with the crop/culture**	**Number of soil blocks where the crop/culture is grown**	**Average annual loss of soil G [t.ha-1.year-1] on blocks with the crop/culture**
Permanent grassland		2493	0,18	2588	0,16	2714	0,14	2801	0,15
Other		1664	3,89	1708	3,81	1814	4,15	1837	3,97

Source: LPIS, ArcGIS, own calculation

The average value of soil erosion per crop type shown in Table 24 was calculated based on the previous table.

Table 24 Average soil erosion per crop type in the study area

	2015	2016	2017	2018	Average
Wheat	4,36	4,71	4,35	3,92	4,33
Barley	4,35	4,3	4,45	4,19	4,32
Rapeseed	3,32	4,51	4,88	3,07	3,94
Maize	3,94	4,03	4,09	4,18	4,06
Fodder mix	5,06	4,92	4,73	4,83	4,88

Source: own calculation

When determining the ecosystem service (or in this case the obvious disservice) for prevention of soil erosion, one has to consider all the costs related to this service, as described in the methodology.

With the costs linked to soil erosion and loss of soil we can now easily make the calculation of the ecosystem disservice provided by different type of crops on arable land due to soil erosion, as seen in Table 25.

Table 25 The costs linked to average soil erosion per crop type in the study area

	Average soil erosion (t/ha/year)	**Costs linked to soil erosion (CZK/ha)**
Wheat	4,33	29584,292
Barley	4,32	29515,968
Rapeseed	3,94	26919,656
Maize	4,06	27739,544
Fodder mix	4,88	33342,112

Source: own calculation

From the overview, it is clear that there are only slight differences between the type of crops being grown on the field in terms of soil erosion. The crop which fares the best in this comparison is rapeseed. If we would however compare these costs to the ones linked to permanent grassland, the difference would be remarkable. The average loss of soil per hectare per year on permanent grassland is only 0,157 tonnes according to Table 23. This would mean that for permanent grassland the disservice is only 1072,6 CZK/hectare.

6.3. Agriculture land lost due to urban sprawl in the study area

As for the urban sprawl, there are different sets of data through which can the land use change be determined. There are two main sources of data – the Czech Statistical Office and from the State Administration of Land Surveying and Cadastre. There are also two different sets of area delimitation, as the study area went from being registered as a district to being the municipality with extended powers, as it is currently now. The Czech Statistical Office provides data only for the district, while the State Administration of Land Surveying and Cadastre holds data for both district and municipality with extended powers. The time period for which both of these sets of data relate to is also different. There are therefore vast differences in the data sets and to determine the final values, an analysis and extrapolation will need to be made.

According to the data from Czech Statistical Office, the area of agriculture land in the district of Třebíč has changed accordingly (see Table 26):

Table 26 Landuse change in the district of Třebíč between years 1996 and 2017

Time period	**Overall area**	**Agriculture land**	**Of which:**					**Non-agriculture land**	**Of which:**	
			Arable land	**Hopyard**	**Vineyard**	**Gardens**	**Permanent grassland**		**Forest land**	**Water surface**
2017	146277,55	93108,53	81477,11	-	5,68	2218,89	9211,93	53169,02	39596,57	2572,92
2016	146278,39	93136,31	81504,19	-	5,68	2216,28	9215,00	53142,08	39597,87	2568,94
2015	146280,94	93190,02	81564,76	-	5,68	2216,37	9207,63	53090,93	39597,11	2557,06
2014	146310,88	93235,95	81585,60	-	5,68	2214,44	9236,12	53074,93	39619,23	2545,75
2013	146305,89	93270,71	81622,18	-	5,68	2207,85	9240,23	53035,19	39621,74	2523,31
2012	146311,43	93304,19	81644,37	-	3,20	2207,93	9253,88	53007,24	39593,30	2518,35
2011	146303,79	93416,64	81722,00	-	3,00	2206,00	9290,00	52887,15	39591,00	2467,00
2010	146299,00	93462,00	81902,00	-	3,00	2206,00	9156,00	52837,00	39575,00	2454,00
2009	146296,25	93547,99	82021,14	-	3,20	2205,97	9123,36	52748,26	39564,65	2440,47
2008	146295,00	93610,00	82069,00	-	3,00	2208,00	9137,00	52685,00	39557,00	2415,00
2007	146303,00	93681,00	82146,00	-	3,00	2201,00	9136,00	52622,00	39553,00	2403,00

Time period	**Overall area**	**Agriculture land**	**Of which:**					**Non-agriculture land**	**Of which:**	
			Arable land	**Hopyard**	**Vineyard**	**Gardens**	**Permanent grassland**		**Forest land**	**Water surface**
2006	150888,00	96617,00	84426,00	-	3,00	2261,00	9729,00	54272,00	40910,00	2469,00
2005	150897,00	96724,00	84528,00	-	3,00	2252,00	9740,00	54174,00	40887,00	2455,00
2004	151880,00	97362,00	85043,00	-	3,00	2264,00	9850,00	54519,00	41202,00	2455,00
2003	151861,00	97419,00	85094,00	-	3,00	2261,00	9857,00	54442,00	41198,00	2452,00
2002	151863,00	97494,00	85166,00	-	3,00	2261,00	9859,00	54369,00	41180,00	2448,00
2001	151867,00	97565,00	85215,00	-	3,00	2258,00	9883,00	54302,00	41112,00	2442,00
2000	151857,00	97613,00	85336,00	-	4,00	2255,00	9810,00	54244,00	41091,00	2437,00
1999	151877,00	97684,00	85449,00	-	-	2255,00	9773,00	54193,00	41025,00	2512,00
1998	151886,00	97613,00	85388,00	-	1,00	2254,00	9762,00	54273,00	41027,00	2508,00
1997	151889,00	97564,00	84865,00	-	-	2238,00	10246,00	54325,00	40993,00	2525,00
1996	151883,00	97571,00	84901,00	-	-	2238,00	10215,00	54312,00	40989,00	2525,00
Change in area (ha)	**-5605,45**	**-4462,47**	**-3423,89**		**4,68**	**-19,11**	**-1003,07**	**-1142,98**	**-1392,43**	**47,92**
Change in area (%)	**-3,69%**	**-4,57%**	**-4,03%**		**468,44%**	**-0,85%**	**-9,82%**	**-2,10%**	**-3,40%**	**1,90%**

Source: Czech Statistical Office, 2018

The data from the State Administration of Land Surveying and Cadastre are presented for two different area types – for districts (from year 1994 up until 2017) and for municipalities with extended powers (from year 2009 to 2017) – see Tables 27 and 28.

Table 27 Landuse change in the district of Třebíč between years 1993 and 2017

Year	Arable land	Hopyard	Vineyard	Garden	Orchard	Permanent grassland	Agriculture land	Forest land	Water surface	Urbanized area	Other area	Sum
2017	81477		6	2219	195	9212	93109	39597	2573	1955	9044	146278
2016	81504		6	2216	195	9215	93136	39598	2569	1957	9018	146278
2015	81565		6	2216	196	9208	93190	39597	2557	1957	8979	146281
2014	81586		6	2214	194	9236	93236	39619	2546	1957	8953	146311
2013	81622		6	2208	195	9240	93271	39622	2523	1958	8933	146306
2012	81644		3	2208	195	9254	93304	39593	2518	1951	8944	146311
2011	81722		3	2206	195	9290	93417	39591	2467	1929	8900	146304
2010	81902		3	2206	195	9156	93462	39575	2454	1927	8882	146299
2009	82021		3	2206	194	9123	93548	39565	2440	1922	8821	146296
2008	82069		3	2208	194	9137	93611	39557	2416	1911	8801	146296
2007	82146		3	2201	196	9136	93682	39553	2403	1901	8764	146303
2006	84426		3	2261	197	9729	96616	40910	2469	1943	8950	150888
2005	84528		3	2252	200	9740	96723	40887	2455	1941	8891	150897
2004	85043		3	2264	202	9850	97362	41202	2455	1946	8915	151880
2003	85094		3	2261	204	9857	97419	41198	2452	1940	8852	151861
2002	85166		3	2261	205	9859	97494	41180	2448	1941	8800	151863
2001	85215		3	2258	206	9883	97565	41112	2442	1935	8813	151867
2000	85336		4	2255	208	9810	97613	41091	2437	1926	8790	151857
1999	85449			2255	207	9773	97684	41025	2512	1920	8736	151877
1998	85388		1	2254	208	9762	97613	41027	2508	1888	8850	151886
1997	85388		1	2254	208	9762	97613	41027	2508	1888	8850	151886
1996	84901			2238	216	10215	97571	40989	2525	1872	8925	151883
1995	84870			2242	217	10263	97592	40992	2523	1865	8916	151888

Year	Arable land	Hopyard	Vineyard	Garden	Orchard	Permanent grassland	Agriculture land	Forest land	Water surface	Urbanized area	Other area	Sum
1994	84897			2239	218	10234	97588	40990	2524	1852	8936	151890
1993	84906			2233	218	10246	97603	40992	2522	1844	8933	151894
Change in area (ha)	**-3429**	**0**	**6**	**-14**	**-23**	**-1034**	**-4494**	**-1395**	**51**	**111**	**111**	**-5616**
Change in area (%)	**-4,0%**		**500,0%**	**-0,6%**	**-10,6%**	**-10,1%**	**-4,6%**	**-3,4%**	**2,0%**	**6,0%**	**1,2%**	**-3,7%**

Source: State Administration of Land Surveying and Cadastre, 2018

Table 28 Landuse change in the municipality with extended powers Třebíč between years 2009 and 2017

Year	Arable land	Hopyard	Vineyard	Garden	Orchard	Permanent grassland	Agriculture land	Forest land	Water surface	Urbanized area	Other area	Sum
2017	46247		6	1276	137	5967	53633	22408	1430	1160	5114	83745
2016	46272		6	1277	138	5968	53660	22404	1424	1161	5093	83743
2015	46316		6	1278	138	5954	53692	22409	1415	1161	5067	83745
2014	46332		6	1280	138	5971	53726	22438	1406	1159	5046	83775
2013	46330		6	1279	138	5976	53729	22440	1399	1162	5042	83771
2012	46330		3	1280	138	5997	53748	22433	1395	1157	5040	83773
2011	46367		3	1280	138	6023	53811	22432	1372	1144	5013	83771

Year	Arable land	Hopyard	Vineyard	Garden	Orchard	Permanent grassland	Agriculture land	Forest land	Water surface	Urbanized area	Other area	Sum
2010	46522		3	1280	139	5882	53862	22421	1371	1143	5008	83768
2009	46579		3	1282	138	5866	53868	22419	1359	1139	4981	83766
Change in area (ha)	**-332**		**3**	**-6**	**-1**	**101**	**-235**	**-11**	**71**	**21**	**133**	**-21**
Change in area (%)	**-0,7%**		**100,0%**	**-0,5%**	**-0,7%**	**1,7%**	**-0,4%**	**0,0%**	**5,2%**	**1,8%**	**2,7%**	**0,0%**

Source: State Administration of Land Surveying and Cadastre, 2018

As the presented table show, there are only slight statistical differences between the data from Czech Statistical Office and State Administration of Land Surveying and Cadastre. Therefore, to further extrapolate and define the land use change for the municipality with extended powers Třebíč, the comparable data were used for the district Třebíč and municipality with extended powers Třebíč (meaning for years 2009 to 2017) to determine the rate of area designated to the municipality and to define the average percentage value dedicated per land use type (see Table 29).

Table 29 Extrapolation of data for district and municipality with extended powers Třebíč

Year	Arable land	Hopyard	Vineyard	Garden	Orchard	Permanent grassland	Agriculture land	Forest land	Water surface	Urbanized area	Other area	Sum
2017	46247		6	1276	137	5967	53633	22408	1430	1160	5114	83745
2017	81477		6	2219	195	9212	93109	39597	2573	1955	9044	146278

Year	**Arable land**	**Hopyard**	**Vineyard**	**Garden**	**Orchard**	**Permanent grassland**	**Agriculture land**	**Forest land**	**Water surface**	**Urbanized area**	**Other area**	**Sum**
	56,76%		100,00%	57,50%	70,26%	64,77%	57,60%	56,59%	55,58%	59,34%	56,55%	57,25%
2016	46272		6	1277	138	5968	53660	22404	1424	1161	5093	83743
2016	81504		6	2216	195	9215	93136	39598	2569	1957	9018	146278
	56,77%		100,00%	57,63%	70,77%	64,76%	57,61%	56,58%	55,43%	59,33%	56,48%	57,25%
2015	46316		6	1278	138	5954	53692	22409	1415	1161	5067	83745
2015	81565		6	2216	196	9208	93190	39597	2557	1957	8979	146281
	56,78%		100,00%	57,67%	70,41%	64,66%	57,62%	56,59%	55,34%	59,33%	56,43%	57,25%
2014	46332		6	1280	138	5971	53726	22438	1406	1159	5046	83775
2014	81586		6	2214	194	9236	93236	39619	2546	1957	8953	146311
	56,79%		100,00%	57,81%	71,13%	64,65%	57,62%	56,63%	55,22%	59,22%	56,36%	57,26%
2013	46330		6	1279	138	5976	53729	22440	1399	1162	5042	83771
2013	81622		6	2208	195	9240	93271	39622	2523	1958	8933	146306
	56,76%		100,00%	57,93%	70,77%	64,68%	57,61%	56,64%	55,45%	59,35%	56,44%	57,26%
2012	46330		3	1280	138	5997	53748	22433	1395	1157	5040	83773
2012	81644		3	2208	195	9254	93304	39593	2518	1951	8944	146311
	56,75%		100,00%	57,97%	70,77%	64,80%	57,61%	56,66%	55,40%	59,30%	56,35%	57,26%
2011	46367		3	1280	138	6023	53811	22432	1372	1144	5013	83771

Year	Arable land	Hopyard	Vineyard	Garden	Orchard	Permanent grassland	Agriculture land	Forest land	Water surface	Urbanized area	Other area	Sum
2011	81722		3	2206	195	9290	93417	39591	2467	1929	8900	146304
	56,74%		100,00%	58,02%	70,77%	64,83%	57,60%	56,66%	55,61%	59,31%	56,33%	57,26%
2010	46522		3	1280	139	5882	53862	22421	1371	1143	5008	83768
2010	81902		3	2206	195	9156	93462	39575	2454	1927	8882	146299
	56,80%		100,00%	58,02%	71,28%	64,24%	57,63%	56,65%	55,87%	59,31%	56,38%	57,26%
2009	46579		3	1282	138	5866	53868	22419	1359	1139	4981	83766
2009	82021		3	2206	194	9123	93548	39565	2440	1922	8821	146296
	56,79%		100,00%	58,11%	71,13%	64,30%	57,58%	56,66%	55,70%	59,26%	56,47%	57,26%
Average	**56,77%**		**100,00%**	**57,85%**	**70,81%**	**64,63%**	**57,61%**	**56,63%**	**55,51%**	**59,30%**	**56,42%**	**57,26%**

Source: own calculation

This average value per land use type was then used to extrapolate the data from the district to the municipality with extended powers for all the available years, as shown in Table 30.

Table 30 Land use change for the municipality with extended powers Třebíč between years 1993 and 2017

Year	Arable land	Hopyard	Vineyard	Garden	Orchard	Permanent grassland	Agriculture land	Forest land	Water surface	Urbanized area	Other area	Sum
2017	46256		6	1284	138	5954	53639	22424	1428	1159	5103	83752

Year	Arable land	Hopyard	Vineyard	Garden	Orchard	Permanent grassland	Agriculture land	Forest land	Water surface	Urbanized area	Other area	Sum
2016	46271		6	1282	138	5956	53655	22424	1426	1161	5088	83752
2015	46306		6	1282	139	5951	53686	22424	1419	1161	5066	83753
2014	46318		6	1281	137	5970	53713	22436	1413	1161	5051	83770
2013	46338		6	1277	138	5972	53733	22438	1401	1161	5040	83768
2012	46351		3	1277	138	5981	53752	22421	1398	1157	5046	83770
2011	46395		3	1276	138	6004	53817	22420	1369	1144	5021	83766
2010	46497		3	1276	138	5918	53843	22411	1362	1143	5011	83764
2009	46565		3	1276	137	5897	53892	22406	1354	1140	4977	83762
2008	46592		3	1277	137	5906	53929	22401	1341	1133	4966	83762
2007	46636		3	1273	139	5905	53969	22399	1334	1127	4945	83766
2006	47930		3	1308	139	6288	55660	23167	1371	1152	5050	86391
2005	47988		3	1303	142	6295	55721	23154	1363	1151	5016	86396
2004	48280		3	1310	143	6366	56089	23333	1363	1154	5030	86959
2003	48309		3	1308	144	6371	56122	23330	1361	1151	4994	86948
2002	48350		3	1308	145	6372	56166	23320	1359	1151	4965	86949
2001	48378		3	1306	146	6388	56206	23282	1356	1148	4972	86952
2000	48447		4	1305	147	6341	56234	23270	1353	1142	4959	86946
1999	48511		0	1305	147	6317	56275	23232	1394	1139	4929	86957

Year	Arable land	Hopyard	Vineyard	Garden	Orchard	Permanent grassland	Agriculture land	Forest land	Water surface	Urbanized area	Other area	Sum
1998	48476		1	1304	147	6310	56234	23233	1392	1120	4993	86962
1997	48476		1	1304	147	6310	56234	23233	1392	1120	4993	86962
1996	48200		0	1295	153	6602	56210	23212	1402	1110	5036	86961
1995	48182		0	1297	154	6633	56222	23214	1401	1106	5030	86964
1994	48197		0	1295	154	6615	56220	23213	1401	1098	5042	86965
1993	48202		0	1292	154	6622	56228	23214	1400	1094	5040	86967
Change in area (ha)	**-1947**		**6**	**-8**	**-16**	**-668**	**-2589**	**-790**	**28**	**66**	**63**	**-3215**
Change in area (%)	**-4,0%**		**600,0%**	**-0,6%**	**-10,6%**	**-10,1%**	**-4,6%**	**-3,4%**	**2,0%**	**6,0%**	**1,2%**	**-3,7%**

Source: own calculation

The statistical difference between the extrapolated data and the actual data for the municipality with extended powers is between 0,002% and 0,78%.

The reading of the data shows the overall trend in the area for the past 24 years. In total, the area dedicated to any of the land use type used in the cadastre registry has decreased by 3215 ha between years 1993 and 2017 – this is represented by a decrease of 3,7% in percentage value. The biggest decrease can be attributed to the share of agriculture land, which has decreased by 2589 ha or by 4,6%. The largest share of agriculture land is arable land, which has therefore decreased accordingly by 1947ha (4,0%). Forest area and permanent grassland has also diminished quite significantly, with the former dropping by 3,4% (790 ha) and the latter by 10,1% (668ha). The area covered with gardens and orchards has decreased only very slightly, by 8 and 16 ha respectively. On the other hand, urbanized area has increased the most, by 6% (66 ha) while other area has increased by 1,2% (63 ha) and water surface has also developed by 28 ha.

Overall, this underlines the trend seen not only here, but in the whole Czech Republic, that the areas with agriculture use are decreasing at the expense of urbanized and other areas. Figures 8 and 9 help to visualize this trend.

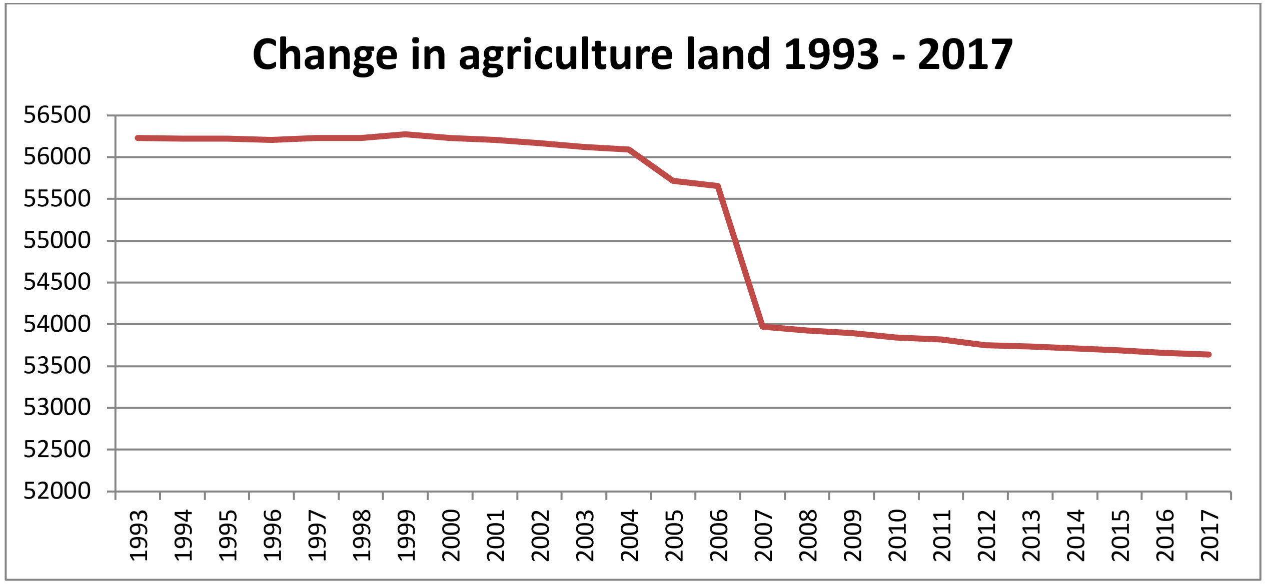


Figure 8 Change in agriculture land use in the municipality with extended powers Třebíč 1993 – 2017. Source: original

As Figure 7 shows, the area of agriculture land has been steadily decreasing ever since the first recorded data show, with the most prominent drop between years 2006 and 2007. This drop can be attributed to land consolidation projects and redrawing of the district lines. As seen in the tables above, the overall area of the study area has decreased in 2006 by 2 625 hectares. In the same time period, the neighbouring district of Jihlava has gained 1301 hectares of land, the district of Žďár nad Sázavou has been attributed 1384 hectares and the area of district of Brno-venkov has increased by record 26 101 hectares.

