Mapping and projection for economic evaluation of ecosystem services
– A case study of a partial catchment area for Ätran

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Summary

To shed light on the value of the measures being done to achieve a good ecological status in our waters, an ecosystem service approach can be applied. In this report, such an approach has been applied to estimate the value of measures that could be possible within the *Vartofta project*. The project was initiated by the Ätran Water Council in collaboration with the drainage association in the area and is also included as a part of the Interreg project *Water Co-Governance*. Supportive, regulating, provisioning and cultural ecosystem services were mapped in the partial catchment area that the *Vartofta project* concerns. Through interviews with participants in the project, two prioritised measures were then selected for further analysis. The measures include the creation of a wetland and expansion of edge zones. Based on the gross list over all conceivable ecosystem services in the case study area, 15 prioritised ecosystem services were identified, all of which will be positively impacted by the measures. From these 15, "retention of nutrients" and "regulation of overfertilisation" were selected for quantification and monetarisation. An important step in this process is to find a way to measure the supply of a given ecosystem service. This is done by choosing an indicator for the service that can be measured in a biophysical unit, such as the concentration of a substance or number of a species. For the above services, kg of nitrogen and phosphorous, respectively, are used as indicators. The value of the wetland's nutrient retention is estimated at between SEK 6,200 and SEK 18,000 for nitrogen and between SEK 3,350 and SEK 5,115 for phosphorous per year, calculated on 1 hectare of wetland. The edge zones' ability to regulate overfertilisation is estimated to be worth from SEK 331 to SEK 505 per year, calculated on a 24,670 m long and 2 m wide edge zone.

Conclusions from the case study of the partial catchment area are that several ecosystem services are found in both the water and cultural landscape and that these interact with, and partially overlap, one another. In addition, it is also necessary to find indicators to estimate the change in the supply of an ecosystem service as a result of measures. This enables a quantification of the ecosystem service and in the next step, a monetarisation, i.e. that the value of the ecosystem service is measured in SEK. "Regulation of overfertilisation" proved to not be the most important ecosystem service as a result of edge zones, which is why an evaluation of this service was not optimal. Instead, an estimate of the edge zones' impact on the ecosystem service of "erosion regulation" would probably have been better to capture the value of the measure's positive effects. At the end of the report, proposals of indicators were therefore provided to do such an evaluation in the future. It should also be pointed out that the studied measures provide

positive effects on multiple services. The value as a result of the greater supply of all services would accordingly need to be assessed to be able to reflect the entire benefit of a given measure.