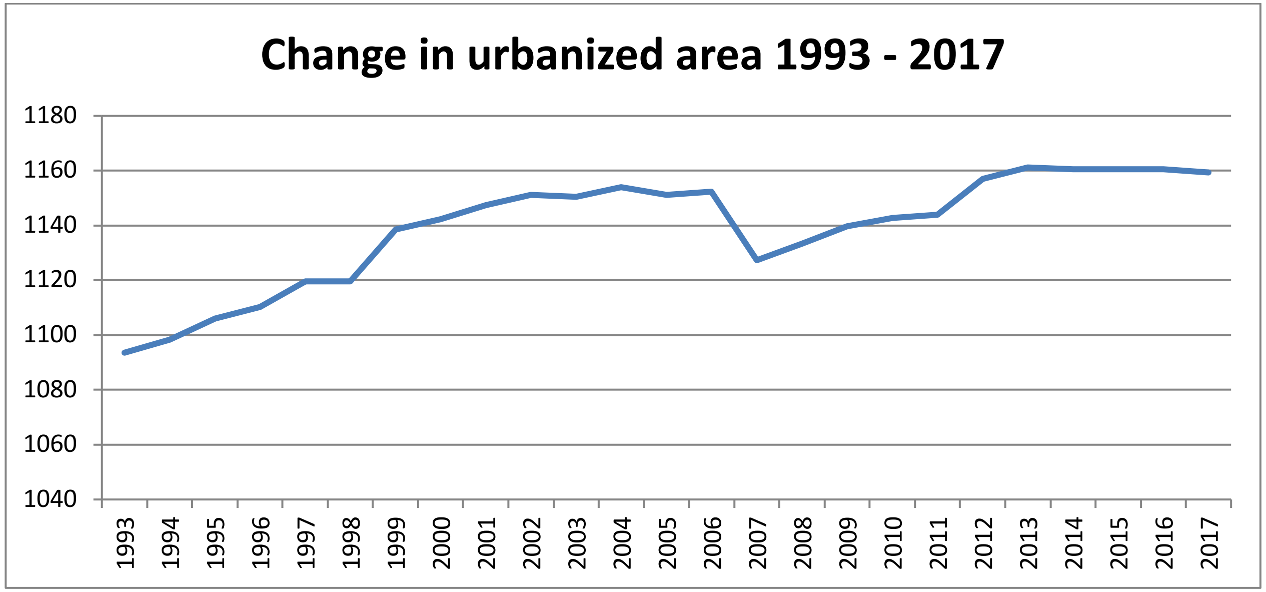


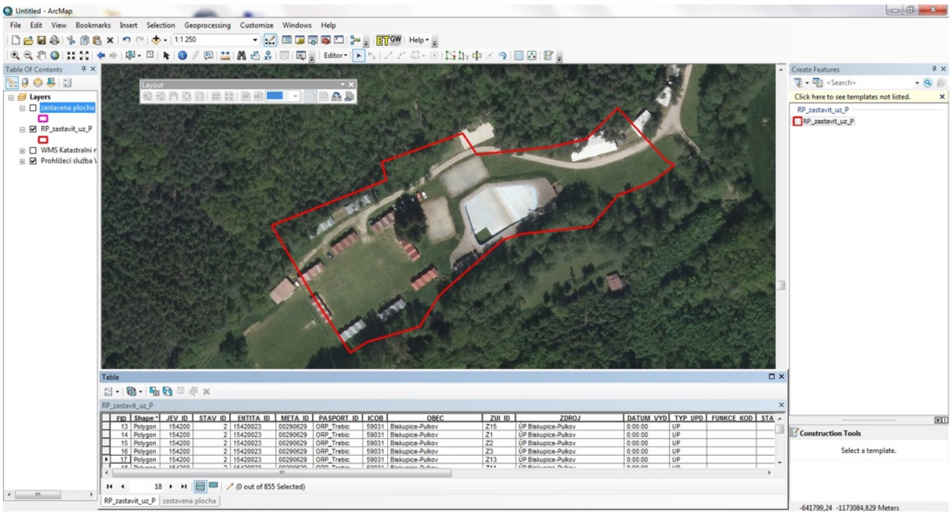
Figure 9 Change in urbanized area in the municipality with extended powers Třebíč 1993 – 2017. Source: original

Figure 9 shows how the rate of urbanized area has been steadily increasing with the slight exception of years 2006 and 2007 when the area unexpectedly decreased. This can be attributed in the redrawing of district lines as described above.

Future trends in urban sprawl

Consequent analysis also focused on what are the future trends and how might the urbanization in the district of Třebíč continue. According to the spatial analytical data of the Třebíč district which were published in 2008, there are 1237 ha of land dedicated for urbanization. Some of the land has already been transformed into urban areas, some still awaits transformation. Prevalent part of the non-urban area dedicated to urbanization is now agriculture land with some permanent grassland and forests as well.

Analysis in ArcGIS of the 854 parcels dedicated for urbanization show that most of this area is adhering to the current towns and villages (Figure 11 and 12), but sometimes it is not necessarily the case (Figure 10).

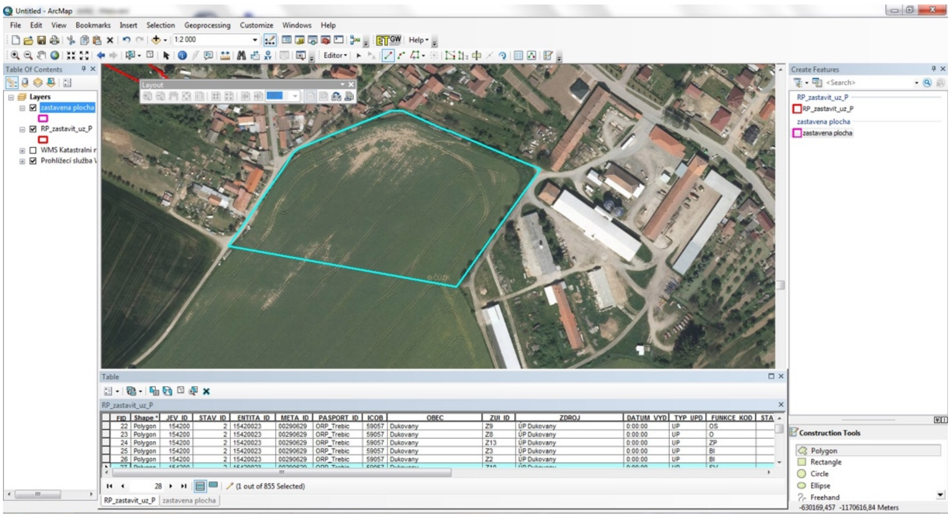


FID	Shape *	JEV_ID	STAV_ID	ENTITA_ID	META_ID	PASPORT_ID	ICOB	OBEC	ZUI_ID	ZDROJ	DATUM_VYD	TYP_UPD	FUNKCE_KOD	STA
13	Polygon	154200	2	15420023	00290629	ORP_Trebic	59031	Biskupice-Pulkov	Z15	ÚP Biskupice-Pulkov	0:00:00	UP		
14	Polygon	154200	2	15420023	00290629	ORP_Trebic	59031	Biskupice-Pulkov	Z1	ÚP Biskupice-Pulkov	0:00:00	UP		
15	Polygon	154200	2	15420023	00290629	ORP_Trebic	59031	Biskupice-Pulkov	Z2	ÚP Biskupice-Pulkov	0:00:00	UP		
16	Polygon	154200	2	15420023	00290629	ORP_Trebic	59031	Biskupice-Pulkov	Z3	ÚP Biskupice-Pulkov	0:00:00	UP		
17	Polygon	154200	2	15420023	00290629	ORP_Trebic	59031	Biskupice-Pulkov	Z13	ÚP Biskupice-Pulkov	0:00:00	UP		

18 (0 out of 855 Selected)

Figure 10 Analysis of areas designated for urbanization in the study area 1. Source: original

Most of the dedicated area is at least partially urbanized at this moment, while there are also large parcels of agriculture still waiting to be transformed.



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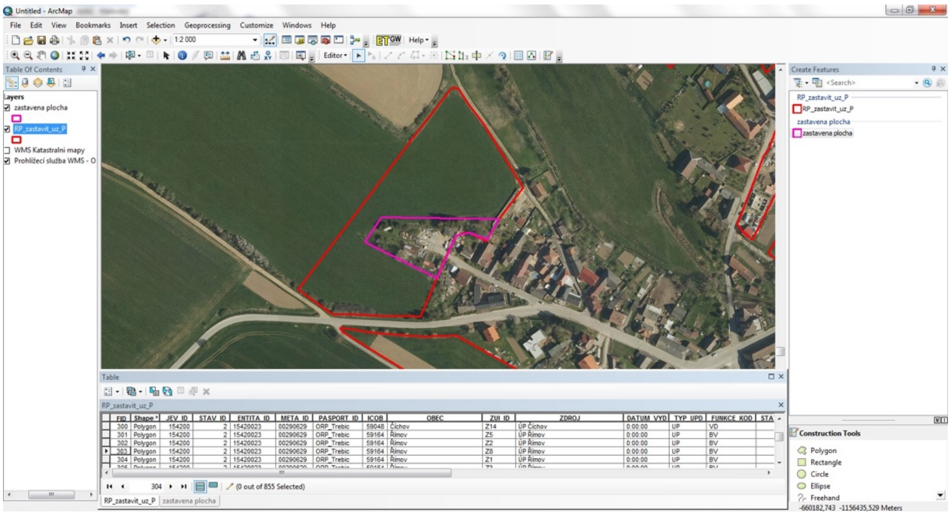
FID	Shape *	JEV_ID	STAV_ID	ENTITA_ID	META_ID	PASPORT_ID	ICOB	OBEC	ZUI_ID	ZDROJ	DATUM_VYD	TYP_UPD	FUNKCE_KOD	STA
22	Polygon	154200	2	15420023	00290629	ORP_Trebic	59057	Dukovany	Z9	ÚP Dukovany	0:00:00	UP	OS	
23	Polygon	154200	2	15420023	00290629	ORP_Trebic	59057	Dukovany	Z8	ÚP Dukovany	0:00:00	UP	O	
24	Polygon	154200	2	15420023	00290629	ORP_Trebic	59057	Dukovany	Z13	ÚP Dukovany	0:00:00	UP	ZP	
25	Polygon	154200	2	15420023	00290629	ORP_Trebic	59057	Dukovany	Z3	ÚP Dukovany	0:00:00	UP	BI	
26	Polygon	154200	2	15420023	00290629	ORP_Trebic	59057	Dukovany	Z2	ÚP Dukovany	0:00:00	UP	BI	

28 (1 out of 855 Selected)

Figure 11 Analysis of areas designated for urbanization in the study area 2. Source: original



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FID	Shape *	JEV_ID	STAV_ID	ENTITA_ID	META_ID	PASPORT_ID	ICOB	OBEC	ZUI_ID	ZDROJ	DATUM_VYD	TYP_UPD	FUNKCE_KOD	STA
300	Polygon	154200	2	15420023	00290629	ORP_Trebic	59048	Čichov	Z14	ÚP Čichov	0:00:00	UP	VD	
301	Polygon	154200	2	15420023	00290629	ORP_Trebic	59164	Římov	Z5	ÚP Římov	0:00:00	UP	BV	
302	Polygon	154200	2	15420023	00290629	ORP_Trebic	59164	Římov	Z2	ÚP Římov	0:00:00	UP	BV	
303	Polygon	154200	2	15420023	00290629	ORP_Trebic	59164	Římov	Z8	ÚP Římov	0:00:00	UP	BV	
304	Polygon	154200	2	15420023	00290629	ORP_Trebic	59164	Římov	Z1	ÚP Římov	0:00:00	UP	BV	

304 (0 out of 855 Selected)

Figure 12 Analysis of areas designated for urbanization in the study area 3. Source: original

The analysis also shows that from the 1237 ha of dedicated area, there is 230 ha already urbanized. This represents 19% of the total dedicated area and therefore shows development roughly between 2008 and 2018. There is still 1007 ha of agriculture land and other land uses waiting to be transformed into urban land.

7 DISCUSSION

The following table sums up the results for each ecosystem service identified for the purpose of this research. See Table 31.

Table 31 Overview of the ecosystem services provided in the study area

Crop	Prevention of water contamination - The cost of nitrogen leached (CZK/ha)	Carbon sequestration - The social cost of carbon sequestrated (CZK/ha)	Production function - Total production CZK/ha	Prevention of soil erosion - Costs linked to soil erosion (CZK/ha)
Wheat	16729,18	2325,52	24750,6	29584,292
Barley	14120,68	1758,32	21380,5	29515,968
Rapeseed	16485,72	6154,12	29681,92	26919,656
Maize	10155,76	2098,64	40000	27739,544
Grassland for fodder	10120,98	-595,56	7243,6	33342,112

Source: original

This overview table clearly shows a trend that has been already been put forward in the literature review, most clearly in Figure 3. Even as agriculture itself provides some services, most notably the production of food, it also draws up on the other services in its surrounding ecosystems and habitats. Some studies name this process, the clear loss of ecosystem services, as land degradation (Sklenička, 2016). Land degradation can be defined as: “reduction or loss of natural beneficial goods and services, notably primary production services, derived from terrestrial ecosystems” (Blaikie and Brookfield, 1987; Sarukhan et al., 2005, Nkonya et al., 2011). This definition therefore embraces both human and natural causes to this process. The most common land degradation types are water and wind erosion, loss of biodiversity and in agricultural areas also water shortages, soil depletion and soil pollution (Nachtergaele et al., 2011)

If we would consider the ecosystem service described in this work case by case, as for the prevention of water contamination (or nutrient run-off) it is clear that the arable land and the type of crops which are grown on this land benefit from a trade-off and provide a disservice to the environment. There are some differences between the crop types, with the grassland dedicated for fodder production clearly polluting the water bodies the least, yet the general trend does not change. What did the methodology and the case studies outline however is that agriculture practices play a role in defining what is the magnitude of this disservice. As this service is linked to the use of nitrogen and how much of it is leached from soil, a proper management in the use of fertilizers could greatly impact this ecosystem disservice.

As the case studies have shown, there were great differences between the different farms in nutrient balance. The Table 7 in the results clearly states that the case study which fared the worst amongst the others was the big conventional farm with cereal and livestock production. The use of nitrogen in this case greatly exceeded the proposed limits. It could be therefore assumed that the nitrogen was overused in this case. On the other hand, the small biological farm with the very limited use of fertilizers used up all the soil potential and stocks of nitrogen by creating a lack of this nutrient. It could be then argued that through a more systematic use of fertilizers, the disservice of nutrient run-off could be minimized to some extent. This could happen with the help of digitisation and precision agriculture, or simply with the use of nutrient management plan, one similar to the tool used for the purpose of this dissertation. The other way would also be to introduce buffer strips alongside water courses to help prevent the run-off. These simple measures could help to minimize this ecosystem disservice. Some long-term studies (Dumbrovský et al., 2015) indeed show that the water quality of reservoirs adhering to the agricultural land has improved after the implementation of erosion control measures. The combination of measures which was targeted was increase in grassland area, soil prevention measures and reduction of fertiliser application rates.

It has to be noted as well that permanent grassland was not included in this research due to the limitations of the model used. Studies that have followed the nutrient run-off on permanent grassland suggest that less than 10% of the nitrogen applied to these areas has been lost due to run-off (Scholefield, 1995), with studies following more dissolved nutrients suggesting this percentage is low as 5% (Schlesinger, 2000). This could imply as well that changing the land use from arable land to permanent grasslands in some part of the farm could positively benefit the prevention of water contamination.

As for carbon sequestration, again the results clearly show that most of the crops grown on arable provide a disservice to the ecosystems in this regard, with the notable exception of grassland for fodder. The case studies also show very great differences between the farm types and farm management, as outlined in Table 17. The large conventional farm with mixed livestock and crop production managed to produce the staggering 19 046 871 CZK/year in carbon footprint while the small family farm also with mixed production of livestock and crops managed to save 336 297 CZK/year. It is to be noted that even as there were included two farms either fully or partly under the organic type of farming, these did not produce the largest savings in carbon sequestration.

Other studies have however suggested that organic farming does play a role in the total carbon content in soils. (Walmsley and Sklenička, 2017) This might be accounted for by the fact that fertilizers used in organic agriculture tend to have higher carbon content (Tuomisto et al., 2012). What also showed to have an impact on the soil biochemical activity, also linked to soil carbon content, is the fact whether the land is farmed by an owner or tenant. This is particularly true for conventional farming. For these farms, according to the study undertaken by Walmsley and Sklenička, 2017, a higher biological activity was indicated for soils managed by the owner. As for organic farms, who have to comply with strict agro-ecological norms in order to get certification of their products, there was no such a strong correlation. This underlines the fact that the willingness to manage agriculture land in a sustainable manner is significantly impacted by the relationship to this land (Kristensen et al., 2004; Yami and Snyder, 2015), as farmers-owners tend to take better care of their land than farmers-tenants do.

As the model used for carbon sequestration suggests, there are number of farming practices through which the carbon sequestration can be addressed and improved. First one is the lowering of tillage intensity, meaning moving away from classical tillage to low tillage in some parts of the farm or even to no-till farming or conservation agriculture (which would mean reducing the tillage and number of field operations to minimum while increasing the use of crop residues). Reduction of carbon footprint can also be addressed through minimizing use of fertilizers and pesticides as this would also imply a smaller number of field operations. The management of crop residues also plays its part, either as having a cover crop or as incorporating the crop residues back to soil and increasing therefore the organic matter in the land.

The model for carbon sequestration takes into account the carbon footprint of the overall production, including all field operations. Other studies have shown however that the agricultural ecosystem on its own stores a high amount of carbon, comparable to a carbon storage potential of mountain meadows. About 75% of the carbon is lost due to respiration, yet this number could be higher if not for the harvest, a very specific aspect of this ecosystem in comparison to others. Some carbon is being lost further down the food value chain and through decomposition, but that already happens outside of the agricultural ecosystem. (Marek et al., 2011) According to this research the overall average carbon storage in the Czech Republic in 2000 in agricultural ecosystems was 4,21 t/ha. The highest amounts were achieved in regions with a higher rate of sugar beet production, which has the most biomass as compared to other crops grown on arable land, and with good climate conditions. Overall however the low value of biomass in agricultural crops cannot significantly influence the carbon storage potential for the whole of Czech Republic. (Marek et al., 2011)

As for the next ecosystem service considered in this research, the production of food is undeniably the one ecosystem service that all arable land does provide. It is also the one that cannot be replaced by any other ecosystem, certainly not in a manner that would sustain the current world population. There are some differences in what value does of the crop provide, with the least attributed to grassland for fodder and the most to maize production. Yet we have to recognize as well that this market value is not the definitive one, while both fodder and maize is used further for livestock production and therefore the final added value would be of that final produce. The market price can also change quite rapidly, with agriculture sector being faced with great volatility, which can be impacted by operational stock, seasonality, adverse weather events yet also by external forces such as international trade agreements and climate change. Therefore, the market price can indicate the final value of this ecosystem service only to a certain extent. Yet what cannot be argued is the irreplaceability of this service and its utmost importance for the feeding of the world population.

When it comes to soil erosion, it is clear again that the arable land with provides a disservice. There is no type of crop which would prevent the soil erosion altogether and there are also very small differences between the rate of erosion for the different crops. All in all, therefore, all arable land is by definition subject to erosion. One of the aspects which was not included in this research is the soil erosion on permanent grassland. The Table 23 shows that the rate of erosion on permanent grassland is much lower than for the arable crops, between 0,14-0,18 t/ha/year in comparison to 4,33 t/ha/year for wheat. Just for the record, according to several studies, soil has the capability to regenerate itself in a rate of 1 t/ha/year. (Šarapatka et al., 2008) The low rate of erosion on permanent grassland could indicate that by switching the land use from arable land to permanent grassland on some parts of the farm could also minimize soil erosion and therefore benefit this ecosystem service.

Interestingly enough, other research has shown that there are significant differences between the soil erosion between different types of crops. Sus, in Holý, 2004, outlined that the average soil erosion for clover is 1%, for winter wheat 50%, for spring wheat 100% and for root crops even 200%. Nonetheless, there are several factors which play into the rate of erosion for different crops, all of which are considered in the general Wischmeier-Smith equation for computing soil erosion. These are the rate of rainfall-induced erosion, soil type, morphology – slope and slope length, soil cover and efficiency of anti-erosion measures. (Šarapatka et al., 2008) This suggest that type of crop is only one piece of the more complex equation.

One aspect which is also closely connected to soil erosion is the size of soil blocks. The analysis shows that the situation in the study area is not as dire as in the other parts of the Czech Republic (see Figure 5) as the average in the study area is slightly below the national average. The Czech Republic also has the largest average farm size in the EU (133 ha) and also in the study area this corresponds to the reality that more than 50% of the agriculture land is farmed by large cooperatives with more than 1000 ha of land (see Table 6). While this was not exactly in the scope of this dissertation, other studies have shown a link between an agriculture land fragmentation, land degradation and fragmentation of ownership. Due to the historical developments in the Czech Republic, the ownership of land is extremely fragmented. A study by Sklenička, Šálek (2007) has outlined that the average size of soil block (26,67 ha) is in stark contrast to the average size of the ownership parcel (0,66 ha). (Sklenička, Šálek, 2007). These very small parcels are often very fragmented, scattered and inaccessible and therefore quite unsuitable for individual farming (Sklenička et al., 2009). There is also a great difference between the number of land owners (3,5 million) and the number of farm entities (30,000). This leads also to the fact that most of the land is being rented, with only about 20% of the land being cultivated by the owner (Sklenička et al., 2014). One of the main causes of ownership fragmentation is partible inheritance, which implies that the land is divided between the heirs in an equal manner. Moreover, the fragmentation process is also influenced by the production potential of the land (as more fertile land tends to be less fragmented) and various historical events that suddenly changed the fragmentation rate. In Czech Republic, these would be expelling the original inhabitants and dividing the land between new owners, land reforms and land consolidation projects (Sklenička et al., 2009). The other cause of fragmentation would be the physical division of parcels during their sale, or change of use – predominantly by the land use change induced by urban development pressures. (Irwin and Bockstael, 2007)

This ownership fragmentation and therefore also tenure insecurity can also be one of the factors that lead to land degradation and the loss of ecosystem services. As it was outlined above, small parcels are no longer economically viable for individual farming – in the Czech Republic this threshold is set at 1 ha (Sklenička et al., 2014). Farming too small parcels is too expensive due to the number of unproductive passages over the parcels and also due to travel time between them (Gonzalez et al., 2014). In the Czech Republic this aspect cannot be overlooked as more than 40% of farmland is distributed across smaller than the viability threshold (Sklenička et al., 2014). These small parcels are also hard to access via road since the road network is not so dense (Sklenička, 2006). The owners of these inaccessible parcels are therefore practically forced to rent the parcel, usually to the owner of neighbouring parcels. This trend therefore significantly increases the rate of farmland being rented. It also has to be noted that this land which is divided into overly small parcels has considerably lower value. In this regard, the farmland is devalued simply because of this fragmentation rate, even as fertility rate and other attributes remain the same. (Sklenička, 2016)

This land fragmentation, level of rented land and tenure insecurity boils down to the fact, which affects the land degradation the most. A number of studies have shown that farming on rented land is less sustainable while the tenant tends to care less for the land entrusted in them than the actual owners do. (Fraser, 2004; Carolan, 2005) Parcels farmed by tenants would have less organic matter content, increased compaction, higher rate of erosion and overall decreased natural fertility, according to the 30-yearlong research conducted in the Czech Republic (Research Institute for Soil and Water Conservation, 2014). Other studies also show that insecure land tenure does not contribute to soil conservation (Nowak and Korsching,1983; Soule et al., 2000; Fraser, 2004) and also decreases the use of organic fertilizers which improve soil fertility (Jacoby et al., 2002). There is also a number of studies highlighting the effect of tenure security on farm improvement and productivity (Feder and Onchan, 1987; Gebremedhin and Swinton, 2003; Fenske, 2011; Feder, 1987; Abdulai et al., 2011).

The insufficient tenure security really strikes at the heart of land degradation, as it diminishes the motivation to invest in holdings, to increase the fertility of soil and it also decreases the motivation to invest in biodiversity protection, landscape renewal and water resource protection. (Sklenička, 2016) The tendency to rent the land to big processors who farm the overly large blocks also contributes considerably to the problem of water and wind erosion (Jenny, 2012), decreased spatial heterogeneity and landscape connectivity (Turner et al., 2011), problematic water management (Qui and Turner, 2015), agronomy (Sklenička and Šálek, 2008), also with negative impacts on visual value of landscape and potential for recreation (de Val et al., 2006). In this regard, tenure insecurity has an influence on these land degradation types: water and wind erosion (Sklenička et al., 2015), reduction of organic matter (Jacoby et al., 2002), soil compaction and nutrient leaching (Scherr, 2000). Two of these ecosystem disservices were also identified as part of this research and outline the link of farming structure on the availability of ecosystem services. Indeed these trends and the findings of this work can outline the close relationship of ecosystem disservices provided by agriculture land and how does this tie in with the ownership fragmentation in the Czech Republic.

Referring back to the topic of soil erosion studied in this work, there are also several practices to help prevent soil erosion on cropland. One of them is maintaining the soil cover throughout the whole year, mainly through the use of cover crop or catch crop or just leaving stubble on the field. Another practice is increasing the rate of organic matter in soil which would in turn increase the water retention of the soil and enhance its resilience to soil erosion. Preventing soil compaction through management of field operations and adequate machinery can also increase the water retention of soil. One of the more common problems in the Czech Republic in general, and as already outlined above, is the large size of land blocks. Even as this might not be a major issue in the study area, such as the Figure 6 suggests, it is generally acknowledged that dividing the large soil block with field copses or hedgerows or simple strips of grassland can also help to prevent erosion. These hedgerows of buffer strips can also greatly benefit the agriculture biodiversity. The reduction of tillage or conservation agriculture can also positively benefit the soil erosion prevention, a measure which was also already suggested to help increase the carbon sequestration. Some studies (Dumbrovský, Larišová, 2016) indeed show that reducing the tillage intensity can lead to a higher porosity of soil while the conventional tillage has a detrimental impact on soil compaction and soil structure. In the most extreme cases with very steep slopes, it is advisable to divide the field into terraces and keep a level-ground between the barriers dividing the terrace levels.

Other soil erosion prevention measures which are suggested are increasing the rate of organic matter in soil, catch crops and cover crops, shortening slope length, crop rotation with a higher rate of permanent crops and cover crops, tillage alongside the contour lines, hedgerows, anti-erosion belts. (Šarapatka et al., 2008) Janeček et al., 2012 also suggests stabilizing the concentrated run-off paths, anti-erosion dikes and field boundaries.

Some studies also highlight how does the price of implementing soil erosion prevention measures compare to the costs of dealing with the results of erosion, as highlighted in this work. On the example of broad-base terraces, Dumbrovský et al., 2014, showcases that through an effective implementation of these measures annual savings can be achieved. Indeed, when looking into the feasibility of different erosion measures, the financial situation and acquisition investment plays an important role. Yet what needs to be taken into account is also the fact that erosion control measures are usually proposed within an entire complex of steps to address the situation. In the example of terraces, we should consider that alongside this measure we would also need to implement a combination of best management practices with grassed waterways, elimination of wide row crops from crop rotation etc. (Dumbrovský et al., 2014)

When reflecting on the agriculture land use in general in the Czech Republic and how this might be influenced, we need to point out that agriculture here exceeds the average of the EU and therefore is the main user of land. According to the data from Farm structure survey, agriculture makes up for 2,9% of the employment, and there are 26 250 farms with 132 130 persons working in agriculture (FSS 2016, 2013). The number of beneficiaries benefitting from direct payments in the scope of the Common Agricultural Policy (CAP) is 29 670 (DG AGRI, 2018). It is therefore safe to say that the objectives, targets and measure implemented under this policy can greatly influence the agriculture patterns. There are two predominant trends now in the agriculture – intensification and specialization in some areas accompanied by marginalization and land abandonment in others, both of which are underscored by growing environmental problems. (Brouwer, 2001) The development of EU countryside goes hand in hand with the shifting priorities of the CAP, focusing on the food security right after the World War II, when the policy was first implemented, and progressing towards focusing also on non-production functions, delivering public goods, protecting the environment and stressing the need for sustainable development. (Hodge, 2001) Even as the agricultural policy has been heavily criticized for not delivering on its objectives, primarily when it comes to protection of environment and addressing the negative impact of intensive agriculture, some studies also highlight the influence the CAP has had on creating better jobs for farmers across the EU and on the reduction of poverty in rural areas. (World Bank, 2018) The policy in the current reform shifts even more towards provision of public goods and protection of environment, with the new result-based system and tailoring the policy more to the local needs promising to do just this. Indeed when addressing the ecosystem disservices provided by agriculture land, much can be achieved through a better targeting of this policy which influences most of the farmers in the Czech Republic.

As for the ecosystem evaluation undertaken in the scope of this work and the possibility to compare the results, we should turn to similar studies done in the conditions of the Czech Republic. One of such broad assessment of ecosystem services was done by Frélichová et al., 2014. This study was first of its kind and used literature review of similar studies performed in Europe to assess the average value per service per ecosystem. This research also produced a methodology for any future assessment of ecosystem services (Vačkář et al., 2014). The outcomes are highlighted in Figure 13 below. Out of the different ecosystem services evaluated, we could compare the climate regulation (as it ties closely to carbon sequestration), erosion regulation and water quality regulation. As the agriculture ecosystem included in our study provides disservices in this account (with the notable exception of permanent grassland), it only highlights what could be the potential of these agricultural ecosystems, should sustainable management practices be established and measures to prevent the nutrient run-off and soil erosion implemented. Even as agriculture land use was included in the study run by Frélichová et al., 2014, the highest values highlighted in the results do not belong to it. As the Figure 13 fbelow shows, the highest recorded value can be attributed to disturbance regulation provided by wetlands, with the timber provision in forests closely following. Forest also scored well for aesthetic value, erosion regulation and climate regulation. (Frélichová et al., 2014). Indeed, this shows that agriculture ecosystems are not on the top when it comes to provision of ecosystem services. This can however be changed through the sustainable management and measure implementation highlighted in this discussion.

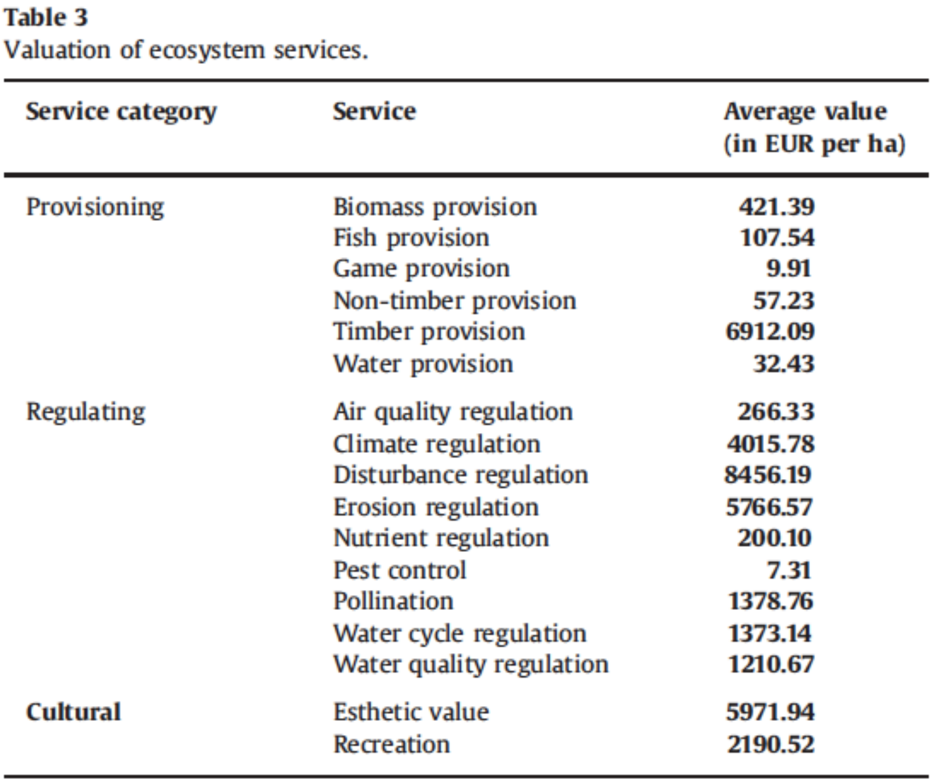

Table 3
Valuation of ecosystem services.

Service category	Service	Average value (in EUR per ha)
Provisioning	Biomass provision	421.39
	Fish provision	107.54
	Game provision	9.91
	Non-timber provision	57.23
	Timber provision	6912.09
	Water provision	32.43
Regulating	Air quality regulation	266.33
	Climate regulation	4015.78
	Disturbance regulation	8456.19
	Erosion regulation	5766.57
	Nutrient regulation	200.10
	Pest control	7.31
	Pollination	1378.76
	Water cycle regulation	1373.14
	Water quality regulation	1210.67
Cultural	Esthetic value	5971.94
	Recreation	2190.52

Figure 13 Valuation of ecosystem services in the Czech Republic. Source: Frélichová et al., 2014

Another study also focused on ecosystem services provided by permanent grasslands (Zisenis et al., 2011). The study highlighted the vital importance of permanent grasslands and their contribution to functioning biodiversity. The ecosystem services provided by permanent grasslands are wide-ranging. The study identified food provision, water provision, raw materials, genetic resource, medicinal resources, ornamental resources, air quality regulation, climate change regulation, moderation of extreme events, water flow regulation, waste regulation, erosion regulation, maintenance of soil fertility, pollination, pest control, cultural and amenity services amongst those that are provided by permanent grasslands. The study then considered the livestock provision, according to the maximum stocking density and estimated livestock numbers. The carbon sequestration, which depends largely on water regime, temperature, nutrient status and grassland management practices was based on marginal abatement cost of carbon. The erosion regulation considered how much soil is preserved in comparison to the average soil loss on cropland and then calculates the on-site and off-site damage. The water flow regulation similarly compares the average run-off on cropland and on permanent grassland. Invasion control was considering the level of alien species included in semi-natural grassland in the Czech Republic. Also, the waste treatment was included in the study, focusing on how much nitrogen can grasslands remove from soil. Permanent grassland also provides for recreation services through many outdoor activities, such as bird-watching, hunting, walking etc. This value can be calculated based on contingent valuation. (Zisenis et al., 2011) Indeed this study shows that ecosystem services provided by permanent grassland are much wider and more fundamental than just those considered in this work. The Figure 14 below gives an overview of the value of ecosystem services of permanent grassland.

CODE	CATEGORY	MAX LIVESTOCK NUMBER [EUR/HA]	CARBON SEQUESTRATI-ON [EUR/HA]	EROSION REGULATION [EUR/HA]	WATER REGULATION [EUR/HA]	INVASION REGULATION [EUR/HA]	NITROGEN REMOVAL [EUR/HA]	RECREATION [EUR/HA]	SUM OF VALUES [EUR/HA]
DG	Dry grasslands	370,72	17,22	265,48	1 875,90			55,45	2 584,76
AM	Alluvial meadows	864,09	68,88	265,48	2 755,00	9,80	161,95	55,45	4 180,64
MG	Mesic grasslands	695,39	43,05	265,48	2 113,00	52,00	161,95	55,45	3 224,37
WG	Seasonally wet and wet grasslands	883,55	68,88	265,48	3 042,00	20,41	161,95	55,45	4 497,71
AG	Alpine and subalpine grasslands	252,83	38,75	265,48	2 028,00	157,45		55,45	2 797,95
FF	Forest fringe vegetation	0,00	43,05	265,48	2 555,00			55,45	2 918,98
SM	Salt marshes	0,00	34,44	265,48	1 875,90			55,45	2 231,27
HT	Heathlands	0,00	25,83	265,48	1 268,00			55,45	1 614,76
P	Pastures and managed grasslands	403,71	43,05	265,48	1 639,00			55,45	2 406,69
	Average	385,59	42,57	265,48	2 127,98	26,63	53,98	55,45	2 647,96

Figure 14 Ecosystem services provided by permanent grassland. Source: Zisenis et al., 2011

As this research focuses on the ecosystem services loss due to urban sprawl, we have to analyse these facts together. As results and most importantly Table 30 show, the area dedicated to agriculture has decreased by 4,6% in the study area between years 1993 and 2017. During the same period, the urbanized area has increased by 6%. There is no clear link saying that this agriculture land has been devoted to urban sprawl, yet the trend speaks clearly in the favour of urban development. When analysing the rate of agriculture land loss, 19% of the total area dedicated for urban development on agriculture land has already been transformed with some 1007 ha of land still unbuilt on.

These developments are raising concerns for protecting rural identity, particularly in those places where urban sprawl is quickly spreading. (Foley and Scott, 2014; Taylor, 2011; Vorel et al., 2003). This residential development often happens beyond the boundaries of a city or village or other community. It also usually takes advantage of the amenities of the community, yet often failing to contribute to this community (Peltan, 2012). It also often disturbs the traditional landscape patterns in rural areas. As for Czech Republic, these patterns date back to the late middle ages (Pánek and Tůma, 2009) and can be defined as relatively regularly distributed towns and villages with high settlement density and open agricultural landscapes. The areas outside of the settlements usually contained very few buildings. This open landscape was also often divided into long narrow fields belonging to the individual farms (Sklenicka et al, 2009; Houfkova et al., 2015). This very distinctive pattern is crucial for preserving the landscape character and rural identity in Central Europe (Löw and Míchal, 2003). This identity can be partially preserved through strict land use planning practices. In the Czech Republic, the legal measures against urban sprawl are in place, even as the effectiveness of these measures could be questionable. The Building Act No. 183/2006 puts forward requirements for detailed land use plans to be drawn up for every municipality. These plans should be regulating land use both in urban areas and in rural areas and should also ensure the continuation of traditional settlement patterns. Yet it does not fully prevent over-intensive urban sprawl, and also the targeting of rural areas through these plans is insufficient. (Janečková et al., 2017)

This conversion of agricultural land to urban land is driven by several factors, such as proximity to a settlement (Cheshire, 1995; Guiling et al., 2009, Naydenov 2009), the quality of infrastructure and accessibility (Stewart and Libby, 1998), presence of natural amenities (Drescher et al., 2001; Lisec and Drobne, 2009) or occurrence of population growth (Forster, 2006). All of these factors influence the real estate market and agriculture land market. As for the Czech Republic, ever since the transition to democracy in 1989, there has been a clear prevalence in the rental market over the sales market, when it comes to agricultural land. This drives up the trend that land owners decide to rather rent the land due to low current prices of agricultural prices and lack of credit policies enabling potential farmers to buy the land. This situation also complements the scenario already described above, when tenants farm on large blocks of land, which is shown to be disadvantageous to the environment and contributes to land degradation. (Sklenička et al., 2011) A legislative act which controls the transformation of agriculture is (apart from the Building Act) the Act No. 334/1992 on Protection of Agriculture Land Resources. Spatial planning embedded in the Building Act protects the agricultural land through zoning, the Act on Protection of Agriculture Land Resources permits authorities to charge relatively high one-off fees for the transformation of agriculture land into urban land within this zoning. Yet the current system does not use measures put forward by some researchers (Deininger and Jin, 2003; Deininger et al., 2003) which would promote efficient land utilisation and facilitate access to land to farmers, such as realistic level of land taxation and efficient credit policies. The determination of agriculture land price is based on the system that considers the natural conditions of the land parcels it refers to – climate conditions, soil type, slope, exposition and soil structure (together known as the BPEJ code). Yet this methodology for expressing the price of land has been put forward in the 1970s' and does not address the more recent methodologies – evaluation of ecosystem services being one of them. If this system should continue to be used, it would require significant update. The outcomes of the study undertaken by Sklenička et al. (2011) also stress the significant importance of land consolidation projects and spatial planning on agriculture land prices and also protecting rural areas from urban sprawl and supporting the land market.

Even as agriculture land does provide some disservices to the ecosystems and benefits from the surrounding habitats, it has a clear potential to improve on those disservices as outlined above. Yet if this cropland would be turned to urban land, there is no longer any of that potential. Even as it is possible to replace some of the ecosystem services lost, as outlined in the literature review, the most important function of agriculture land – food production – is hard to be replaced on a scale that would matter.

Keeping the facts outlined above in mind, the notion of sustainable development touches upon both of those issues. The current model of agriculture has to be improved to become more sustainable in order to produce more ecosystem services or at least minimize the ecosystem disservices. Also, the urban planning needs to address the issue of urban sprawl and plan for more sustainable cities in the future. The idea of sustainable development clearly transcends all these issues and should be clearly more addressed in the policy making for all the sectors involved. Some studies have highlighted this struggle to achieve a sustainable development in agriculture in the light of decreasing area of land dedicated to this land use. Indeed, there is now an increasing pressure to meet the growing food demand of exponentially evolving human population with limited land expansion while at the same time minimizing the consumption of energy and water and conserving the environment. The approach to try to meet all these different demands is described as a food-energy-water nexus approach (Nie et al., 2019). It outlines that major challenge in agricultural land use arises from the presence of multiple stakeholders with different and often competing objectives, such as profit, food demand, environmental goals and efficient use of resources (Stewart et al., 2004, Garcia and You, 2016). In this regard, the problem of land optimization has to be studied as a multi-objective problem. (Seppelt, 2016). These challenges suggest that there is a need for a robust and systematic method to derive trade-offs for land use decision making. (Nie et al., 2019)

8 CONCLUSION

This dissertation focused on the ecosystem services which are provided by agriculture land and urban sprawl in the study area of municipality with extended powers Třebíč. Four ecosystem services provided by agricultural land were identified and evaluated through different methodologies in the scope of this research. These services were prevention of water contamination, carbon sequestration, production function and prevention of soil erosion. The research also focused on determining the amount of area lost due to urban sprawl in the municipality with extended powers Třebíč.