Contents

1 Introduction

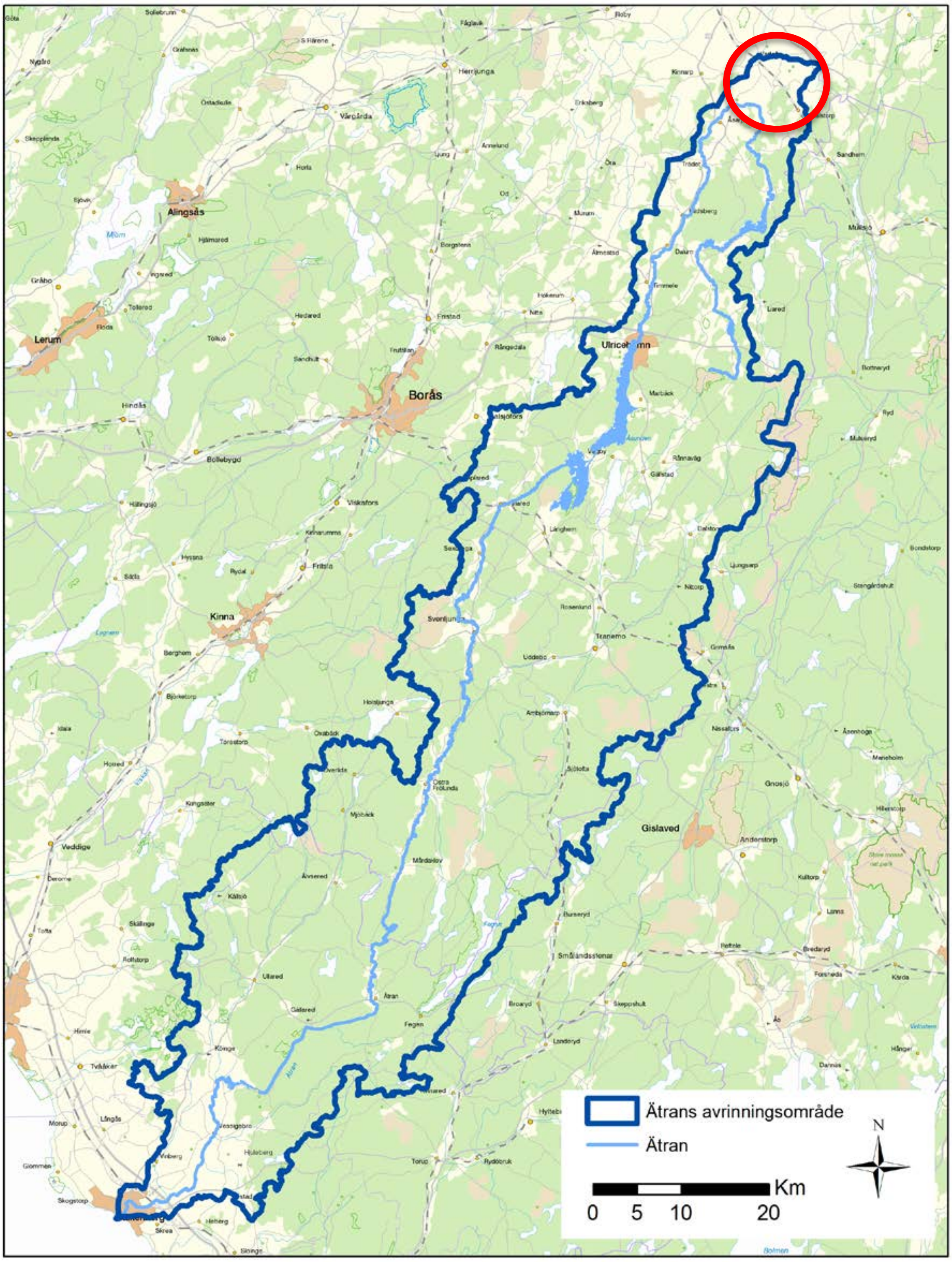
In this report, a mapping was done of ecosystem services in a case study area in Falköping Municipality. The case study area is comprised of a partial catchment area for the Ätran River and the mapping was done as a result of the pilot project, the *Vartofta project* which is being conducted by the Ätran Water Council in collaboration with the drainage association. Through the project, the Ätran Water Council wants to establish collaboration with local land owners to develop good and effective measures to achieve an improved ecological status in the partial catchment area. The purpose of the report was to map which ecosystem services are in the case study area to then identify which of them are affected by a few prioritised measures. The ecosystem services affected positively by the measures are both in the watercourses and in the cultural landscape. To indicate the value of the measures, a quantification and monetarisation were done of ecosystem services. The report constitutes an example of how an ecosystem service approach can be used to illustrate the value of the work for an improved ecological status of our waters. The report was also requested by the County Administrative Board in its work to develop

Photo: Peter Nolbrant.

a regional action plan for green infrastructure. In this context, the report aims to provide examples of how the ecosystem service analysis can strengthen the work of making natural assets visible and serve as a basis for prioritising measures in areas of value for various types of nature, in this case a valuable watercourse.

1.1 Background

The Ätran has a catchment area of 3,342 km^2 and flows from a bog in Gullared, through Västergötland to then feed out into Kattegatt at Falkenberg (SMHI, 1996). The Ätran is valuable from several perspectives and the valley is classed as a national interest for nature conservation, heritage conservation and outdoor life. In addition to good water



quality, the Ätran holds unique salmon and salmon trout stocks and a number of other natural assets in flora and fauna (Ätran Water Council, n.d.).

The Ätran Water Council is one of the 36 water councils in the North Sea water district that work for the achievement and maintenance of the water directive's targets and established environmental quality norms in lakes, watercourses and groundwater in the catchment area. The Ätran Water Council strives to create local participation through collaboration between representatives from various stakeholders and to utilise existing local knowledge and expertise to find solutions for an improved water quality (Ätran Water Council, n.d.). As a part of the water management work, the Water Council started the *Vartofta project*, which is a part of the EU project *Water Co-Governance*. The EU project's overall objective is investigating how participation in water management can increase. This may, for example, take place by illustrating new solutions and techniques to develop sustainably managed ecosystems. An important condition should be local participation where the understanding of the ecosystem services is integrated into planning, measures and follow-up.