The main outcomes of this dissertation show that in most cases and for most of the typical arable crops in the Czech Republic, agriculture provides a disservice to the ecosystems rather than a service. The one notable exception is the provision of food, which is indeed the vital and primary function of agriculture land. There was evidence suggesting that permanent grassland could be much more benefitting in the terms of the provision of ecosystem services, yet it was not fully included in this study due to modelling limitations. The results also showed that much can be done for a better provision of ecosystem services through sustainable management of land and through implementation of different practices and measures. It should also be noted that the research focused solely on arable and did not study the benefits of features adhering to agriculture land, which often have much more value in terms of ecosystems and biodiversity.

As for the urban sprawl, the research showed that the area of agricultural land is indeed steadily decreasing and some if it can be attributed to urban sprawl. The analysis of possible future trends also showed that this development will continue. It can be concluded that even if agriculture land does not provide all ecosystem services, it is still our main resource of food. Some of the ecosystem services can be reinstated in urban ecosystems, yet the provision of food is hardly replaceable on a scale that would matter.

The discussion and comparison to studies on similar topics in the Czech Republic has put the results in a wider context. The provision of ecosystem disservices ties closely to land degradation, as most of the processes identified through this research fit into the definition. Several studies have also suggested that due to historical developments in the Czech Republic and some specific conditions, this degradation process can be linked with the land fragmentation and tenure insecurity. The agriculture land in terms of ownership in the Czech Republic tends to be very fragmented yet the average area of soil blocks is the biggest in the EU. Most of the land is also rented as the small ownership blocks can hardly be used otherwise and also due to the fact that historic developments have prevented the preservation of family farm model. This research showcased similarities with these conclusions as most of the land in the area is farmed on by large cooperatives and large blocks of soil are also occurring.

As for the ecosystem services themselves, other studies have proven that better management of agriculture land can lead to provision of more services. More wider studies have also shown that for some crop types and for permanent grassland there are more ecosystem services to be considered than just the ones included in this research. Also the values attributed to some ecosystem services vary due to different methodologies used. Some studies have also found closer ties of ecosystem services provision to management types (e.g. organic agriculture) than this research.

As for the policies which impact all the elements included in this research, the Common Agricultural Policy influences the management of agricultural land, the spatial planning is controlled through Building Act and the agriculture land is also protected against urban development through Act on Protection of Agriculture Land Resources. The CAP can shape the agriculture towards a more sustainable management of land and better protection of environment, while the Building Act can be formulated to protect against uncontrolled urban sprawl and better preservation of rural areas and communities. The methodology used in the Act on Protection of Agriculture Land Resources to calculate the fees to change the landuse can also be updated with the ecosystem services evaluation to better reflect the evolving notions of ecosystem functioning and biodiversity protection.

As the wide notion of sustainable development suggests, the underlying issue of ecosystem disservice provision, land degradation, ownership fragmentation and urban sprawl can be targeted through a policy mix aiming at the three pillars of sustainability – economic, environmental and social. Indeed, if we would look at the economic side, we would need a better provision of credit and better access to land for farmers, with an income that would be comparable to the rest of the society, to tackle the ownership fragmentation. The social pillar also plays a role in providing for a decent lifestyle of farmers and preservation of rural communities. The environmental comes as the result of these changes, as more competitive farmers who would be able to buy the farmland would be able to provide for a better provision of public goods and better environment protection, responding in this regard also to the societal demands.

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12 PUBLISHED WORK OF THE PHD STUDENT

Journal articles

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Ing. Katerina Vrublova, Mgr. Jarmila Fillipovova, Mgr. Tomas Vitek. APPLYING OF BIOGEOGRAPHY MODEL TO FOREST MANAGEMENT STRATEGY UNDER CLIMATE CHANGE IN CENTRAL EUROPE. In SGEM2017 Conference Proceedings, ISBN 978-619-7408-05-8 / ISSN 1314-2704, 29 June - 5 July, 2017, Vol. 17, Issue 32, 727-734 pp, DOI: DOI: 10.5593/sgem2017/32/S14.094

Conference presentations

Vrublova, K. Jak agenda greeningu, a zejména plochy v ekologickém zájmu, ovlivňují podobu zemědělské krajiny v Česku (in Czech). (Presented at conference Venkovská Krajina, Hostětín, Czech Republic, 19-21th May, 2017)

13 ANNEX I CLASSIFICATION OF ECOSYSTEM SERVICES ACCORDING TO CICES

Section	Division	Group	Class
Provisioning (Biotic)	Biomass	Cultivated terrestrial plants for nutrition, materials or energy	Cultivated terrestrial plants (including fungi, algae) grown for nutritional purposes
Provisioning (Biotic)	Biomass	Cultivated terrestrial plants for nutrition, materials or energy	Fibres and other materials from cultivated plants, fungi, algae and bacteria for direct use or processing (excluding genetic materials)
Provisioning (Biotic)	Biomass	Cultivated terrestrial plants for nutrition, materials or energy	Cultivated plants (including fungi, algae) grown as a source of energy
Provisioning (Biotic)	Biomass	Cultivated aquatic plants for nutrition, materials or energy	Plants cultivated by in- situ aquaculture grown for nutritional purposes
Provisioning (Biotic)	Biomass	Cultivated aquatic plants for nutrition, materials or energy	Fibres and other materials from in-situ aquaculture for direct use or processing (excluding genetic materials)
Provisioning (Biotic)	Biomass	Cultivated aquatic plants for nutrition, materials or energy	Plants cultivated by in- situ aquaculture grown as an energy source
Provisioning (Biotic)	Biomass	Reared animals for nutrition, materials or energy	Animals reared for nutritional purposes
Provisioning (Biotic)	Biomass	Reared animals for nutrition, materials or energy	Fibres and other materials from reared animals for direct use or processing (excluding genetic materials)
Provisioning (Biotic)	Biomass	Reared animals for nutrition, materials or energy	Animals reared to provide energy (including mechanical)
Provisioning (Biotic)	Biomass	Reared aquatic animals for nutrition, materials or energy	Animals reared by in-situ aquaculture for nutritional purposes

Section	Division	Group	Class
Provisioning (Biotic)	Biomass	Reared aquatic animals for nutrition, materials or energy	Fibres and other materials from animals grown by in-situ aquaculture for direct use or processing (excluding genetic materials)
Provisioning (Biotic)	Biomass	Reared aquatic animals for nutrition, materials or energy	Animals reared by in-situ aquaculture as an energy source
Provisioning (Biotic)	Biomass	Wild plants (terrestrial and aquatic) for nutrition, materials or energy	Wild plants (terrestrial and aquatic, including fungi, algae) used for nutrition
Provisioning (Biotic)	Biomass	Wild plants (terrestrial and aquatic) for nutrition, materials or energy	Fibres and other materials from wild plants for direct use or processing (excluding genetic materials)
Provisioning (Biotic)	Biomass	Wild plants (terrestrial and aquatic) for nutrition, materials or energy	Wild plants (terrestrial and aquatic, including fungi, algae) used as a source of energy
Provisioning (Biotic)	Biomass	Wild animals (terrestrial and aquatic) for nutrition, materials or energy	Wild animals (terrestrial and aquatic) used for nutritional purposes
Provisioning (Biotic)	Biomass	Wild animals (terrestrial and aquatic) for nutrition, materials or energy	Fibres and other materials from wild animals for direct use or processing (excluding genetic materials)
Provisioning (Biotic)	Biomass	Wild animals (terrestrial and aquatic) for nutrition, materials or energy	Wild animals (terrestrial and aquatic) used as a source of energy
Provisioning (Biotic)	Genetic material from all biota (including seed, spore or gamete production)	Genetic material from plants, algae or fungi	Seeds, spores and other plant materials collected for maintaining or establishing a population
Provisioning (Biotic)	Genetic material from all biota (including seed, spore or gamete production)	Genetic material from plants, algae or fungi	Higher and lower plants (whole organisms) used to breed new strains or varieties

Section	Division	Group	Class
Provisioning (Biotic)	Genetic material from all biota (including seed, spore or gamete production)	Genetic material from plants, algae or fungi	Individual genes extracted from higher and lower plants for the design and construction of new biological entities
Provisioning (Biotic)	Genetic material from all biota (including seed, spore or gamete production)	Genetic material from animals	Animal material collected for the purposes of maintaining or establishing a population
Provisioning (Biotic)	Genetic material from all biota (including seed, spore or gamete production)	Genetic material from animals	Wild animals (whole organisms) used to breed new strains or varieties
Provisioning (Biotic)	Genetic material from all biota (including seed, spore or gamete production)	Genetic material from organisms	Individual genes extracted from organisms for the design and construction of new biological entities
Provisioning (Biotic)	Other types of provisioning service from biotic sources	Other	Other
Provisioning (Abiotic)	Water	Surface water used for nutrition, materials or energy	Surface water for drinking
Provisioning (Abiotic)	Water	Surface water used for nutrition, materials or energy	Surface water used as a material (non-drinking purposes)
Provisioning (Abiotic)	Water	Surface water used for nutrition, materials or energy	Freshwater surface water used as an energy source
Provisioning (Abiotic)	Water	Surface water used for nutrition, materials or energy	Coastal and marine water used as energy source
Provisioning (Abiotic)	Water	Ground water for used for nutrition, materials or energy	Ground (and subsurface) water for drinking
Provisioning (Abiotic)	Water	Ground water for used for nutrition, materials or energy	Ground water (and subsurface) used as a material (non-drinking purposes)
Provisioning (Abiotic)	Water	Ground water for used for nutrition, materials or energy	Ground water (and subsurface) used as an energy source
Provisioning (Abiotic)	Water	Other aqueous ecosystem outputs	Other

Section	Division	Group	Class
Regulation & Maintenance (Biotic)	Transformation of biochemical or physical inputs to ecosystems	Mediation of wastes or toxic substances of anthropogenic origin by living processes	Bio-remediation by micro-organisms, algae, plants, and animals
Regulation & Maintenance (Biotic)	Transformation of biochemical or physical inputs to ecosystems	Mediation of wastes or toxic substances of anthropogenic origin by living processes	Filtration/sequestration/storage/accumulation by micro-organisms, algae, plants, and animals
Regulation & Maintenance (Biotic)	Transformation of biochemical or physical inputs to ecosystems	Mediation of nuisances of anthropogenic origin	Smell reduction
Regulation & Maintenance (Biotic)	Transformation of biochemical or physical inputs to ecosystems	Mediation of nuisances of anthropogenic origin	Noise attenuation
Regulation & Maintenance (Biotic)	Transformation of biochemical or physical inputs to ecosystems	Mediation of nuisances of anthropogenic origin	Visual screening
Regulation & Maintenance (Biotic)	Regulation of physical, chemical, biological conditions	Regulation of baseline flows and extreme events	Control of erosion rates
Regulation & Maintenance (Biotic)	Regulation of physical, chemical, biological conditions	Regulation of baseline flows and extreme events	Buffering and attenuation of mass movement
Regulation & Maintenance (Biotic)	Regulation of physical, chemical, biological conditions	Regulation of baseline flows and extreme events	Hydrological cycle and water flow regulation (Including flood control, and coastal protection)
Regulation & Maintenance (Biotic)	Regulation of physical, chemical, biological conditions	Regulation of baseline flows and extreme events	Wind protection
Regulation & Maintenance (Biotic)	Regulation of physical, chemical, biological conditions	Regulation of baseline flows and extreme events	Fire protection
Regulation & Maintenance (Biotic)	Regulation of physical, chemical, biological conditions	Lifecycle maintenance, habitat and gene pool protection	Pollination (or 'gamete' dispersal in a marine context)

Section	Division	Group	Class
Regulation & Maintenance (Biotic)	Regulation of physical, chemical, biological conditions	Lifecycle maintenance, habitat and gene pool protection	Seed dispersal
Regulation & Maintenance (Biotic)	Regulation of physical, chemical, biological conditions	Lifecycle maintenance, habitat and gene pool protection	Maintaining nursery populations and habitats (Including gene pool protection)
Regulation & Maintenance (Biotic)	Regulation of physical, chemical, biological conditions	Pest and disease control	Pest control (including invasive species)
Regulation & Maintenance (Biotic)	Regulation of physical, chemical, biological conditions	Pest and disease control	Disease control
Regulation & Maintenance (Biotic)	Regulation of physical, chemical, biological conditions	Regulation of soil quality	Weathering processes and their effect on soil quality
Regulation & Maintenance (Biotic)	Regulation of physical, chemical, biological conditions	Regulation of soil quality	Decomposition and fixing processes and their effect on soil quality
Regulation & Maintenance (Biotic)	Regulation of physical, chemical, biological conditions	Water conditions	Regulation of the chemical condition of freshwaters by living processes
Regulation & Maintenance (Biotic)	Regulation of physical, chemical, biological conditions	Water conditions	Regulation of the chemical condition of salt waters by living processes
Regulation & Maintenance (Biotic)	Regulation of physical, chemical, biological conditions	Atmospheric composition and conditions	Regulation of chemical composition of atmosphere and oceans
Regulation & Maintenance (Biotic)	Regulation of physical, chemical, biological conditions	Atmospheric composition and conditions	Regulation of temperature and humidity, including ventilation and transpiration

Section	**Division**	**Group**	**Class**
Regulation & Maintenance (Biotic)	Other types of regulation and maintenance service by living processes	Other	Other
Cultural (Biotic)	Direct, in-situ and outdoor interactions with living systems that depend on presence in the environmental setting	Physical and experiential interactions with natural environment	Characteristics of living systems that that enable activities promoting health, recuperation or enjoyment through active or immersive interactions
Cultural (Biotic)	Direct, in-situ and outdoor interactions with living systems that depend on presence in the environmental setting	Physical and experiential interactions with natural environment	Characteristics of living systems that enable activities promoting health, recuperation or enjoyment through passive or observational interactions
Cultural (Biotic)	Direct, in-situ and outdoor interactions with living systems that depend on presence in the environmental setting	Intellectual and representative interactions with natural environment	Characteristics of living systems that enable scientific investigation or the creation of traditional ecological knowledge
Cultural (Biotic)	Direct, in-situ and outdoor interactions with living systems that depend on presence in the environmental setting	Intellectual and representative interactions with natural environment	Characteristics of living systems that enable education and training
Cultural (Biotic)	Direct, in-situ and outdoor interactions with living systems that depend on presence in the environmental setting	Intellectual and representative interactions with natural environment	Characteristics of living systems that are resonant in terms of culture or heritage
Cultural (Biotic)	Direct, in-situ and outdoor interactions with living systems that depend on presence in the environmental setting	Intellectual and representative interactions with natural environment	Characteristics of living systems that enable aesthetic experiences
Cultural (Biotic)	Indirect, remote, often indoor interactions with living systems that do not require presence in the environmental setting	Spiritual, symbolic and other interactions with natural environment	Elements of living systems that have symbolic meaning

Section	Division	Group	Class
Cultural (Biotic)	Indirect, remote, often indoor interactions with living systems that do not require presence in the environmental setting	Spiritual, symbolic and other interactions with natural environment	Elements of living systems that have sacred or religious meaning
Cultural (Biotic)	Indirect, remote, often indoor interactions with living systems that do not require presence in the environmental setting	Spiritual, symbolic and other interactions with natural environment	Elements of living systems used for entertainment or representation
Cultural (Biotic)	Indirect, remote, often indoor interactions with living systems that do not require presence in the environmental setting	Other biotic characteristics that have a non-use value	Characteristics or features of living systems that have an existence value
Cultural (Biotic)	Indirect, remote, often indoor interactions with living systems that do not require presence in the environmental setting	Other biotic characteristics that have a non-use value	Characteristics or features of living systems that have an option or bequest value
Cultural (Biotic)	Other characteristics of living systems that have cultural significance	Other	Other

14 ANNEX II SURVEY AMONGST FARMERS

INFORMATION ABOUT THE FARM	
Name of the farm	
Village	
Average annual temperature	
Size of the farm	1) small 2) medium 3) big
Intensity of production	1) small 2) medium 3) big
Type of farm	1) arable crops
	2) land lying fallow
	3) arable land - other
	4) arable land - specialized
	5) livestock
	6) livestock - PG
	7) livestock - grassland
	8) livestock - no land
	9) dairy farming - no land
	10) dairy farming - other
	11) dairy - PG
	12) dairy - grassland
	13) garden products
	14) mixed farm
	15) mixed livestock production
	16) permanent crops
	17) pig farming - no land
	18) pig farming - other
	19) poultry
GENERAL INFORMATION	
Type of crop/production	
4 most important crops + number of ha	1) permanent grassland
	2) clover mixtures
	3) clover
	4) lucerne
	5) leguminous crops

	6) other nitrogen fixing crops
	7) maize
	8) winter barley
	9) spring barley
	10) spring wheat
	11) winter wheat
	12) rye
	13) other cereals
	14) potatoes
	15) rape
	16) other non-nitrogen crops
	17) other root crops
	18) other crops with tubers
	19) other crops
Year of production	
Date of planting	
Date of harvest	
The amount of fresh produce in tonnes	
The amount of final produce in tonnes	
Are there any side products?	
Percentage rate of the side product from the main crop	
What is the harvest index?	0,3 - 0,6
INFORMATION ABOUT THE CROP	
Prevailing texture of soil	fine/medium/coarse
Soil type	fine: sandy clay, clay, dusty clay
	Medium: clay soil with clay
	Coarse: sandy soil or clay soil without clay, flood plains
Soil organic matter	up to 1,72% of organic matter in soil
	1,72 – 5,16%
	5,16 – 10,32%
	more than 10,32%
Soil moisture	1) Moist - if there is no significant limitation associated with soil moisture or

	2) Dry - if there is a limit, eg at a certain time the evaporation exceeds the amount of precipitation
Field water capacity	cm3/cm3
Soil moisture when planting	wet/moist/dry
Soil permeability	1) Clay - bad permeability
	2) Other soils - good permeability
Prevailing soil pH	pH under 5.5
	5.5 - 7.3
	7.3 - 8.5
	Over 8.5
FERTILIZERS	
Overall application of fertilizers in tonnes	
How many tonnes of fertilizers are applied on arable land?	
Nutrient consumption in mineral fertilizers - tonnes of nutrients alone	N, P2O5, K2O
Type of fertilizer	compost (from fully aerated production) - 1% N
	Compost from non-aerated 1% N production
	Compost without emissions 1% N
	Ammonium carbonate 18% N
	Ammonium Chloride 25% N
	Ammonium nitrate 33.5% N, granulated
	Ammonium nitrate, 33.5% N,
	Sulfur nitrate 21% N
	Sulfur ammonium nitrate
	Ammonium anhydride 82% N
	Ammonium calcium nitrate 27% N
	Calcium nitrate 15.5% N
	Own NPK
	NPK 15% N, 15% K2O, 15% P2O5 - acidic process
	NPK 15% N, 15% K2O, 15% P2O5 - nitrophosphate process
	Ammonium Phosphate 18% N

	ammonium dihydrogenphosphate 11% N 52% P2O5
	Potash / Potassium Chloride, 60% K2O
	Phosphate / phosphate rock 32% P2O5
	Superphosphate 21% P2O5
	Triple superphosphate 48% P2O5
	Urea
	Urea solution and ammonium nitrate
	Dung: from broilers / turkeys
	Cow manure 0,6% N
	Cattle cattle
	Horse manure 0.7% N
	Pig dung
	Pigmeat
	Poultry manure
	Separated porcine slurry - liquid part
	Separated porcine slurry - rigid part
	Sheep and Goat Dung
	Limestone of 55% CaCO3
Country of origin	
Amount (tonnes/ha)	
Rate measure	
Application method	1) application in solution,
	2) full-area application,
	3) Incorporation into soil,
	4) Subsurface drip
Did you use the inhibitor of emissions?	
PESTICIDES	
Category	1 / post-emergence (post-emergence) 2 / seed treatment 3 / soil treatment
Applicaton	
management of post-harvest remnants	

Amount in tonnes	
How are the remnants after grasslands managed	1. remain in the field / incorporated / mulched
	2. Removed, left untreated in heaps or excavations
	3. Removed, composting without aeration
	4. Removed, composting with aeration
	5. Burned
	6. exported outside the farm
Harvest of straw in tonnes	1. cereals
	2. legumes
	3. oilseeds
LAND MANAGEMENT	
Was any part of the farm area transformed from one land use type to another during the last 20 years?	Select land use type: arable land, permanent grassland, forest
How many years ago was this?	
The percentage amount of the area transformed	
Did you change the farm management in the last 20 years?	1 / from plowing - change to reduced plow
	Explanatory note: Without plow means direct sowing with the help of a sowing machine without any preliminary preparation
	2 / no plow - change to conventional plow
	Explanation - A conventional plow uses plows or uses discs to a depth of more than 5 cm
	3 / reduced plowing - without plowing
	4 / reduced plowing - conventional plows
	5 / conventional plow - no plow
	6 / conventional plowing - plow reduction
How many years ago was this?	
The percentage amount of area with different farm management	
Did you start to grow a cover crop during the last 20 years?	1 / no, I farm for 20 years without cover crop
	2 / Yes, I introduced a cover crop

If so, how many years ago was the cover crop introduced?	
The percentage amount of are with cover crop	
The amount of cover crop in tonnes used for manure	
ENERGY SOURCES FOR FIELD OPERATIONS	
Energy source	diesel
	benzine
	bioethanol
	biodiesel
	electricity from the grid
	electricity from water sources
	electricity from photovolatics,
	high quality biomass
	firewood
	coal
	gas
	oil
The amount of energy used	kg, volume of substance, energy unit
Field operations	
	Plow
	Smooth plow
	Chain / knife blade
	Disc gates
	Disk "Potato Rake / Other"
	Field Cultivator
	Baker
	Seeder
	Seed drill for immortal technology
	Trencher
	Sniper
	Pneumatic drill - pneumatic seed drill (universal, ...)

	Hoop / rod gate
	Roller gates
	Roller runner / roller
	Rotary hoe / stubble
	Row crop cultivator
	Line crop chopper
	Underlayer
	rotary plow (sweep plow)
	Nail gates
	Assembling (shredder)
	Pneumatic gates
	Fertilizer injector
	Disk entrainment
	Cylinder traction
	Potato planter
	Potato harvester
	SPRAYERS / DIMENSIONERS
	Spraying of herbicides
	Spreading of fertilizers
	Fertilizer spreading
	Spray of Biocides "
	HARVEST
	Lis (common)
	Beet harvester
	Combine
	Combine harvester, for maize
	Cotton picker / potato cutter
	Sweeper
	The forage harvester
	Manure spreader
	Mowing machine / grader (grader)
	Fowler
	Potato harvester
	Potato mowers

	Scrapper / Scrapper
	Tomato raptor
	Cutting machine
Type of fuel	oil/gas
Number of operations per year	
Irrigation	
Waste water	
TRANSPORTATION TO AND FROM FARM	
Type of transportation	1 / road transport - diesel,
	2 / road transport - gasoline
	3 / road transport - CNG / LNG
	4 / Railways
	5 / air transport - for very short distances
	6 / air transport - short distances
	7 / air - long distances
	8 / shipping - small tanker
	9 / Ship - Large tanker
	10 / ship - very large tanker
	11 / ship - small carrier of goods
	12 / Ship - a large freight forwarder
	13 / ship - very large commodity carrier
	14 / ship - small container transport
	15 / Ship - Large container shipping
Weight in tonnes	
Distance	

Palacký University Olomouc

Faculty of Science
Department of Development and Environmental Studies

Study programme/Studijní program: **P1314 Geography/P1314 Geografie**

Discipline/Obor: **International Development Studies/Mezinárodní rozvojová studia**

Evaluation of ecosystem services loss due to urban sprawl on agricultural land in the context of sustainable development

Hodnocení ztrát ekosystémových služeb vlivem zástavby zemědělské půdy v kontextu udržitelného rozvoje

Doctoral dissertation summary
Autoreferát dizertační práce

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Obhajoba disertační práce se koná ve dnech 13-14. 6. 2019 před komisí pro obhajoby disertačních prací doktorského studia v oboru P1314 Geografie, studijním oboru 6702V004 Mezinárodní rozvojová studia, v prostorách Přírodovědecké fakulty Univerzity Palackého v Olomouci, 17. listopadu 12, 771 47 Olomouc.

The defence of this dissertation will be held on 13-14th June 2019 in front of the commission for Ph.D. degree dissertation defence in study programme P1314 Geography, specialization 6702V004 International Development Studies, on the premises of the Faculty of Science, Palacký University in Olomouc, 17. listopadu 12, 771 47 Olomouc.

S disertační prací je možno se seznámit na studijním oddělení Přírodovědecké fakulty Univerzity Palackého v Olomouci, 17. listopadu 12, 77 46 Olomouc.

The dissertation thesis is available at the Study Department, Faculty of Science,

Palacký University in Olomouc, 17. listopadu 12, 771 46 Olomouc.

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2 ABSTRACT

This dissertation focuses on the ecosystem services which are provided by agriculture land and urban sprawl in the study area of municipality with extended powers Třebíč. The main focus of the dissertation is to evaluate what ecosystem services are provided to Czech society by the agricultural land and assess their financial value and also evaluate which ecosystem services disappear or are limited due to urban sprawl on agricultural land.

The practical output of this dissertation will comprise of better insight on function and value of land under agriculture use which is lost due to urban development and raising the awareness amongst the society on the fast-growing trend of unsustainable urban sprawl.

The main outcomes of this dissertation show that in most cases and for most of the typical arable crops in the Czech Republic, agriculture provides a disservice to the ecosystems rather than a service. The one notable exception is the provision of food, which is indeed the vital and primary function of agriculture land. The results also show that much can be done for a better provision of ecosystem services through sustainable management of land and through implementation of different practices and measures.

As for the urban sprawl, the research shows that the area of agricultural land is indeed steadily decreasing and some if it can be attributed to urban sprawl. The analysis of possible future trends also showed that this development will continue. It can be concluded that even if agriculture land does not provide all ecosystem services, it is still our main resource of food. Some of the ecosystem services can be reinstated in urban ecosystems, yet the provision of food is hardly replaceable on a scale that would matter.

As for the policies which impact all the elements included in this research, the Common Agricultural Policy influences the management of agricultural land, the spatial planning is controlled through Building Act and the agriculture land is also protected against urban development through Act on Protection of Agriculture Land Resources. The CAP can shape the agriculture towards a more sustainable management of land and better protection of environment, while the Building Act can be formulated to protect against uncontrolled urban sprawl and better preservation of rural areas and communities. The methodology used in the Act on Protection of Agriculture Land Resources to calculate the fees to change the landuse can also be updated with the ecosystem services evaluation to better reflect the evolving notions of ecosystem functioning and biodiversity protection.

As the wide notion of sustainable development suggests, the underlying issue of ecosystem disservice provision, land degradation, ownership fragmentation and urban sprawl can be targeted through a policy mix aiming at the three pillars of sustainability – economic, environmental and social.

Key words: ecosystem services evaluation, urban sprawl, land degradation, biodiversity, carbon sequestration, nutrient run-off, soil erosion

Tato disertační práce se zaměřuje na ekosystémové služby, které jsou poskytovány zemědělskou půdou a zástavbě této zemědělské půdy v zájmové oblasti obce s rozšířenou působností Třebíč. Hlavním cílem disertační práce je zhodnotit, jaké ekosystémové služby jsou české společnosti poskytovány zemědělskou půdou a posoudit jejich finanční hodnotu a také zhodnotit, které ekosystémové služby zanikají nebo jsou omezeny v důsledku zástavby zemědělské půdy.

Praktickým výstupem této disertační práce bude lepší pochopení hodnoty zemědělsky využívané půdy, které je ztracena v důsledku rozvoje měst a take zvyšování povědomí společnosti o rychle rostoucím trendu neudržitelné zástavby zemědělské půdy.

Hlavní výsledky této disertační práce ukazují, že ve většině případů poskytuje zemědělství pro okolní ekosystémy spíše zátěž než službu. Jednou z důležitých výjimek je poskytování potravin, což je skutečně zásadní a primární funkce zemědělské půdy. Výsledky také ukazují, že mnoho lze udělat pro lepší poskytování ekosystémových služeb prostřednictvím udržitelného hospodaření s půdou a prostřednictvím implementace různých přírodě blízkých postupů a opatření.

Pokud jde o zástavbu zemědělské půdy, výzkum ukazuje, že procento zemědělské půdy se neustále snižuje a částečně to lze připsat rozrůstání měst a obcí. Analýza možných budoucích trendů také ukázala, že tento vývoj bude pokračovat. Lze konstatovat, že i když zemědělská půda neposkytuje všechny ekosystémové služby, je stále naším hlavním zdrojem potravin. Některé z ekosystémových služeb mohou být obnoveny v městských ekosystémech, ale poskytování potravin je těžko nahraditelné v takové kapacitě, jakou poskytuje zemědělská půda.

Pokud jde o politiku, které má vliv na všechny prvky tohoto výzkumu, společná zemědělská politika ovlivňuje hospodaření na zemědělské půdě, územní plánování je řízeno stavebním zákonem a zemědělská půda je chráněna před rozvojem měst prostřednictvím zákona o ochraně zemědělské půdního fondu. SZP může formovat zemědělství směrem k udržitelnému zacházení s půdou a lepší ochraně životního prostředí, zatímco stavební zákon může být formulován tak, aby chránil před nekontrolovaným rozrůstáním měst a lepší ochranou venkovských oblastí. Metodika použitá v zákoně o ochraně zemědělských půdy pro výpočet poplatků za vynětí ze zemědělského půdního fondu může být také aktualizována hodnocením ekosystémových služeb, aby tak lépe odrážela rozvíjející se představy o fungování ekosystémů a ochraně biodiverzity.

Základní představa o udržitelném rozvoji naznačuje, že problém poskytování ekosystémových služeb, degradace půdy, roztříštěnosti vlastnictví zemědělské půdy a rozrůstání měst a obcí může být řešen prostřednictvím kombinace politik zaměřených na tři pilíře udržitelnosti - ekonomický, environmentální a sociální.

Klíčová slova: hodnocení ekosystémových služeb, zástavba zemědělské půdy, degradace půdy, biodiverzita, sekvestrace uhlíku, odtok živin, eroze půdy

3 INTRODUCTION

Ecosystem services and their evaluation is a concept which has been long gaining steam amongst scientists. The idea behind this concept is to assess the value of those services that nature provides to us (e.g. provision of oxygen through photosynthesis, climate regulation, carbon sequestration, food production, recreation etc.). It also became self-evident that we do need to put forward this concept and raise the awareness just as the value of these ecosystems is declining and we face a severe biodiversity loss in span of just a couple of decades. Through the ecosystem services evaluation we help to transform these values into a concept that every citizen would understand – into monetary value. This aims to bring the attention to severe ecosystem services loss and bring this closer to everyday discourse, outside of the scope of purely scientific bodies.

The idea of ecosystem services also closely links to sustainability and the strive to make our lives and our everyday practices and development more sustainable. The concept of sustainability came into broader knowledge in the 90’s and it is also connected to the idea of halting biodiversity loss and adjust our actions in order to achieve a sustainable development. In this sense, all these concepts are still rather new and aim to educate the wider population that our current way of life has its consequences and we need to make radical changes in order to sustain this planet for the future generation.

One of the ways of how the landscape and ecosystems around us are dramatically changing is urban sprawl, which means transforming the area from its natural way in order to fit our needs, in most cases permanently and without the possibility to reverse it. This is one of the most prolific cases when human settlements shape the area we inhabit in a permanent manner. In order to address this issue, we should in the best-case scenario aim to the point in which this urban sprawl takes place in a manner which is sustainable and takes into consideration also the provision of ecosystem services.

Most of the area which is now being urbanized in Europe is agriculture land. This is due to the nature of colonisation in Europe where urban settlement has been proceeding for many centuries and therefore most of the landscape is cultural, with agriculture and forestry being the most prevalent type of land use. In this regard, most of the land which is being transformed is being now used for agriculture. If we would therefore want to address how might the urban sprawl impact on the sustainability and ecosystem services, we would need to assess what values are we losing through the development on agriculture land.

This will be indeed the main goal of this dissertation - to evaluate what ecosystem services are provided to Czech society by the agricultural land and assess their financial value and also evaluate which ecosystem services disappear or are limited due to urban sprawl on agricultural land. The outcome of this dissertation will be a note of recommendation to policy makers. Ecosystem services are today one of the main indicators of what financial value does each ecosystem have and their calculation will lead to specification of its overall value in the Czech Republic.

The practical output of this dissertation will comprise of better insight on function and value of land under agriculture use which is lost due to urban development and raising the awareness amongst the society on the fast-growing trend of unsustainable urban sprawl. By including the evaluation of ecosystem services into policy making a better protection of land might be achieved. It would also strengthen the pursuit of sustainable development of cities and villages without the uncontrolled urban sprawl. There are currently about 6100 hectares of agriculture land that disappear every year. In order for this area loss to resonate even louder, we need to put a price tag on the services which have been lost and stand for a more balanced approach in future policy making.

4 LITERATURE REVIEW

4.1. Ecosystem services

4.1.1. Definition of ecosystem services

The notion of naming and systematizing services provided by nature and environment to the human population began to take shape in the 1970´s with the term “environmental services”. The term was introduced in the 1970 report of the Study of Critical Environmental Problems (SCEP, 1970) and the definition and classification of environment services goes as follows:

“Environmental services refer to qualitative functions of natural non—produced assets of land, water and air (including related ecosystem) and their biota.” (Glossary of Environment Statistics, 1997)

They are classified as:

(a) disposal services which reflect the functions of the natural environment as an absorptive sink for residuals,

(b) productive services which reflect the economic functions of providing natural resource inputs and space for production and consumption, and

(c) consumer or consumption services which provide for physiological as well as recreational and related needs of human beings. (Glossary of Environment Statistics, 1997)

Moving on in time, in 1977, Westman (1977) presented the idea that the social value of the benefits that ecosystems provide could potentially be enumerated so that society can make more informed policy and management decisions and he named these social benefits ‘nature’s services.

Later the term “ecosystem services” was coined and it has been used in the scientific circles ever since. The term itself was first used by Ehrlich and Ehrlich (1981). Then the ecosystem services came into wider knowledge in the 1997 following among other things the publication of the article “The value of the world’s ecosystem services and natural capital” (Costanza, 1997) and the book Nature´s services: Societal dependence on natural ecosystems (Daily, 1997). Costanza defines ecosystem services as: *“benefits human populations derive, directly or indirectly, from ecosystem functions”* (Costanza, 1997) while Daily describes them as: *“conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfil human life”* (Daily, 1997). These definitions were later expanded in the Millennium Ecosystem Assessment into: “*benefits people obtain from ecosystems. These include provisioning services such as food and water; regulating services such as regulation of floods, drought, land degradation, and disease; supporting services such as soil formation and nutrient cycling; and cultural services such as recreational, spiritual, religious and other non-material benefits.”* (MEA, 2005) Yet this concept is under scrutiny and several lead authors have acknowledged the need to keep this as an evolving concept (see Carpenter et al., 2006; Sachs and Reid, 2006).

Important is the notion that ecosystem services are linked to human well-being. Indeed naming the functions provided by the nature and by the environment as “services” provides a clear link to the terminology used in economics (even as it might seem as a degradation of ecosystem functions, in a sense that they supposedly only exist in order to fulfil human needs) and gives an opportunity to value these services.

4.1.2. Classification of ecosystem services

As the knowledge on ecosystem services expanded, so has the need to classify and name these services became more urgent. In his 1997 work, Costanza lists 17 ecosystem services, without any further classification into categories. De Groot (2002) expands on this list by adding six more services and classifies them into four categories: regulation functions, habitat functions, production functions and information functions. The list is following:

Regulation functions:

- Gas regulation
- Climate regulation
- Disturbance prevention
- Water regulation
- Water supply
- Soil retention
- Soil formation
- Nutrient regulation
- Waste treatment
- Pollination
- Biological control

Habitat functions:

- Refugium function
- Nursery function

Production functions:

- Food
- Raw materials
- Genetic resources
- Medicinal resources
- Ornamental resources

Information functions:

- Aesthetic information
- Recreation
- Cultural and artistic information
- Spiritual and historic information
- Science and education (Costanza et al. 1997, De Groot 1992, De Groot et al. 2000, De Groot 2002)

The methodology to classify ecosystem services has been changing throughout the years meaning that also the Millennium Ecosystem Assessment brought a slightly different categorization. It listed four main categories of ecosystem services, which are provisioning, regulating, cultural and supporting services (mostly renaming production function to provisioning services and information function to cultural services) with subcategories that slightly alternate with the categories by de Groot (2002). It needs to be noted that this classification is not meant to fit all purposes, and this has been pointed out for contexts regarding environmental accounting, landscape management and valuation, for which alternative classifications have been proposed (Boyd and Banzhaf, 2007; Wallace, 2007; Fisher and Turner, 2008). For the more contemporary initiatives for evaluation of ecosystem services and the categorization they use, The Economics of Ecosystems and Biodiversity (TEEB), a global initiative for mainstreaming the values of ecosystems and biodiversity, uses roughly the same list as the MEA (with slight alternations in the subcategories).

The most current classification is provided by the initiative of the Common International Classification of Ecosystem Services (CICES) which was developed from the work on environmental accounting done by the European Environment Agency (EEA). They saw it as particularly important to come up with a common classification. As the ecosystem accounting methods will continue to be developed, comparisons will have to be made between the different methods for which a standardized classification is needed. The first version of CICES was published in 2013 and the structure and scope has since then expanded, with versions being published regularly (the most recent one in March 2018). According to CICES, ecosystem services can be classified into three main categories – provisioning, regulation and maintenance and cultural, with many subcategories, divided also by the fact of being biotic and abiotic (see Annex I).

In the overview presented, we can see that ecosystem services are being promoted as a tool to assess the value humans place on these ecosystems and describe the benefits derived from natural resources (Costanza et al., 1997; De Groot et al., 2002; Abel et al., 2003; Chee, 2004; Groffman et al., 2004; Eamus et al., 2005; Kremen, 2005; Millennium Ecosystem Assessment, 2005; Farber et al., 2006). Indeed, if a wider use of ecosystem services is to be promoted, an effective framework for decision making needs to be presented, which would also assume a classification to allow comparisons and trade-offs amongst the relevant set of potential benefits (Wallace, 2007). Yet the current classifications tend to mix processes (means) for achieving services and the services themselves (ends) within the same classification category. Similar problem can be found in general texts and applied uses of ecosystem services and similar valuations (for example, Abel et al., 2003; Groffman et al., 2004; Anielski and Wilson, 2005; Kremen, 2005; Naiman et al., 2005). In order to provide a comprehensive classification useful for policymaking purposes, a set of key characteristics needs to be included:

- A minimum set of sharply defined terms that effectively encompass the topic.
- Clarity concerning the terms used to characterise services.
- Specification of the point at which linked processes deliver a service (Wallace, 2007).

Following this logic, a workable classification can be developed.

4.1.3. Concept of ecosystem services

When speaking about the concept of ecosystem services, there needs to be a clear distinction in terminology. In research, the term ecosystem comes together usually with the terms structure, function and finally the service. However, this does not mean that they are identical or synonymous. Ecosystem structure and function have been identified and studied for years without making any reference to the services to humans, which they also provide. Even as most ecosystem structures and processes do provide services they are not the same thing. Indeed, as mentioned above, the ecosystem services are only relevant when speaking about the benefits they provide to humans; otherwise the concept would not exist (Fisher, 2009).