The *Vartofta project* is a pilot project within *Water Co-Governance* and has a broad approach that concerns both water and the cultural landscape[1]. The geographical area for the project is a partial catchment area in the Ätran's catchment area (Figure 2). It belongs to Falköping Municipality and is surrounded by an active agricultural community.

[1] http://www.vattenorganisationer.se/atransvro/modules.php?name=Content&op=showcategory&cat=635

Figure 2. Map of the partial catchment area covered by the Vartofta project.

The partial catchment area is around 11 km long and 3 km wide and the watercourse is comprised of the old main flow for the Ätran, which has now become a secondary flow due to excavation. In the landscape, there is valuable meadow and pasture land, which is adjacent or close to the watercourse. This contributes to important green infrastructure for pollinators, pest controls, red-listed species and biodiversity (P. Nolbrant, personal message, 21 June 2017). There are also strong elements of recreational and cultural value in the form of e.g. pilgrim paths, boulder ridges, nature reserves with unique plants and bird species, such as curlews and lapwings, as well as a hunting pavilion. The ecological status of the partial catchment area is, however, classed as moderate, mainly due to problems of overfertilisation.

In 2018, the drainage association will conduct a river clean-up. In connection with this, discussions have arisen on how it can be done as carefully as possible and possibly together with environmental improvement measures. The possible measures discussed in consultation with local land owners include reinforcement and creation of edge zones, an increase of the share of shaded watercourses and the installation of nutrient traps (see a more detailed explanation of these measures under section 2.3.1 and 2.3.1 below). By creating this kind of local collaboration, the *Vartofta project* seeks to develop a working method where agriculture is involved to thereby develop well-rooted measures for reduced nutrient loading and thereby achieve good ecological status in the waters in question. This is in accordance with requirements in the approved programme of measures. It is also hoped that these measures will improve the supply of most ecosystem services linked to the Ätran and the cultural landscape, including reduced erosion, greater biodiversity and reduction of nutrient leakage from agricultural land[2].

Besides improving the current environment in the catchment area, the project is a part of Sweden's climate adaptation. Climate adaptation means that efforts are done to adapt our society to a future changed climate, which is expected to entail e.g. greater precipitation in Western Sweden[3]. Greater precipitation entails a risk of flooding and erosion and thereby a loss of income for farmers in Ätran's catchment area, which is why prevention work by improving the ecosystem services that regulate it is a necessity.

1.2 Objective of the report

This report aims to be an example of how an ecosystem service approach can be used to show the value of measures to achieve improved ecological status.

This is done through an initial identification and mapping of ecosystem services in the case study area, which is the partial catchment area covered by the *Vartofta project*. Thereafter an estimation is done of how the supply of these services can be improved and what other ecosystem services can be created as a result of measures taken. Attempts at quantification and a monetary valuation of selected ecosystem services are also made.

1.3 Delimitations

After having identified and mapped ecosystem services in the case study area, the report will be delimited to conduct a special study of a few of these services. They are linked to two of the most central measures that the land owners intend to undertake. The ecosystem services that have been prioritised are those that the participants have pointed out as some of the most important. Of the prioritised ecosystem services, a few have been selected for the estimation of quantitative and monetary measures. The selection has been done based on available data.

2 Ecosystem services

Ecosystem services can be defined as the ecosystem's direct and indirect contributions to human well-being (TEEB, 2010). The concept of ecosystem services includes both direct benefits such as drinking water and indirect benefits such as soil formation. The ecosystem services constitute a basis for human survival and welfare, which is why changes to or destruction of them can lead to major risks to life and health. To illustrate human dependence on functioning ecosystem services and with it the impact on the future supply

[2] http://www.vattenorganisationer.se/atransvro/modules.php?name=Content&op=showcontent&id=1845
[3] http://www.lansstyrelsen.se/VastraGotaland/Sv/miljo-och-klimat/klimat-och-energi/Klimatanpassning/Pages/klimatanpassning.aspx

of these services, it is necessary to evaluate them economically (Swedish Environmental Protection Agency, 2015; Swedish Environmental Protection Agency, 2017).

Mapping and subsequent evaluation of ecosystem services allows their value to be illustrated and included in decision making to achieve a sustainable management of our shared resources. By evaluating ecosystem services economically, the importance of taking steps to improve the supply of prioritised ecosystem services is also clarified. The value of an improved supply of a given ecosystem service often benefits society as a whole.

2.1 Categorisation of ecosystem services

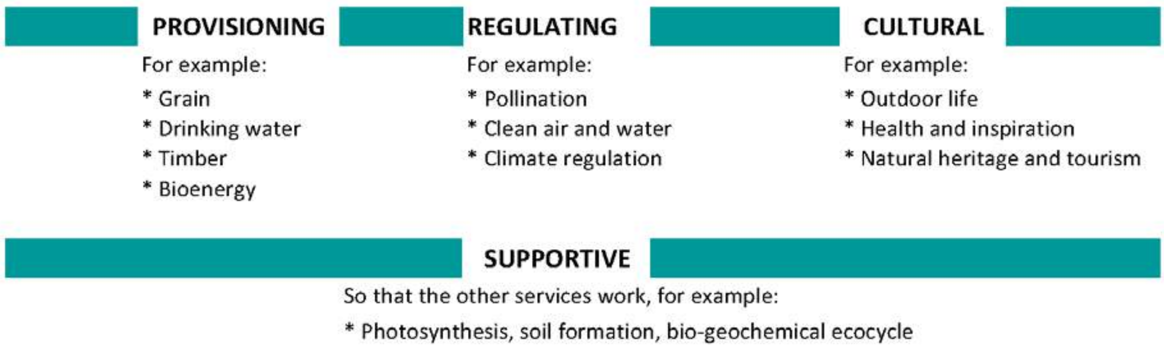
To map and evaluate ecosystem services, there are several different classification systems to apply. Some standard works are: Millennium Ecosystem Assessment (MEA), 2005; The Economics of Ecosystems and Biodiversity (TEEB), 2010 and Common International Classification of Ecosystem Services (CICES), 2011. There are many fundamental similarities between the various systems, as well as differences in terms of approach and categorisation. The Swedish Environmental Protection Agency's recommendation is to initially conduct a broad identification of affected ecosystem services based on the categorisation that best suits the specific study (Swedish Environmental Protection Agency, 2015). TEEB (2010) has prepared a general list that is broadly applicable. The Swedish Environmental Protection Agency (2015) has since compiled a gross list over ecosystem services adapted to Swedish conditions based on CICES (2011), with the addition of supportive services (see explanation of this group of services below). As this report seeks to identify ecosystem services linked both to watercourses and adjacent cultural landscapes, a gross list has been developed through a compilation of earlier literature (Gisselman et al., 2015; Swedish Agency for Marine and Water Management, 2017; Swedish Environmental Protection Agency, 2012).

Depending on how the ecosystem services contribute to human welfare, they were divided into four different categories according to the division in MEA (2005); provisioning, regulating, cultural and supportive. The benefits of water, food and bioenergy belong to the provisioning services. The regulating ecosystem services contribute to human well-being by regulating natural processes, such as flow control, water purification and regulating air quality and local climate. The cultural ecosystem services contribute non-material value through recreation and inspiration while the supportive services are necessary for the other ecosystem services to work. Examples of supportive ecosystem services are primary production, ecological interaction and maintaining the soil's fertility. As Figure 1 illustrates below, the supportive ecosystem services form the basis for the provisioning, regulating and cultural ecosystem services to work.

In terms of categorisation of "biodiversity", the literature differs. MEA (2005), TEEB (2010) and CICES (2011) have chosen to interpret the importance of variability among living organisms as a prerequisite for all ecosystem services, while the Swedish

Environmental Protection Agency (2012) categorises biodiversity as a supportive ecosystem service. According Gisselman et al., (2015) an argument for biodiversity to be seen as its own ecosystem service is that people can value nature's diversity regardless of its capacity to provide benefits. In this report, the division is done based on the Swedish Environmental Protection Agency's interpretation where biodiversity is defined as a supportive service, which contributes to the preservation of the gene pool and endangered species as well as diversity on the genetic, species or habitat level (Swedish Environmental Protection Agency, 2012).