The logic behind ecosystem services could be represented by the cascade in Figure 1. This diagram (making also the relationships and connections simpler and more linear as opposed to real world) makes a distinction between the primary structure which creates a potential for ecosystem service (ecological structure, e.g. woodlands or wetlands) and the benefits people derive from these structures – which are indeed the ecosystem services. (Haines-Young et al., 2010)

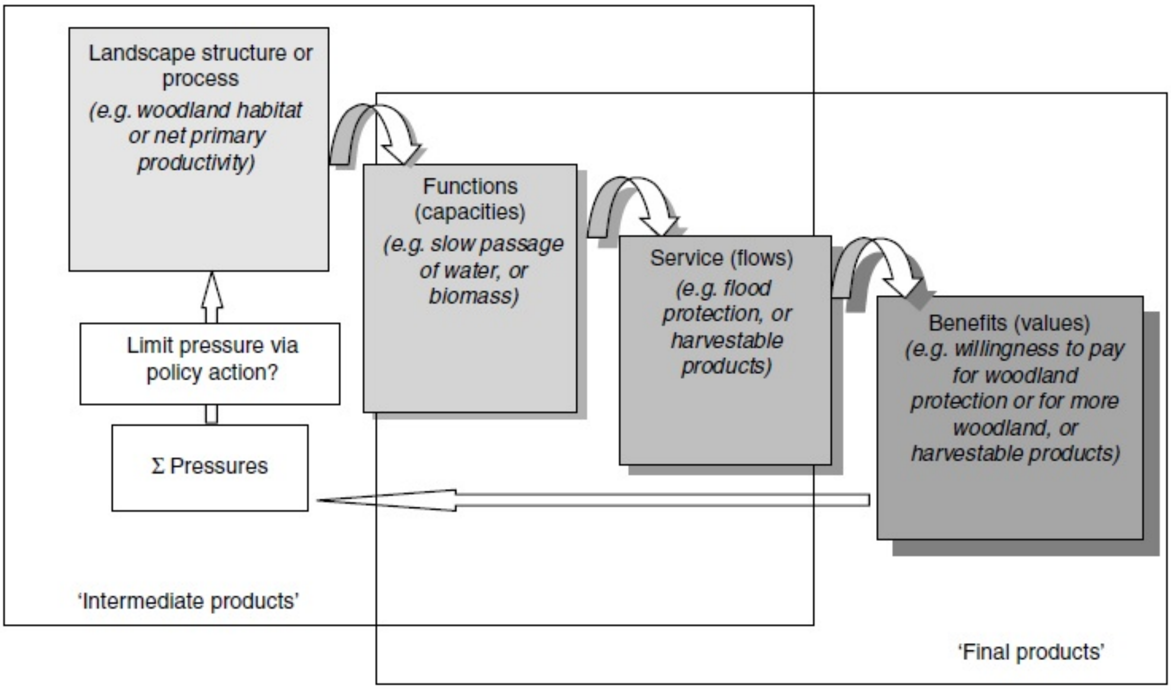

Figure 1 The relationship between biodiversity, ecosystem function and human well-being (Haines-Young et al., 2010)

It is important to say that the capacity or function (from which the ecosystem service is derived) of the primary structure is only taken into consideration when it is deemed useful for humans – therefore separating it from other fundamental capabilities or functions. Indeed for this we also need to find a specific benefit or beneficiary in order to distinguish clearly what is an ecosystem service and what is not. The observation that ecosystem services are defined by human activities and needs comes with an implication that due to the contingent nature of these services, a simple, generic checklist of services might never be devised. This links to the fact that categorization of ecosystem services is constantly evolving to incorporate new knowledge and new findings. (Haines-Young et al., 2010)

This cascade model can serve as a basis for developing conceptual models used for a wide assessment of ecosystem services. For example the conceptual framework developed as part of the Mapping and Assessment of Ecosystems and their Services was based on this cascade model together with the TEEB framework (de Groot et al.,2010) and the UK National Ecosystem Assessment (UKNEA, 2011) as well as some elements from the DPSIR framework (Drivers-Pressures-State-Impact-Response) (Kandziora et al.,2013). The DPSIR approach has traditionally been used in the conception and implementation of environmental legislation in Europe (Niemeijer and de Groot,2008). All together a working conceptualisation is needed for a viable approach to assess and value ecosystem services.

4.1.4. Methods for evaluating ecosystem services

Methods for evaluating ecosystem services have been outlined ever since the concept of ecosystem service came into popular view. The concept of valuation goes hand in hand with the idea that ecosystem services provide for human well-being and are thus linked to the production of added value in our daily lives. Otherwise the idea of putting a value on something as intangible as environmental aesthetics would be rather unwise or outright impossible (Costanza, 1997). Even though we can argue that we should protect ecosystems purely for moral or aesthetics reasons and do not need a valuation for this purpose, it is sometimes important to outline the value in terms every human understands (meaning in monetary terms) to win an argument for example when making a policy regarding nature conservation.

Many of ecosystem services valuation methods are based on the willingness to pay concept – stipulating that if for example if ecosystem functions in a well-managed forest leads up to 50 EUR/ha increment to the timber productivity, then beneficiaries of this service are expected to provide for this additional cost (Costanza, 1997). Moreover, we can usually distinct three different types of values – 1) actual or direct use values, 2) potential or indirect use values and 3) non-use or intrinsic values. To calculate monetary value, two methods are usually used – market pricing and shadow pricing. Note that market prices are mostly linked to active use values. (de Groot, 2000).

The measurement, modelling and monitoring of ecosystem functions are the foundation for ecosystem service valuation and are thus the basis for the sustainable use of biodiversity, ecosystems and natural resources in general (Carpenter et al. 2009). These different methods are discussed in detail through a variety of reviews and guidelines - for example, Barbier (2007), Bateman (2007), Bateman et al. (2002a), Champ et al. (2003), Freeman (2003), Hanley and Barbier (2009), Heal et al. (2005), Kanninen (2006) and Pagiola et al. (2004). The evaluation of ecosystem services in economic terms became an increasingly popular approach not only to assess alternative land use strategies but also to demonstrate and justify the need for the conservation of biodiversity (Bayon and Jenkins, 2010; Chan et al., 2007; Costanza et al., 1997; de Groot et al., 2002; Fisher et al., 2009; Ghazoul, 2007a, 2007b; Ridder, 2008; Wallace, 2007).

5 METHODOLOGY

5.1. Research objective, hypothesis and main research question

The objective of this research is to determine the value of ecosystem services provided by agriculture land which is lost due to urban sprawl. As many hectares of agriculture land a year are lost due to urban development, this valuation would serve as an argument for preserving agriculture land and preventing urban sprawl. The study area dedicated for this research is the municipality with extended powers Třebíč. This research aims to collect the data on the amount of agriculture land lost to urbanization in Třebíč and evaluate the ecosystem services that could no longer be provided by this land.

This topic was chosen in the light of the ever-growing rate of urban sprawl in Czech lands without sufficient policy and argumentation tool to address this trend. Hopefully the notion of ecosystem services evaluation might help to scale back this negative development.

The default hypothesis which is basis for this research is as follows: *"The value of ecosystem services provided by agriculture land in the municipality with extended powers Třebíč has decreased due to urban sprawl."*

From this hypothesis stems the main research question:

What is the value of ecosystem services provided by agriculture land which has been lost due to urban sprawl in the region of Třebíč?

This main research question will be divided into three more specific research question:

- Research question 1: What are the different ecosystem services provided by agriculture land?
- Research question 2: What is the value of these ecosystem services?
- Research question 3: What amount of agriculture land has been lost due to urban sprawl?

The structure of the research and of this dissertation shall be based on these research questions and conclusions shall be drawn accordingly.

5.2. Methods

5.2.1. Research question 1 – ecosystem services provided by agriculture land

To determine answer to research question one desk research will be used to conclude which ecosystem services are provided by agriculture land and more importantly for which of these ecosystem services can we determine their value. The preliminary research has identified these ecosystem services which can be remunerated in terms of this study: carbon sequestration, prevention of erosion, prevention of water contamination, production function. To determine the ecosystem service of prevention of water contamination, the nutrient run-off needs to be established first.

5.2.2. Research question 2 – evaluation of ecosystem services provided by agriculture land

Nutrient run-off (prevention of water contamination) and carbon sequestration

To determine the nutrient runoff and carbon sequestration (both methodologies shall be described together, as the collection of data for both of them was done simultaneously) on agriculture land and evaluate the belonging ecosystem services will involve several steps. The first step would be to collect data on different samples of agriculture land with different type of management through case studies. Case studies were chosen in the municipality with extended powers Třebíč and to provide multiple samples, farms with different type of management were chosen, ranging from small ecological farms with prevalent permanent grassland to big farms with cereal production and animal production. As this research was conducted as part of the study commissioned by the Ministry of Agriculture on the provision of public goods and ecosystem services through agro-envi-climate measures, all farms had part of their land designated as grassland on arable land under this scheme. Farms were chosen through the database provided by the Ministry and to provide anonymity for the responders, no names were included in the published outcomes. To collect the data, qualitative semi-structured questionnaire (mixing closed and open question) was prepared to get all the needed data to feed into the models used for this exercise. The questions in the questionnaire were divided into several blocks, which were:

- General information about the farm (type of farm, number of hectares/animals, climate)
- Information about the agriculture production (types of plants, date of planting/collecting, final yield in tones, by-products)
- Information about the soil (soil structure, organic matter, moisture, pH)
- Information about fertilizers (types of fertilizers, amount of tones used, method for fertilizing)
- Information about pesticides (types of pesticides, amount of tones used)
- Information about the by-product (type of by-product, amount, management)
- Land use (changes in land use over last couple of years, use of cover crops/catch crops)
- Types of machinery used (yearly consumption of fuel, machinery output)

- Operations in the field (number of operations in the field during the agriculture year)
- Transport to and from farm

The complete survey with all questions included can be found in Annex II. The interviews were conducted with the owners at their farm; each interview took overall 2 hours. The interviews took place in autumn 2017.

The overview of the selected farm types:

- **Farm 1** – Mixed medium sized privately-owned ecological farm (81 pieces of cattle, 23 horses, 6 sheep), grassland on arable land, permanent grassland and pastures, 130.47 ha in total
- **Farm 2** – Large conventional farm (wheat, maize, rapeseed, alfalfa, low percentage of grassland), 579.98 ha in total
- **Farm 3** – Large conventional mixed farm (wheat, maize, rapeseed, permanent grassland, 1000 pieces of cattle, biofuel station), 1172.56 ha in total
- **Farm 4** – Large conventional mixed farm (wheat, rapeseed, maize, barley, permanent grassland, 30 000 chicken, 420 dairy cows), 3487.45 ha in total
- **Farm 5** – Small privately-owned ecological farm with cattle, horses, sheep and pigs, 25.41 ha in total
- **Farm 6** – Small privately-owned mixed farm (wheat, barley, permanent grassland, 35 pieces of cattle), 94.30 ha in total

The data collected through the interviews were then used to feed into the model computing and visualizing processes in soil. Namely the models Cool Farm Tool, model on the flow of nutrients and model on nitrate leaching were used.

Determining the price for carbon sequestration

There are several ways how to determine the costs related to carbon emissions. The so-called Social Cost of Carbon (SSC) might be used for assessing the value of carbon sequestration in ecosystems, since those very ecosystems contribute to climate change mitigation. Social cost of carbon is the cost of each tonne of carbon dioxide which is being emitted as a consequence of climate change. This social cost is evaluated according to the integrated models for economics of climate change.

In terms of this dissertation, the assessment for SSC which is recommended by the US Environmental Protection Agency (EPA) shall be used. This assessment is regularily used in science studies focusing on the role of ecosystems in carbon sequestration and climate change mitigation. It is also used for the purposes of the Regulation Impact Assessment in the US.

For determining the social cost of carbon, the values presented in the study on the evaluation of the ecosystem of permanent grassland biodiversity and its role in carbon sequestration shall be used (Hungate et al., 2017). The values used in the study derive from the EPA recommended values based on carbon dioxide emission and the molecular weight of carbon. The final values determine the social cost of carbon for one tonne of carbon emitted.

The calculation from the US based methodology was done by using the exchange rate and determining the difference in purchasing power parity as according to OECD indexation.

Production function

The production function of agricultural land shall be determined through a simple method of direct market value. Therefore, for each selected crop a total average yield per hectare shall be established together with a determination of the average market value for given year. The combination of the two elements should give the desired value. After the application of weighting factors, an average value for production function in the Czech Republic could also be established.

Soil erosion

The assessment of yearly soil loss due to soil erosion shall be done with the help of ArcGIS software. The soil erosion shall be calculated per crop type to evaluate the differences in crop management. For these purposes, the data from LPIS (Land Parcel Identification System) shall be used – in this system, all farmers have to put in the information on what type of crop they are growing on which part of the land. This will help to assess the average soil erosion per crop type in the municipality with extended powers Třebíč. The ecosystem service associated with soil will be determined based on the costs for cleaning the soil run-off from water bodies.

The average annual loss of soil due to erosion was calculated for those blocks with selected crops based on the data received from LPIS. The data was requested from the paying agency under the Czech Ministry of Agriculture. The entry values for the annual yearly loss were calculated based on the data from 2017, so therefore in this regard data from this year are the most relevant. To assess the trends the soil erosion was calculated also for years 2015, 2016 and 2018 – the placement of soil blocks with type of crop is unique for each year yet the entry data for erosion remain the same.

Based on the nature of the data provided (tables and not shapefiles), a corrective calculation had to be done for those soil blocks where more than one crop was grown. On these blocks, an average soil erosion was calculated for the whole block and not only for the part designated to the crops in question. Yet this correction only represents 5% of the data between the four years and therefore does not affect the final average value.

The ArcGIS software was used for the calculation and the primary tool was the zonal statistics for the vector shapefiles of LPIS and the soil loss was assessed based on the raster data for water erosion G.

Costs connected to soil erosion

When determining the ecosystem service (or in this case the obvious disservice) for prevention of soil erosion, one has to consider all the costs related to this service. Average soil loss determines the amount of fertile land which is lost. The next thing that happens is that this soil contaminates the water and is being swept away in the river flow. By default, the nutrients which are embedded in the soil are lost. Therefore, we first need to determine the price of these nutrients. Next is the price of the soil itself. As the soil which has been run off from the field contaminates the water and builds up in the nearest water body, the costs for clearing up the water body have to be considered together with the costs for transporting the soil and storing it in a landfill.

Analysis of land parcel size

For a significant part of the degradation processes on soil the size of a land parcel is a significant element (as it also indicates the slope length) and therefore it is important to assess how large land parcels are in the municipality with extended powers Třebíč. The LPIS was used to evaluate the size land parcels of arable land. The following analysis was performed with LPIS data on soil for the municipality with extended powers. Only those land parcels, which at least partially fall into the relevant area, were selected and of those only those with cultivated arable land were included in the final selection. Subsequently, a value of 95% quantile of land parcel size was determined, indicating the 5% of the largest land parcels in the study area.

For comparison purposes, an analysis was made for the whole Czech Republic district by district. For the whole CR the limit of 5% for the largest land parcels with arable land is 41.7 ha (a total of 235 125 land parcels were analysed).

5.2.3. Research question 3 – agricultural land lost due to urban sprawl

The answer to research question three, the number of hectares of agriculture land lost due to urban sprawl were determined via a collection of data from the Czech Statistical Office and from the State Administration of Land Surveying and Cadastre. As the data provided by the Czech Statistical Office only comes per district, while the data from the State Administration of Land Surveying and Cadastre is defined for the municipality with extended powers, an extrapolation was made and these two sets of data were compared. For the analysis of the future situation, the data from spatial plans of all individual villages are used in order to determine what rate of area is designated for construction and what the current land use of these areas is. This analysis was be executed in ArcGIS.

5.3. Study area

The research is conducted for the area of the municipality with extended powers Třebíč. The total area of this municipality is 83 773 ha and comprises of 93 villages and their cadastral areas. Agriculture land in this municipality makes up for 64,1% of the total area.

6 RESULTS

6.1. Ecosystem services provided by agriculture land in the study area

The answer to this question was determined through desk research as part of the literature review. The four ecosystem services which will be researched in this dissertation are:

- prevention of water contamination,
- carbon sequestration,
- production function,
- prevention of soil erosion.

6.2. Evaluation of ecosystem services provided by agriculture land in the study area

6.2.1. Prevention of water contamination

To determine the ecosystem service for prevention of water contamination, the nutrient run-off which causes this contamination needs to be determined first. This section will present the data gained from the case studies from the two models on nitrogen leaching and nutrient flow. First the outcome from the nutrient flow model shows values for three basic nutrients in agriculture, nitrogen, potassium and phosphorus as shown below.

From the results on nitrogen balance in the soil it is clear that most nitrogen (152.88 kg N/ha) stays in soil on farm number 3, therefore on a big farm with crop and animal production. Yet the average yearly excess residue of nitrogen in soil should not exceed 60 kg N/ha. In this perspective, the only farm which can be viewed positively is farm number 4. The most negative balance of nitrogen residue in soil is on farm number 5 – small ecological farm only with permanent grassland with no fertilizers. In this case, there is significant shortage of nitrogen in soil.

Acquired data were used to evaluate what rate of nitrogen is being leached from arable land in the Czech Republic as shown in Table 1 and what is an average value for nitrogen leaching in arable land.

Table 1 Nitrogen leaching in the Czech Republic

Crop	2016 crop area (ha)	Nitrogen leaching kg N/ha	Nitrogen leached (t)

Wheat	839 710,5	48,1	40390,07
Barley	325 725,3	40,6	13224,45
Rapeseed	392 991,3	47,4	18627,79
Maize	241 500,0	29,2	7051,80
Grassland 2017	9 832,93	30,7	301,87
Grassland for fodder	114 093,58	29,1	3320,12
Sum	**1 923 853,56**		**82916,10**

Source: original

An average value for nitrogen leaching on arable land is 43.1 kg N/ha.

Determining the cost for water cleaning

The expenditure on cleaning the leached nitrogen from water was determined according to data obtained from water treatment plant. Detailed data on water treatment methods were acquired from plants of different capacity shown in Table 2 (small, medium and large capacity) from which the rate of water treatment expenditure on nitrogen and phosphorus cleaning was separated. It has to be noted that since these two nutrients are cleaned together in the technological process, the price for their cleaning cannot be separated.

Table 2 Expenditure on nitrogen and phosphorus cleaning per water treatment plant

	Expenditure for water cleaning in 2017 (CZK)	**Expenditure for cleaning nitrogen (CZK)**	**Expenditure for cleaning potassium (CZK)**
1 – Large water treatment plant	336,3	302,4	33,9
2 – Medium water treatment plant	340,6	306,3	34,3
3 – Small water treatment plant	366,6	329,7	36,9
Average		312,8	35,0
Total			**347,8**

Source: calculation according to water treatment plant data and price of water delivery

When combining these two aspects – the amount of nitrogen leeched per hectare and the price for cleaning the nitrogen, the final ecosystem service can be easily determined (see Table 3).

Table 3 Nitrogen leaching per crop

Crop	**Nitrogen leaching kg N/ha**	**The cost of nitrogen leached (CZK/ha)**
Wheat	48,1	16729,18
Barley	40,6	14120,68
Rapeseed	47,4	16485,72
Maize	29,2	10155,76
Fodder	29,1	10120,98

Source: original

As the table shows, when it comes to nutrient run off and especially nitrogen leaching, the agriculture land with the main types of crops provide a disservice. This means that instead of providing the service of prevention of water contamination, they enable it.

6.2.2. Carbon sequestration

The output from the Cool Farm Tool model shows these results, as by case study. The Table 4 shows how much has each of the farms contributed to carbon sequestration through changing the land use on part of the farm from arable land to temporary grassland. This was one part of the research project for the Ministry of agriculture, for which the case studies were executed – to determine, how does land use change from arable land to grassland contribute to carbon sequestration.

Types of farms as indicated in the case study description:

1 - Mixed medium sized privately-owned ecological farm

2 - Large conventional farm

3 - Large conventional mixed farm

4 - Large conventional mixed farm

5 - Small privately-owned ecological farm

6 - Small privately-owned mixed farm

Table 4 Carbon sequestration per case study in the study area

	Change of CO2 emissions after land use change	CO2 before land use change	CO2 after land use change	Change of CO2 on the farm	CO2 related expenditure before land use change	CO2 related expenditure after land use change	The amount saved due to land use change
	tonnes	**t/farm/year**	**t/farm/year**	**tonnes**	**CZK**	**CZK**	**CZK**
1	-1,59	-4,63	-18,73	14,1	-13 135	-53 120	39 985
2	-1,44	1371,75	1342,73	29,01	3 890 276	3 807 990	82 286
3	-0,593	2300,61	2149,49	151,12	6 524 536	6 095 968	428 568
4	-1,99	6947,76	6716,1	231,66	19 703 847	19 046 871	656 975
5	-2,06	-33,81	-49,58	15,76	-95 891	-140 595	44 704
6	-1,69	-80,05	-118,58	38,53	-227 021	-336 297	109 275

Source: original

The results show clear differences between farms when it comes to lowering carbon emission through conversion to grassland. The results vary between -0,59 t CO2 to -2,06 t CO2. The largest amount of carbon sequestrated was achieved by farm number 5. This was mostly due to minimum number of operations in the field, no use of fertilizers, pesticides, minimum mechanization and no transport out of the farm. Farm number 3 fared the worst amongst others and this was due to fertilizers application and larger amount of field operations and transportation.

Determining the price for carbon sequestration

The average value of carbon is based on 3% bank rate while estimating a yearly damage as a consequence of climate change until year 2050. The lower estimate for the social cost is based on 5% bank rate and the high estimate on 2,5% bank rate for aggregated impacted based on the current value. The results for these estimates are:

- Low estimate – 867 CZK
- Average estimate – 2836 CZK

- High estimate – 8272 CZK.

For the purposes of this dissertation, the average estimate shall be used.

The factors that play a role when determining how much carbon is sequestrated at a farm is the amount of fuel used or transportation mode – basically the farm management. This is closely linked to crop which is being grown at the farm. With the use of the model, the carbon sequestration per crop was determined and it was linked with the average value for social cost of carbon to establish how much does the crop contribute to the ecosystem service of carbon sequestration (see Table 5).

Table 5 Carbon sequestration per crop for the case studies in the study area

Crop	**CO_2 t/ha**	**The social cost of carbon sequestrated (CZK/ha)**
Wheat	0,82	2325,52
Barley	0,62	1758,32
Rapeseed	2,17	6154,12
Maize	0,74	2098,64
Grassland for fodder	-0,21	-595,56

Source: original

The table clearly shows that the only type of cropland that indeed does sequestrate carbon, are those grassland which are grown for fodder. The other crops only boost carbon emissions, with rapeseed faring the worst. This can be attributed to the farm management connected with the crop, the number of field operations and also the management of residues.

6.2.3. Production function

To determine the production function of each of the selected crops, the total average yield was first determined as according to the agriculture norms.

- Wheat 6t
- Barley 5t
- Rapeseed 3,2t

- Maize 40t
- Grassland on arable land (fodder) 5,2t (2014, VURV),

The average market price for each crop was also determined, for these the data from Czech Statistical Office on agriculture production was used and average was calculated as shown in Table 19.