Figure 3. Categorisation of ecosystem services as provisioning, regulating, cultural or supportive ecosystem services (Swedish National Environmental Protection Agency, 2015, p. 16).



2.2 Mapping of ecosystem services in the case study area

The mapping of ecosystem services in the case study area was done with the influence of earlier literature in the area. The mapping was primarily done based on the Swedish Environmental Protection Agency's (2015) guide for the evaluation of ecosystem services and the existing standard works (CICES, 2011; MEA, 2005; TEEB, 2010;), as well as reports from similar case study areas. The gross list is fundamentally based on the Swedish Environmental Protection Agency's categorisation (2012). Thereafter, supplementation has been done using lists of ecosystem services linked to cultural landscapes (Gisselman et al., 2015) and fresh water (Swedish Agency for Marine and Water Management, 2017) in order for it to be applicable to the specific case study area. In total, 37 ecosystem services were mapped, of which several occur both in connection to water and cultural landscapes. Many of the ecosystem services identified are also dependent on and overlap with each other. The gross list over the ecosystem services in the case study area is found in Appendix 1.

2.3 Prioritised measures and ecosystem services

Within the *Vartofta project*, there are several possible measures for improved ecological status. Through study visits in the case study area and interviews with Wanja Wallemyr, Chairman of the Ätran Water Council and Peter Nolbrant, Swedish Agency for Marine and Water Management, who are involved in the project, the most central measures were identified, of which two were selected for further analysis. The selected measures (see sections 2.3.1 and 2.3.2 for descriptions) include installation of a general nutrient trap and the expansion of the edge zones between arable lands and watercourses. Based on these measures, the 15 ecosystem services from the gross list (Appendix 1) which are mainly affected were compiled in Table 1. Brief qualitative descriptions of the various ecosystem services and their value are presented after Table 1. In addition, two ecosystem services were chosen for quantification and monetarisation to estimate the measures' effects on the supply of these services.

2.3.1 Nutrient trap through installation of wetlands

Wetlands are a collective name for a number of different types of nature that border between land and water (Hidås, n.d.). Wetlands fill a number of important functions for people, but today, around 80% of the remaining wetlands are affected by human activity, such as agriculture and forestry. By installing wetlands, their ecological and water management function is maintained, which is a part of the environmental quality objective of "living wetlands" (Swedish National Environmental Protection Agency, 2012). Wetlands give rise to a number of different ecosystem services including biodiversity, flow equalisation, habitats for plants and animals and water purification from nitrogen and phosphorous. An installed wetland is formed in different ways depending on what function it should fill or what kind of flora and fauna is desired to be benefited. A general guide is, however, that the wetland may not be installed in such a way that it gives rise to unnatural migration obstacles to fish and other marine organisms. This leads to a degradation of other ecosystem services (Hidås, n.d.).

In wetlands that are installed with the aim of cleaning the water of nitrogen and phosphorous, the purification process takes place through retention that includes the biochemical process denitrification, sedimentation and purification with the help of plants[4]. Denitrification is the process where bacteria convert the dissolved nitrate nitrogen in the water into nitrogen gas that is removed up in the atmosphere. The plants are primarily important in the form of a living environment and energy source for the bacteria, but in the summer, they also take up nutrients. When the plants are broken down during the winter, it is important to harvest them so that the nutrients are not released again. The nitrogen that occurs in particle-bound form and phosphorous is cleaned through sedimentation when the water is slowed in the wetland, which is why a longer interruption period leads to more sedimented particles (Hidås, n.d.).

At present, there are some different kinds of wetlands in the partial catchment area that give rise to the majority of ecosystem services. Around Bredska Kvarn, which is located in the lower part of the partial catchment area adjacent to Ätran, there are both existing floodplains and wetlands. These provide e.g. the services of retention of nutrients, flow and flood regulation and aesthetic value. There are also some floodplains and nice wetlands at Öjevalla, located in the upper half of the case study area (P. Nolbrant, personal message, 12 June 2017). In addition, there is a nitrogen trap in the case study area that one of the land owners has already created. The trap was created by cleaning out an old forest ditch and according to visual measurements it fills its function well. To increase the supply of the ecosystem services that a wetland gives rise to, another wetland is installed in the case study area at around 1 hectare. It should serve as a general nutrient trap for the reduction of both nitrogen and phosphorous in the partial catchment area (W. Wallemyr, personal message, 14 June 2017).

2.3.2 Edge zones between arable land and watercourses

Edge zones are a type of protective zone or buffer zone that is installed between arable land and a water occurrence, such as a watercourse or an agricultural trench. Here, the roots are permanent and no spraying of chemical plant protectant or fertilisation may occur. The literature uses different terminology for this kind of measure and in this report, the term edge zones has been chosen and this is the term used in the *Vartofta project*. To be entitled to environmental compensation, the edge zone must be structured according to the restrictions that exist. One kind of edge zone must be constantly grass-covered and be located at marked out watercourses or watercourses that have running water year-round (Gyllström et al., n.d.). There is also a possibility to install adapted edge zones that may be placed everywhere erosion and drainage occur, such as at agricultural trenches or at

[4] https://www.smhi.se/kunskapsbanken/vattenkvalitet-i-forandrat-klimat-1.96366

drains for surface water intake (Gyllström et al., n.d.). The zone may only be cultivated with pasture grass or a mix of pasture grass and pasture legumes. Harvesting may be done, but only at specific intervals during the year.

Edge zones constitute important filters for soil particles, nutrients and particle-bound plant protectants and contribute to a number of ecosystem services (Almqvist & Arwidsson, 2010). The main ecosystem services include "regulation of overfertilisation" and "water purification". These are provided through reduced transport of particle-bound phosphorous from arable lands to the water by the vegetation that grows in the edge zone slowing down the water's speed, which means that some of the water can be filtered down in the soil. The phosphorous that is bound to soil particles and is kept in the vegetation can then be taken up by plants. Depending on the edge zone's width and the field's incline, the reduction of phosphorous varies between 13 to 72% (Gyllström et al., n.d.). Through soil particle infiltration and permanent roots in the edge zones, problems with erosion are also reduced, which is a significant problem in the partial catchment area today. This is partly due to it having been ploughed down to the water's edge and to the characteristics of the soil (W. Wallemyr, personal message, 14 June 2017). The area is characterised by silty and humus-rich soils, which are more easily struck by wind and water erosion. This leads to nutrient leakage together with cultivable soil disappearing out in the watercourses to later get stuck as sludge or carried on out to the sea. As a result of the unstable soils at the pasture edge, the laying of covered edge zones entails some challenges as it is difficult to make them stable. Alternative aids through fibre mats are therefore discussed to succeed with the measure.

In addition, there are ecosystem services that are negatively impacted by the measure. Despite the covered edge zones providing a great deal of good, they entail an allocation of arable land and thereby reduced harvest for the farmer, i.e. a degradation of the ecosystem service "food from cultivated plants". It is therefore worth striving for to cultivate such in the edge zone that can be harvested periodically and provide yield, such as wood or feed (Haddaway et al., 2016).

The existing edge zones along the arable lands in the partial catchment area are very limited and vary between 0 - 2 m, while the edge sections in the upper part of the case study area upstream of Stensholmen are dominated by natural pasturelands (P. Nolbrant, personal message, 21 June 2017). So in terms of the edge zones along the arable lands, there is great potential. By increasing the width of the edge zones and achieving permanent roots in the soil, many environmental improvements can be achieved, which is why installation of edge zones is one of the main measures within the *Vartofta project*. The ambition is that they will reduce problems of erosion through erosion regulation and reduce nutrient leakage through regulation of overfertilisation and water purification. It is also hoped to be able to have an edge zone crop that provides some form of return to the farmers and that the edge zones will improve the green infrastructure to benefit biodiversity (W. Wallemyr, personal message, 14 June 2017). Other important ecosystem services that are obtained through edge zones are living environments for biological damage control, birds and game for hunting, pollinators and recreation through walking paths (Almqvist & Arwidsson, 2010).