Table 6 Market price of different crops in 2018

	2018					
Crop	**July**	**August**	**September**	**November**	**December**	**Average value**
	CZK	CZK	CZK	CZK	CZK	CZK
Wheat for food production	3917	4050	4347	4474	4479	4253,4
Wheat for fodder	3736	3813	4038	4210	4187	3996,8
						4125,1
Barley for food production	4516	4457	4710	4836	5116	4727
Barley for fodder	3468	3605	3937	4083	4033	3825,2
						4276,1
Rapeseed	9057	9166	9305	9377	9473	9275,6

Source: CSU, 2019, own calculations

The price for maize (designated for silage) was determined through desk research, the indicated price is 1000 CZK (VURV, 2106) for when the maize is destined to be used in the biogas station. The price for hay is indicated to be 1339 CZK (CSU, 2017).

To introduce a weighting factor, a total cropland in the Czech Republic was determined and the total share of the selected crops in this cropland.

Finally, these data were combined to determine the production function per crop and the average production function in the Czech Republic.

Table 7 Average production function in the Czech Republic

Crop	**Average yield**	**Average price**	**Total production**	**Weighting factor**	**Final value**
	in t/ha	**in CZK per tonne**	**CZK/ha**		**CZK/ha**
Wheat	6	4125,10	24750,60	0,42	10281,46
Barley	5	4276,10	21380,50	0,16	3518,45
Rapeseed	3,2	9275,60	29681,92	0,21	6194,40
Maize	40	1000,00	40000,00	0,11	4537,27
Fodder	5,2	1393,00	7243,60	0,10	709,22
			Average production in CZK/ha		**5048,16**

Source: Agriculture norms, CSU 2019, own calculations

The total production function of arable land in the Czech Republic is therefore 5048 CZK, while the most profitable crop is maize, with rapeseed closely following. The least value is attributed to grasslands. For the purposes of this research, the total production value per hectare per crop shall be used.

6.2.1. Prevention of soil erosion

6.2.1.1. Soil erosion per crop type

From this overview it is clear that the problem of erosion is not very pronounced in this municipality in comparison to the rest of the republic (the soil erosion could go well beyond 30 t/ha/year in the most endangered sites in the country as according to the Research Institute for Soil and Water Conservation) and therefore also the figures used in this research will be quite low. Table 8 shows the overview of soil erosion per crop type.

Table 8 Soil erosion per crop type in the study area, 2015 - 2018

		2015		2016		2017		2018	
Crop	**Name of crop or culture**	**Number of soil blocks where the crop/culture is grown**	**Average annual loss of soil G [t.ha-1.year-1] on blocks with the crop/culture**	**Number of soil blocks where the crop/culture is grown**	**Average annual loss of soil G [t.ha-1.year-1] on blocks with the crop/culture**	**Number of soil blocks where the crop/culture is grown**	**Average annual loss of soil G [t.ha-1.year-1] on blocks with the crop/culture**	**Number of soil blocks where the crop/culture is grown**	**Average annual loss of soil G [t.ha-1.year-1] on blocks with the crop/culture**
Arable land	Spring barley	526	4,26	385	4,56	412	4,58	304	4,48
	Winter barley	216	4,43	292	4,04	253	4,32	301	3,9
	Clover	123	4,71	157	4,39	173	4,46	204	4,47
	Clover mixture	145	5,4	136	5,45	159	4,99	152	5,18

		2015		2016		2017		2018	
Crop	Name of crop or culture	Number of soil blocks where the crop/culture is grown	Average annual loss of soil G [t.ha-1.year-1] on blocks with the crop/culture	Number of soil blocks where the crop/culture is grown	Average annual loss of soil G [t.ha-1.year-1] on blocks with the crop/culture	Number of soil blocks where the crop/culture is grown	Average annual loss of soil G [t.ha-1.year-1] on blocks with the crop/culture	Number of soil blocks where the crop/culture is grown	Average annual loss of soil G [t.ha-1.year-1] on blocks with the crop/culture
	Maize	450	3,94	454	4,03	462	4,09	447	4,18
	Spring wheat	93	4,57	56	5,13	98	4,54	39	3,6
	Winter wheat	1254	4,14	1296	4,29	1202	4,16	1307	4,24
	Spring rapeseed	1	2,27	2	4,88	4	5,66	1	1,79
	Winter rapeseed	564	4,37	547	4,13	664	4,09	652	4,34
	Fodder mix for northern lapwing	2	0,6	1	0,65	1	0,65	1	0,77
	Fodder mix for buffer strip	23	4,57	25	3,36	30	3,39	46	3,4
Permanent grassland		2493	0,18	2588	0,16	2714	0,14	2801	0,15
Other		1664	3,89	1708	3,81	1814	4,15	1837	3,97

Source: LPIS, ArcGIS, own calculation

When determining the ecosystem service (or in this case the obvious disservice) for prevention of soil erosion, one has to consider all the costs related to this service, as described in the methodology.

With the costs linked to soil erosion and loss of soil we can now easily make the calculation of the ecosystem disservice provided by different type of crops on arable land due to soil erosion, as seen in Table 9.

Table 9 The costs linked to average soil erosion per crop type in the study area

	Average soil erosion (t/ha/year)	**Costs linked to soil erosion (CZK/ha)**
Wheat	4,33	29584,292
Barley	4,32	29515,968
Rapeseed	3,94	26919,656
Maize	4,06	27739,544
Fodder mix	4,88	33342,112

Source: own calculation

From the overview, it is clear that there are only slight differences between the type of crops being grown on the field in terms of soil erosion. The crop which fares the best in this comparison is rapeseed. If we would however compare these costs to the ones linked to permanent grassland, the difference would be remarkable. The average loss of soil per hectare per year on permanent grassland is only 0,157 tonnes. This would mean that for permanent grassland the disservice is only 1072,6 CZK/hectare.

6.3. Agriculture land lost due to urban sprawl in the study area

As for the urban sprawl, there are different sets of data through which can the land use change be determined. There are two main sources of data – the Czech Statistical Office and from the State Administration of Land Surveying and Cadastre. There are also two different sets of area delimitation, as the study area went from being registered as a district to being the municipality with extended powers, as it is currently now. The Czech Statistical Office provides data only for the district, while the State Administration of Land Surveying and Cadastre holds data for both district and municipality with extended powers. The time period for which both of these sets of data relate to is also different. There are therefore vast differences in the data sets and to determine the final values, an analysis and extrapolation will need to be made.

Table 10 Land use change for the municipality with extended powers Třebíč between years 1993 and 2017

Year	Arable land	Hopyard	Vineyard	Garden	Orchard	Permanent grassland	Agriculture land	Forest land	Water surface	Urbanized area	Other area	Sum
2017	46256		6	1284	138	5954	53639	22424	1428	1159	5103	83752
2016	46271		6	1282	138	5956	53655	22424	1426	1161	5088	83752
2015	46306		6	1282	139	5951	53686	22424	1419	1161	5066	83753
2014	46318		6	1281	137	5970	53713	22436	1413	1161	5051	83770
2013	46338		6	1277	138	5972	53733	22438	1401	1161	5040	83768
2012	46351		3	1277	138	5981	53752	22421	1398	1157	5046	83770

Year	Arable land	Hopyard	Vineyard	Garden	Orchard	Permanent grassland	Agriculture land	Forest land	Water surface	Urbanized area	Other area	Sum
2011	46395		3	1276	138	6004	53817	22420	1369	1144	5021	83766
2010	46497		3	1276	138	5918	53843	22411	1362	1143	5011	83764
2009	46565		3	1276	137	5897	53892	22406	1354	1140	4977	83762
2008	46592		3	1277	137	5906	53929	22401	1341	1133	4966	83762
2007	46636		3	1273	139	5905	53969	22399	1334	1127	4945	83766
2006	47930		3	1308	139	6288	55660	23167	1371	1152	5050	86391
2005	47988		3	1303	142	6295	55721	23154	1363	1151	5016	86396
2004	48280		3	1310	143	6366	56089	23333	1363	1154	5030	86959
2003	48309		3	1308	144	6371	56122	23330	1361	1151	4994	86948
2002	48350		3	1308	145	6372	56166	23320	1359	1151	4965	86949
2001	48378		3	1306	146	6388	56206	23282	1356	1148	4972	86952
2000	48447		4	1305	147	6341	56234	23270	1353	1142	4959	86946

Year	**Arable land**	**Hopyard**	**Vineyard**	**Garden**	**Orchard**	**Permanent grassland**	**Agriculture land**	**Forest land**	**Water surface**	**Urbanized area**	**Other area**	**Sum**
1999	48511		0	1305	147	6317	56275	23232	1394	1139	4929	86957
1998	48476		1	1304	147	6310	56234	23233	1392	1120	4993	86962
1997	48476		1	1304	147	6310	56234	23233	1392	1120	4993	86962
1996	48200		0	1295	153	6602	56210	23212	1402	1110	5036	86961
1995	48182		0	1297	154	6633	56222	23214	1401	1106	5030	86964
1994	48197		0	1295	154	6615	56220	23213	1401	1098	5042	86965
1993	48202		0	1292	154	6622	56228	23214	1400	1094	5040	86967
Change in area (ha)	**-1947**		**6**	**-8**	**-16**	**-668**	**-2589**	**-790**	**28**	**66**	**63**	**-3215**
Change in area (%)	**-4,0%**		**600,0%**	**-0,6%**	**-10,6%**	**-10,1%**	**-4,6%**	**-3,4%**	**2,0%**	**6,0%**	**1,2%**	**-3,7%**

Source: own calculation

The statistical difference between the extrapolated data and the actual data for the municipality with extended powers is between 0,002% and 0,78%.

The reading of the data shows the overall trend in the area for the past 24 years. In total, the area dedicated to any of the land use type used in the cadastre registry has decreased by 3215 ha between years 1993 and 2017 – this is represented by a decrease of 3,7% in percentage value. The biggest decrease can be attributed to the share of agriculture land, which has decreased by 2589 ha or by 4,6%. The largest share of agriculture land is arable land, which has therefore decreased accordingly by 1947ha (4,0%). Forest area and permanent grassland has also diminished quite significantly, with the former dropping by 3,4% (790 ha) and the latter by 10,1% (668ha). The area covered with gardens and orchards has decreased only very slightly, by 8 and 16 ha respectively. On the other hand, urbanized area has increased the most, by 6% (66 ha) while other area has increased by 1,2% (63 ha) and water surface has also developed by 28 ha. Overall, this underlines the trend seen not only here, but in the whole Czech Republic, that the areas with agriculture use are decreasing at the expense of urbanized and other areas. Figures 8 and 9 help to visualize this trend

7 DISCUSSION

The following table sums up the results for each ecosystem service identified for the purpose of this research. See Table 31.

Table 11 Overview of the ecosystem services provided in the study area

Crop	Prevention of water contamination - The cost of nitrogen leached (CZK/ha)	Carbon sequestration - The social cost of carbon sequestrated (CZK/ha)	Production function - Total production CZK/ha	Prevention of soil erosion - Costs linked to soil erosion (CZK/ha)
Wheat	16729,18	2325,52	24750,6	29584,292
Barley	14120,68	1758,32	21380,5	29515,968
Rapeseed	16485,72	6154,12	29681,92	26919,656
Maize	10155,76	2098,64	40000	27739,544
Grassland for fodder	10120,98	-595,56	7243,6	33342,112

Source: original

This overview table clearly shows a trend that has been already been put forward in the literature review, most clearly in Figure 3. Even as agriculture itself provides some services, most notably the production of food, it also draws up on the other services in its surrounding ecosystems and habitats. Some studies name this process, the clear loss of ecosystem services, as land degradation (Sklenička, 2016). Land degradation can be defined as: “reduction or loss of natural beneficial goods and services, notably primary production services, derived from terrestrial ecosystems” (Blaikie and Brookfield, 1987; Sarukhan et al., 2005, Nkonya et al., 2011). This definition therefore embraces both human and natural causes to this process. The most common land degradation types are water and wind erosion, loss of biodiversity and in agricultural areas also water shortages, soil depletion and soil pollution (Nachtergaele et al., 2011)

If we would consider the ecosystem service described in this work case by case, as for the prevention of water contamination (or nutrient run-off) it is clear that the arable land and the type of crops which are grown on this land benefit from a trade-off and provide a disservice to the environment. There are some differences between the crop types, with the grassland dedicated for fodder production clearly polluting the water bodies the least, yet the general trend does not change. What did the methodology and the case studies outline however is that agriculture practices play a role in defining what is the magnitude of this disservice. As this service is linked to the use of nitrogen and how much of it is leached from soil, a proper management in the use of fertilizers could greatly impact this ecosystem disservice.

As the case studies have shown, there were great differences between the different farms in nutrient balance. The case study which fared the worst amongst the others was the big conventional farm with cereal and livestock production. The use of nitrogen in this case greatly exceeded the proposed limits. It could be therefore assumed that the nitrogen was overused in this case. On the other hand, the small biological farm with the very limited use of fertilizers used up all the soil potential and stocks of nitrogen by creating a lack of this nutrient. It could be then argued that through a more systematic use of fertilizers, the disservice of nutrient run-off could be minimized to some extent. This could happen with the help of digitisation and precision agriculture, or simply with the use of nutrient management plan, one similar to the tool used for the purpose of this dissertation. The other way would also be to introduce buffer strips alongside water courses to help prevent the run-off. These simple measures could help to minimize this ecosystem disservice. Some long-term studies (Dumbrovský et al., 2015) indeed show that the water quality of reservoirs adhering to the agricultural land has improved after the implementation of erosion control measures. The combination of measures which was targeted was increase in grassland area, soil prevention measures and reduction of fertiliser application rates.

It has to be noted as well that permanent grassland was not included in this research due to the limitations of the model used. Studies that have followed the nutrient run-off on permanent grassland suggest that less than 10% of the nitrogen applied to these areas has been lost due to run-off (Scholefield, 1995), with studies following more dissolved nutrients suggesting this percentage is low as 5% (Schlesinger, 2000). This could imply as well that changing the land use from arable land to permanent grasslands in some part of the farm could positively benefit the prevention of water contamination.

As for carbon sequestration, again the results clearly show that most of the crops grown on arable provide a disservice to the ecosystems in this regard, with the notable exception of grassland for fodder. The case studies also show very great differences between the farm types and farm management. The large conventional farm with mixed livestock and crop production managed to produce the staggering 19 046 871 CZK/year in carbon footprint while the small family farm also with mixed production of livestock and crops managed to save 336 297 CZK/year. It is to be noted that even as there were included two farms either fully or partly under the organic type of farming, these did not produce the largest savings in carbon sequestration.

Other studies have however suggested that organic farming does play a role in the total carbon content in soils. (Walmsley and Sklenička, 2017) This might be accounted for by the fact that fertilizers used in organic agriculture tend to have higher carbon content (Tuomisto et al., 2012). What also showed to have an impact on the soil biochemical activity, also linked to soil carbon content, is the fact whether the land is farmed by an owner or tenant. This is particularly true for conventional farming. For these farms, according to the study undertaken by Walmsley and Sklenička, 2017, a higher biological activity was indicated for soils managed by the owner. As for organic farms, who have to comply with strict agro-ecological norms in order to get certification of their products, there was no such a strong correlation. This underlines the fact that the willingness to manage agriculture land in a sustainable manner is significantly impacted by the relationship to this land (Kristensen et al., 2004; Yami and Snyder, 2015), as farmers-owners tend to take better care of their land than farmers-tenants do.

As the model used for carbon sequestration suggests, there are number of farming practices through which the carbon sequestration can be addressed and improved. First one is the lowering of tillage intensity, meaning moving away from classical tillage to low tillage in some parts of the farm or even to no-till farming or conservation agriculture (which would mean reducing the tillage and number of field operations to minimum while increasing the use of crop residues). Reduction of carbon footprint can also be addressed through minimizing use of fertilizers and pesticides as this would also imply a smaller number of field operations. The management of crop residues also plays its part, either as having a cover crop or as incorporating the crop residues back to soil and increasing therefore the organic matter in the land.

The model for carbon sequestration takes into account the carbon footprint of the overall production, including all field operations. Other studies have shown however that the agricultural ecosystem on its own stores a high amount of carbon, comparable to a carbon storage potential of mountain meadows. About 75% of the carbon is lost due to respiration, yet this number could be higher if not for the harvest, a very specific aspect of this ecosystem in comparison to others. Some carbon is being lost further down the food value chain and through decomposition, but that already happens outside of the agricultural ecosystem. (Marek et al., 2011) According to this research the overall average carbon storage in the Czech Republic in 2000 in agricultural ecosystems was 4,21 t/ha. The highest amounts were achieved in regions with a higher rate of sugar beet production, which has the most biomass as compared to other crops grown on arable land, and with good climate conditions. Overall however the low value of biomass in agricultural crops cannot significantly influence the carbon storage potential for the whole of Czech Republic. (Marek et al., 2011)

As for the next ecosystem service considered in this research, the production of food is undeniably the one ecosystem service that all arable land does provide. It is also the one that cannot be replaced by any other ecosystem, certainly not in a manner that would sustain the current world population. There are some differences in what value does of the crop provide, with the least attributed to grassland for fodder and the most to maize production. Yet we have to recognize as well that this market value is not the definitive one, while both fodder and maize is used further for livestock production and therefore the final added value would be of that final produce. The market price can also change quite rapidly, with agriculture sector being faced with great volatility, which can be impacted by operational stock, seasonality, adverse weather events yet also by external forces such as international trade agreements and climate change. Therefore, the market price can indicate the final value of this ecosystem service only to a certain extent. Yet what cannot be argued is the irreplaceability of this service and its utmost importance for the feeding of the world population.

When it comes to soil erosion, it is clear again that the arable land with provides a disservice. There is no type of crop which would prevent the soil erosion altogether and there are also very small differences between the rate of erosion for the different crops. All in all, therefore, all arable land is by definition subject to erosion. One of the aspects which was not included in this research is the soil erosion on permanent grassland. The rate of erosion on permanent grassland is much lower than for the arable crops, between 0,14-0,18 t/ha/year in comparison to 4,33 t/ha/year for wheat. Just for the record, according to several studies, soil has the capability to regenerate itself in a rate of 1 t/ha/year. (Šarapatka et al., 2008) The low rate of erosion on permanent grassland could indicate that by switching the land use from arable land to permanent grassland on some parts of the farm could also minimize soil erosion and therefore benefit this ecosystem service.

Interestingly enough, other research has shown that there are significant differences between the soil erosion between different types of crops. Sus, in Holý, 2004, outlined that the average soil erosion for clover is 1%, for winter wheat 50%, for spring wheat 100% and for root crops even 200%. Nonetheless, there are several factors which play into the rate of erosion for different crops, all of which are considered in the general Wischmeier-Smith equation for computing soil erosion. These are the rate of rainfall-induced erosion, soil type, morphology – slope and slope length, soil cover and efficiency of anti-erosion measures. (Šarapatka et al., 2008) This suggest that type of crop is only one piece of the more complex equation.

One aspect which is also closely connected to soil erosion is the size of soil blocks. The analysis shows that the situation in the study area is not as dire as in the other parts of the Czech Republic (see Figure 5) as the average in the study area is slightly below the national average. The Czech Republic also has the largest average farm size in the EU (133 ha) and also in the study area this corresponds to the reality that more than 50% of the agriculture land is farmed by large cooperatives with more than 1000 ha of land (see Table 6). While this was not exactly in the scope of this dissertation, other studies have shown a link between an agriculture land fragmentation, land degradation and fragmentation of ownership. Due to the historical developments in the Czech Republic, the ownership of land is extremely fragmented. A study by Sklenička, Šálek (2007) has outlined that the average size of soil block (26,67 ha) is in stark contrast to the average size of the ownership parcel (0,66 ha). (Sklenička, Šálek, 2007). These very small parcels are often very fragmented, scattered and inaccessible and therefore quite unsuitable for individual farming (Sklenička et al., 2009). There is also a great difference between the number of land owners (3,5 million) and the number of farm entities (30,000). This leads also to the fact that most of the land is being rented, with only about 20% of the land being cultivated by the owner (Sklenička et al., 2014). One of the main causes of ownership fragmentation is partible inheritance, which implies that the land is divided between the heirs in an equal manner. Moreover, the fragmentation process is also influenced by the production potential of the land (as more fertile land tends to be less fragmented) and various historical events that suddenly changed the fragmentation rate. In Czech Republic, these would be expelling the original inhabitants and dividing the land between new owners, land reforms and land consolidation projects (Sklenička et al., 2009). The other cause of fragmentation would be the physical division of parcels during their sale, or change of use – predominantly by the land use change induced by urban development pressures. (Irwin and Bockstael, 2007)

This ownership fragmentation and therefore also tenure insecurity can also be one of the factors that lead to land degradation and the loss of ecosystem services. As it was outlined above, small parcels are no longer economically viable for individual farming – in the Czech Republic this threshold is set at 1 ha (Sklenička et al., 2014). Farming too small parcels is too expensive due to the number of unproductive passages over the parcels and also due to travel time between them (Gonzalez et al., 2014). In the Czech Republic this aspect cannot be overlooked as more than 40% of farmland is distributed across smaller than the viability threshold (Sklenička et al., 2014). These small parcels are also hard to access via road since the road network is not so dense (Sklenička, 2006). The owners of these inaccessible parcels are therefore practically forced to rent the parcel, usually to the owner of neighbouring parcels. This trend therefore significantly increases the rate of farmland being rented. It also has to be noted that this land which is divided into overly small parcels has considerably lower value. In this regard, the farmland is devalued simply because of this fragmentation rate, even as fertility rate and other attributes remain the same. (Sklenička, 2016)

This land fragmentation, level of rented land and tenure insecurity boils down to the fact, which affects the land degradation the most. A number of studies have shown that farming on rented land is less sustainable while the tenant tends to care less for the land entrusted in them than the actual owners do. (Fraser, 2004; Carolan, 2005) Parcels farmed by tenants would have less organic matter content, increased compaction, higher rate of erosion and overall decreased natural fertility, according to the 30-yearlong research conducted in the Czech Republic (Research Institute for Soil and Water Conservation, 2014). Other studies also show that insecure land tenure does not contribute to soil conservation (Nowak and Korsching,1983; Soule et al., 2000; Fraser, 2004) and also decreases the use of organic fertilizers which improve soil fertility (Jacoby et al., 2002). There is also a number of studies highlighting the effect of tenure security on farm improvement and productivity (Feder and Onchan, 1987; Gebremedhin and Swinton, 2003; Fenske, 2011; Feder, 1987; Abdulai et al., 2011).