Table 1. Prioritised ecosystem services and what measure they are affected by

Type of ecosystem service	Ecosystem service	Nutrient trap	Edge zones
Supportive	Maintenance of the soil's fertility		X
	Retention of nutrients	X	
	Primary production	X	
	Bio-geochemical cycles	X	
	Biodiversity	X	X
	Habitats	X	X
Regulating	Flow and flood control	X	
	Water purification	X	X
	Regulation of pests		X
	Pollination		X
	Erosion regulation		X
	Regulation of overfertilisation	X	X
Provisioning	Food from cultivated plants	X	X
Cultural	Recreation possibilities	X	X
	Aesthetic values	X	X

Maintenance of the soil's fertility

There are a number of factors that affect the soil's fertility, both short and long term, e.g. biological activity and the humus content (HIR Malmöhus, n.d.). By installing edge zones, the ecosystem service of "erosion regulation" will be improved, i.e. reduced erosion, which in turn leads to improvement of the supportive ecosystem services "maintenance of the soil's fertility". The service is fundamental to the production of plants and contributes to the provisioning ecosystem service "food from cultivated plants".

Retention of nutrients

"Retention of nutrients" is handled here as a supportive service as it creates conditions for several other ecosystem services' function such as "regulation of overfertilisation" and "water purification" (Figure 3). As previously mentioned, the purification takes place through denitrification of nitrogen and sedimentation of both nitrogen and phosphorous and uptake by plants (Hidås, n.d.). This biological process that takes place in wetlands contributes to "regulation of overfertilisation" by the wetland having a possibility of taking up a surplus of nutrients in the catchment water, which leads to reduced fertilisation. The process is also an important basis for the regulating service "water purification" as the water with the help of the retention process in the wetland is purified from pollutants of nitrogen and phosphorous. The pollutants are comprised of the nutrients that were added to the water as a result of human activity.

Primary production

Primary production is an essential supportive service, which entails the photosynthesis conversion of carbon dioxide and energy, in the form of sunlight, into carbohydrates, i.e. biomass, and oxygen (Swedish Agency for Marine and Water Management, 2017). It is therefore necessary for the maintenance of bio-geochemical cycles. The supply of the ecosystem service will be improved through the plant plankton that lives in wetlands.

Bio-geochemical cycles

The bio-geochemical cycles will also be benefited by the installation of wetlands. Several important cycles belong to this of which some of the most central to both ecosystems and society are the ecocycles of carbon, nitrogen, oxygen and phosphorous (Swedish Agency for Marine and Water Management, 2017).

Biodiversity

Biodiversity is a fundamental requirement for the other ecosystem services and it is defined by the Convention on Biological Diversity as "the variability among living organisms from all sources including, inter alia, 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" (CBD, 1992). Both edge zones and wetlands contribute to greater biodiversity by creating variability in the landscape, green infrastructure and habitats for various species. The improvement of the biodiversity is an important part of the *Vartofta project.*

Habitats

Edge zones and wetlands offer habitats for many plant and animal species, which is why this ecosystem service is strongly linked to biodiversity. In the case study area, habitats are provided for example for game for hunting and red listed birds. Pollinators that are dependent on continuous food are also benefited by permanently covered edge zones with elements of flowers (Cederberg et al., 2016). Wetlands form habitats for e.g. organisms that bind carbon and nutrients and decay bacteria, which contribute to water purification.

Flow and flood control

Regulation of the flows and floods is an ecosystem service provided by wetlands. If it does not exist or work well, it can lead to major costs for private individuals and society (Swedish Environmental Protection Agency, 2017). One study of British wetlands confirmed that flood protection was the ecosystem service that people were willing to pay the most for, namely GBP 608/hectare of wetland/year (Morris & Camino, 2011 referred to in Swedish Environmental Protection Agency, 2017). Even though floods are a relatively small problem in the area at present, greater future precipitation will probably require an improved supply of this service.

Water purification

Both stable edge zones and wetlands contribute to better water purification. The edge zones help by the drainage water from the agricultural land being filtered through the edge zones (Gisselman et al., 2015). This way, phosphorous and remnants of pesticides that accompany soil particles in the drainage water are prevented from transport to the watercourse. In wetlands, there are organisms that are an important part of the water purification through photosynthesis where oxygen is produced (Swedish Agency of Marine and Water Management, 2017). Wetlands also provide the supportive service "retention of nutrients" which contributes to purifying the water from pollutants and thereby constitutes a condition for the purification of the water. The ecosystem service "water purification" overlaps with "regulation of overfertilisation", but as they partly fill different functions for mankind, both have been included. Water purification leads to e.g. removal of environmental toxins and is therefore necessary for the provisioning service "drinking water" while regulation of overfertilisation is important to the provisioning of fish.