The insufficient tenure security really strikes at the heart of land degradation, as it diminishes the motivation to invest in holdings, to increase the fertility of soil and it also decreases the motivation to invest in biodiversity protection, landscape renewal and water resource protection. (Sklenička, 2016) The tendency to rent the land to big processors who farm the overly large blocks also contributes considerably to the problem of water and wind erosion (Jenny, 2012), decreased spatial heterogeneity and landscape connectivity (Turner et al., 2011), problematic water management (Qui and Turner, 2015), agronomy (Sklenička and Šálek, 2008), also with negative impacts on visual value of landscape and potential for recreation (de Val et al., 2006). In this regard, tenure insecurity has an influence on these land degradation types: water and wind erosion (Sklenička et al., 2015), reduction of organic matter (Jacoby et al., 2002), soil compaction and nutrient leaching (Scherr, 2000). Two of these ecosystem disservices were also identified as part of this research and outline the link of farming structure on the availability of ecosystem services. Indeed these trends and the findings of this work can outline the close relationship of ecosystem disservices provided by agriculture land and how does this tie in with the ownership fragmentation in the Czech Republic.

Referring back to the topic of soil erosion studied in this work, there are also several practices to help prevent soil erosion on cropland. One of them is maintaining the soil cover throughout the whole year, mainly through the use of cover crop or catch crop or just leaving stubble on the field. Another practice is increasing the rate of organic matter in soil which would in turn increase the water retention of the soil and enhance its resilience to soil erosion. Preventing soil compaction through management of field operations and adequate machinery can also increase the water retention of soil. One of the more common problems in the Czech Republic in general, and as already outlined above, is the large size of land blocks. Even as this might not be a major issue in the study area, such as the Figure 6 suggests, it is generally acknowledged that dividing the large soil block with field copses or hedgerows or simple strips of grassland can also help to prevent erosion. These hedgerows of buffer strips can also greatly benefit the agriculture biodiversity. The reduction of tillage or conservation agriculture can also positively benefit the soil erosion prevention, a measure which was also already suggested to help increase the carbon sequestration. Some studies (Dumbrovský, Larišová, 2016) indeed show that reducing the tillage intensity can lead to a higher porosity of soil while the conventional tillage has a detrimental impact on soil compaction and soil structure. In the most extreme cases with very steep slopes, it is advisable to divide the field into terraces and keep a level-ground between the barriers dividing the terrace levels.

Other soil erosion prevention measures which are suggested are increasing the rate of organic matter in soil, catch crops and cover crops, shortening slope length, crop rotation with a higher rate of permanent crops and cover crops, tillage alongside the contour lines, hedgerows, anti-erosion belts. (Šarapatka et al., 2008) Janeček et al., 2012 also suggests stabilizing the concentrated run-off paths, anti-erosion dikes and field boundaries.

Some studies also highlight how does the price of implementing soil erosion prevention measures compare to the costs of dealing with the results of erosion, as highlighted in this work. On the example of broad-base terraces, Dumbrovský et al., 2014, showcases that through an effective implementation of these measures annual savings can be achieved. Indeed, when looking into the feasibility of different erosion measures, the financial situation and acquisition investment plays an important role. Yet what needs to be taken into account is also the fact that erosion control measures are usually proposed within an entire complex of steps to address the situation. In the example of terraces, we should consider that alongside this measure we would also need to implement a combination of best management practices with grassed waterways, elimination of wide row crops from crop rotation etc. (Dumbrovský et al., 2014)

When reflecting on the agriculture land use in general in the Czech Republic and how this might be influenced, we need to point out that agriculture here exceeds the average of the EU and therefore is the main user of land. According to the data from Farm structure survey, agriculture makes up for 2,9% of the employment, and there are 26 250 farms with 132 130 persons working in agriculture (FSS 2016, 2013). The number of beneficiaries benefitting from direct payments in the scope of the Common Agricultural Policy (CAP) is 29 670 (DG AGRI, 2018). It is therefore safe to say that the objectives, targets and measure implemented under this policy can greatly influence the agriculture patterns. There are two predominant trends now in the agriculture – intensification and specialization in some areas accompanied by marginalization and land abandonment in others, both of which are underscored by growing environmental problems. (Brouwer, 2001) The development of EU countryside goes hand in hand with the shifting priorities of the CAP, focusing on the food security right after the World War II, when the policy was first implemented, and progressing towards focusing also on non-production functions, delivering public goods, protecting the environment and stressing the need for sustainable development. (Hodge, 2001) Even as the agricultural policy has been heavily criticized for not delivering on its objectives, primarily when it comes to protection of environment and addressing the negative impact of intensive agriculture, some studies also highlight the influence the CAP has had on creating better jobs for farmers across the EU and on the reduction of poverty in rural areas. (World Bank, 2018) The policy in the current reform shifts even more towards provision of public goods and protection of environment, with the new result-based system and tailoring the policy more to the local needs promising to do just this. Indeed when addressing the ecosystem disservices provided by agriculture land, much can be achieved through a better targeting of this policy which influences most of the farmers in the Czech Republic.

As for the ecosystem evaluation undertaken in the scope of this work and the possibility to compare the results, we should turn to similar studies done in the conditions of the Czech Republic. One of such broad assessment of ecosystem services was done by Frélichová et al., 2014. This study was first of its kind and used literature review of similar studies performed in Europe to assess the average value per service per ecosystem. This research also produced a methodology for any future assessment of ecosystem services (Vačkář et al., 2014). The outcomes are highlighted in Figure 2 below. Out of the different ecosystem services evaluated, we could compare the climate regulation (as it ties closely to carbon sequestration), erosion regulation and water quality regulation. As the agriculture ecosystem included in our study provides disservices in this account (with the notable exception of permanent grassland), it only highlights what could be the potential of these agricultural ecosystems, should sustainable management practices be established and measures to prevent the nutrient run-off and soil erosion implemented. Even as agriculture land use was included in the study run by Frélichová et al., 2014, the highest values highlighted in the results do not belong to it. As the Figure 2 below shows, the highest recorded value can be attributed to disturbance regulation provided by wetlands, with the timber provision in forests closely following. Forest also scored well for aesthetic value, erosion regulation and climate regulation. (Frélichová et al., 2014). Indeed, this shows that agriculture ecosystems are not on the top when it comes to provision of ecosystem services. This can however be changed through the sustainable management and measure implementation highlighted in this discussion.

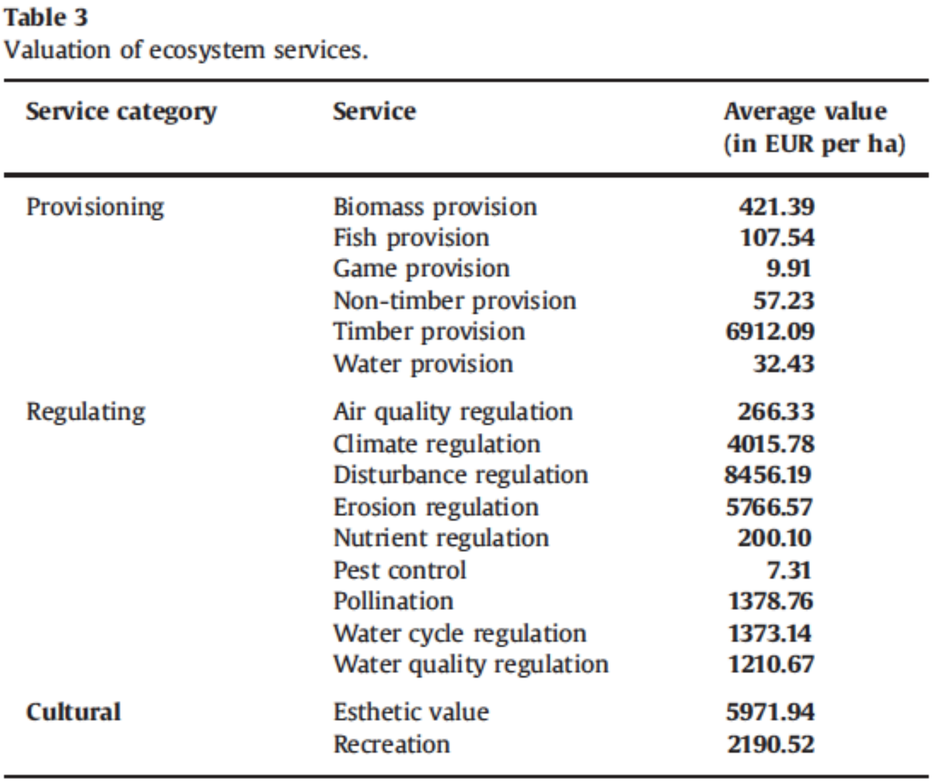

Table 3
Valuation of ecosystem services.

Service category	Service	Average value (in EUR per ha)
Provisioning	Biomass provision	**421.39**
	Fish provision	**107.54**
	Game provision	**9.91**
	Non-timber provision	**57.23**
	Timber provision	**6912.09**
	Water provision	**32.43**
Regulating	Air quality regulation	**266.33**
	Climate regulation	**4015.78**
	Disturbance regulation	**8456.19**
	Erosion regulation	**5766.57**
	Nutrient regulation	**200.10**
	Pest control	**7.31**
	Pollination	**1378.76**
	Water cycle regulation	**1373.14**
	Water quality regulation	**1210.67**
Cultural	Esthetic value	**5971.94**
	Recreation	**2190.52**

Figure 2 Valuation of ecosystem services in the Czech Republic. Source: Frélichová et al., 2014

Another study also focused on ecosystem services provided by permanent grasslands (Zisenis et al., 2011). The study highlighted the vital importance of permanent grasslands and their contribution to functioning biodiversity. The ecosystem services provided by permanent grasslands are wide-ranging. The study identified food provision, water provision, raw materials, genetic resource, medicinal resources, ornamental resources, air quality regulation, climate change regulation, moderation of extreme events, water flow regulation, waste regulation, erosion regulation, maintenance of soil fertility, pollination, pest control, cultural and amenity services amongst those that are provided by permanent grasslands. The study then considered the livestock provision, according to the maximum stocking density and estimated livestock numbers. The carbon sequestration, which depends largely on water regime, temperature, nutrient status and grassland management practices was based on marginal abatement cost of carbon. The erosion regulation considered how much soil is preserved in comparison to the average soil loss on cropland and then calculates the on-site and off-site damage. The water flow regulation similarly compares the average run-off on cropland and on permanent grassland. Invasion control was considering the level of alien species included in semi-natural grassland in the Czech Republic. Also, the waste treatment was included in the study, focusing on how much nitrogen can grasslands remove from soil. Permanent grassland also provides for recreation services through many outdoor activities, such as bird-watching, hunting, walking etc. This value can be calculated based on contingent valuation. (Zisenis et al., 2011) Indeed this study shows that ecosystem services provided by permanent grassland are much wider and more fundamental than just those considered in this work.

As this research focuses on the ecosystem services loss due to urban sprawl, we have to analyse these facts together. As results show, the area dedicated to agriculture has decreased by 4,6% in the study area between years 1993 and 2017. During the same period, the urbanized area has increased by 6%. There is no clear link saying that this agriculture land has been devoted to urban sprawl, yet the trend speaks clearly in the favour of urban development. When analysing the rate of agriculture land loss, 19% of the total area dedicated for urban development on agriculture land has already been transformed with some 1007 ha of land still unbuilt on.

These developments are raising concerns for protecting rural identity, particularly in those places where urban sprawl is quickly spreading. (Foley and Scott, 2014; Taylor, 2011; Vorel et al., 2003). This residential development often happens beyond the boundaries of a city or village or other community. It also usually takes advantage of the amenities of the community, yet often failing to contribute to this community (Peltan, 2012). It also often disturbs the traditional landscape patterns in rural areas. As for Czech Republic, these patterns date back to the late middle ages (Pánek and Tůma, 2009) and can be defined as relatively regularly distributed towns and villages with high settlement density and open agricultural landscapes. The areas outside of the settlements usually contained very few buildings. This open landscape was also often divided into long narrow fields belonging to the individual farms (Sklenicka et al, 2009; Houfkova et al., 2015). This very distinctive pattern is crucial for preserving the landscape character and rural identity in Central Europe (Löw and Míchal, 2003). This identity can be partially preserved through strict land use planning practices. In the Czech Republic, the legal measures against urban sprawl are in place, even as the effectiveness of these measures could be questionable. The Building Act No. 183/2006 puts forward requirements for detailed land use plans to be drawn up for every municipality. These plans should be regulating land use both in urban areas and in rural areas and should also ensure the continuation of traditional settlement patterns. Yet it does not fully prevent over-intensive urban sprawl, and also the targeting of rural areas through these plans is insufficient. (Janečková et al., 2017)

This conversion of agricultural land to urban land is driven by several factors, such as proximity to a settlement (Cheshire, 1995; Guiling et al., 2009, Naydenov 2009), the quality of infrastructure and accessibility (Stewart and Libby, 1998), presence of natural amenities (Drescher et al., 2001; Lisec and

Drobne, 2009) or occurrence of population growth (Forster, 2006). All of these factors influence the real estate market and agriculture land market. As for the Czech Republic, ever since the transition to democracy in 1989, there has been a clear prevalence in the rental market over the sales market, when it comes to agricultural land. This drives up the trend that land owners decide to rather rent the land due to low current prices of agricultural prices and lack of credit policies enabling potential farmers to buy the land. This situation also complements the scenario already described above, when tenants farm on large blocks of land, which is shown to be disadvantageous to the environment and contributes to land degradation. (Sklenička et al., 2011) A legislative act which controls the transformation of agriculture is (apart from the Building Act) the Act No. 334/1992 on Protection of Agriculture Land Resources. Spatial planning embedded in the Building Act protects the agricultural land through zoning, the Act on Protection of Agriculture Land Resources permits authorities to charge relatively high one-off fees for the transformation of agriculture land into urban land within this zoning. Yet the current system does not use measures put forward by some researchers (Deininger and Jin, 2003; Deininger et al., 2003) which would promote efficient land utilisation and facilitate access to land to farmers, such as realistic level of land taxation and efficient credit policies. The determination of agriculture land price is based on the system that considers the natural conditions of the land parcels it refers to – climate conditions, soil type, slope, exposition and soil structure (together known as the BPEJ code). Yet this methodology for expressing the price of land has been put forward in the 1970s' and does not address the more recent methodologies – evaluation of ecosystem services being one of them. If this system should continue to be used, it would require significant update. The outcomes of the study undertaken by Sklenička et al. (2011) also stress the significant importance of land consolidation projects and spatial planning on agriculture land prices and also protecting rural areas from urban sprawl and supporting the land market.

Even as agriculture land does provide some disservices to the ecosystems and benefits from the surrounding habitats, it has a clear potential to improve on those disservices as outlined above. Yet if this cropland would be turned to urban land, there is no longer any of that potential. Even as it is possible to replace some of the ecosystem services lost, as outlined in the literature review, the most important function of agriculture land – food production – is hard to be replaced on a scale that would matter.

Keeping the facts outlined above in mind, the notion of sustainable development touches upon both of those issues. The current model of agriculture has to be improved to become more sustainable in order to produce more ecosystem services or at least minimize the ecosystem disservices. Also, the urban planning needs to address the issue of urban sprawl and plan for more sustainable cities in the future. The idea of sustainable development clearly transcends all these issues and should be clearly more addressed in the policy making for all the sectors involved. Some studies have highlighted this struggle to achieve a sustainable development in agriculture in the light of decreasing area of land dedicated to this land use. Indeed, there is now an increasing pressure to meet the growing food demand of exponentially evolving human population with limited land expansion while at the same time minimizing the consumption of energy and water and conserving the environment. The approach to try to meet all these different demands is described as a food-energy-water nexus approach (Nie et al., 2019). It outlines that major challenge in agricultural land use arises from the presence of multiple stakeholders with different and often competing objectives, such as profit, food demand, environmental goals and efficient use of resources (Stewart et al., 2004, Garcia and You, 2016). In this regard, the problem of land optimization has to be studied as a multi-objective problem. (Seppelt, 2016). These challenges suggest that there is a need for a robust and systematic method to derive trade-offs for land use decision making. (Nie et al., 2019)

8 CONCLUSION

This dissertation focused on the ecosystem services which are provided by agriculture land and urban sprawl in the study area of municipality with extended powers Třebíč. Four ecosystem services provided by agricultural land were identified and evaluated through different methodologies in the scope of this research. These services were prevention of water contamination, carbon sequestration, production function and prevention of soil erosion. The research also focused on determining the amount of area lost due to urban sprawl in the municipality with extended powers Třebíč.

The main outcomes of this dissertation show that in most cases and for most of the typical arable crops in the Czech Republic, agriculture provides a disservice to the ecosystems rather than a service. The one notable exception is the provision of food, which is indeed the vital and primary function of agriculture land. There was evidence suggesting that permanent grassland could be much more benefitting in the terms of the provision of ecosystem services, yet it was not fully included in this study due to modelling limitations. The results also showed that much can be done for a better provision of ecosystem services through sustainable management of land and through implementation of different practices and measures. It should also be noted that the research focused solely on arable and did not study the benefits of features adhering to agriculture land, which often have much more value in terms of ecosystems and biodiversity.

As for the urban sprawl, the research showed that the area of agricultural land is indeed steadily decreasing and some if it can be attributed to urban sprawl. The analysis of possible future trends also showed that this development will continue. It can be concluded that even if agriculture land does not provide all ecosystem services, it is still our main resource of food. Some of the ecosystem services can be reinstated in urban ecosystems, yet the provision of food is hardly replaceable on a scale that would matter.

The discussion and comparison to studies on similar topics in the Czech Republic has put the results in a wider context. The provision of ecosystem disservices ties closely to land degradation, as most of the processes identified through this research fit into the definition. Several studies have also suggested that due to historical developments in the Czech Republic and some specific conditions, this degradation process can be linked with the land fragmentation and tenure insecurity. The agriculture land in terms of ownership in the Czech Republic tends to be very fragmented yet the average area of soil blocks is the biggest in the EU. Most of the land is also rented as the small ownership blocks can hardly be used otherwise and also due to the fact that historic developments have prevented the preservation of family farm model. This research showcased similarities with these conclusions as most of the land in the area is farmed on by large cooperatives and large blocks of soil are also occurring.

As for the ecosystem services themselves, other studies have proven that better management of agriculture land can lead to provision of more services. More wider studies have also shown that for some crop types and for permanent grassland there are more ecosystem services to be considered than just the ones included in this research. Also the values attributed to some ecosystem services vary due to different methodologies used. Some studies have also found closer ties of ecosystem services provision to management types (e.g. organic agriculture) than this research.

As for the policies which impact all the elements included in this research, the Common Agricultural Policy influences the management of agricultural land, the spatial planning is controlled through Building Act and the agriculture land is also protected against urban development through Act on Protection of Agriculture Land Resources. The CAP can shape the agriculture towards a more sustainable management of land and better protection of environment, while the Building Act can be formulated to protect against uncontrolled urban sprawl and better preservation of rural areas and communities. The methodology used in the Act on Protection of Agriculture Land Resources to calculate the fees to change the landuse can also be updated with the ecosystem services evaluation to better reflect the evolving notions of ecosystem functioning and biodiversity protection.

As the wide notion of sustainable development suggests, the underlying issue of ecosystem disservice provision, land degradation, ownership fragmentation and urban sprawl can be targeted through a policy mix aiming at the three pillars of sustainability – economic, environmental and social. Indeed, if we would look at the economic side, we would need a better provision of credit and better access to land for farmers, with an income that would be comparable to the rest of the society, to tackle the ownership fragmentation. The social pillar also plays a role in providing for a decent lifestyle of farmers and preservation of rural communities. The environmental comes as the result of these changes, as more competitive farmers who would be able to buy the farmland would be able to provide for a better provision of public goods and better environment protection, responding in this regard also to the societal demands.

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