Regulation of pests

Edge zones create habitats for natural enemies of various pests that cause crop loss, such as the pollen beetle and aphids (Cederberg et al., 2016). Natural enemies that are benefited are, for example, hymenopter, ladybirds and spiders. According to Cederberg et al. (2016), a well-functioning biological control can reduce the attacks on the crops to a significant extent, so the provisioning ecosystem service "food from cultivated plants" can be benefited.

Pollination

Flowering and permanently covered edge zones create habitats for pollinators, which is why the ecosystem service "pollination" is in turn improved. Pollination is done by honey bees and wild pollinators, such as bumble bees, solitary bees and flower flies and is important for several crops, such as oil plants (Cederberg et al., 2016). For clover seed cultivation, pollination is necessary. Greater pollination leads to increased harvests and sometimes also better quality of the harvest. The intensified agriculture has struck pollinators hard, which is why measures are of the greatest importance.

Erosion regulation

The need for greater erosion regulation is one of the main reasons that the participants in the *Vartofta project* plan to install wider edge zones along arable land. Erosion entails a removal of soil by wind or water. Factors that affect erosion are land characteristics, incline, vegetation, openness, drainage and precipitation. Erosion has a negative impact on ecosystem services both in the water and in the actual agricultural land (Cederberg et al., 2016). For example, it leads to worse conditions for yields on the crops and the silting up of watercourses.

Regulation of overfertilisation

Overfertilisation of lakes and watercourses is a major problem in Sweden today and overfertilisation is also the main reason that the partial catchment area is classed with a moderate status. Overfertilisation is created as a result of human activities through the addition of extra nutrients in the water, primarily nitrogen and phosphorous. A large source of the problems is agriculture through leakage of nutrients from agricultural land. This leads, among other things, to cloudier water and an oxygen deficit, resulting in mass fish kills (Swedish Agency of Marine and Water Management, 2017). Edge zones lead to a better function of the overfertilisation regulation as they capture nutrients with the help of infiltration and plants. Wetlands also contribute positively as the service "retention of nutrients" that is provided by the wetlands supports "regulation of overfertilisation" (Figure 3). This is because the nutrient retention process helps to take up surpluses of phosphorous and nitrogen in the water. However, these two services partly overlap one another as the uptake of phosphorous from plants is included in both of the services. This is a result of the gross list (Appendix 1) being a compilation of lists of ecosystem services in both cultural landscapes and water environments. In the optimal case study, a list over ecosystem services for both water and cultural landscapes is applied in connection with each other.

Food from cultivated plants

Food from cultivated plants is a provisioning and for us humans vital ecosystem service that is obtained through the production of crops such as grains, oil plants and legumes. This is an example of an ecosystem service that is expected to be affected positively and negatively by current measures. Both edge zones and wetlands may entail an allocation of cultivable land, with leads to a reduced harvest. However, this service can be positively affected as edge zones benefit biological pest control and erosion regulation.

Recreation possibilities

Wetlands contribute to landscape variation and form habitats for multiple species, such as frogs, which makes them attractive for recreation. There are ideas about increasing the proportion of eco-tourism in the case study area and edge zones could contribute walking paths or possibilities for duck hunting as there are plenty of birds (W. Wallemyr, personal message, 14 June 2017).

Aesthetic values

A varying landscape with farm land, natural pastures, wetlands, flowering edge zones, watercourses and sections of forest create aesthetic values for mankind, which is why all measures are expected to affect this ecosystem service positively. At present, there are both meadowlands and boulder ridges of large aesthetic value (P. Nolbrant, personal message, 21 June 2017). Establishment of permanent edge zones with walking paths makes it easier for people to move between the beautiful settings in the area.

3 Evaluation of ecosystem services

The various methods for evaluation of the ecosystem services are qualitative (words), semi-quantitative (point system), quantitative (physical unit) and monetary valuation (SEK). To evaluate the ecosystem service quantitatively, one or more indicators for the service are used. The starting point for the application of indicators is that some aspects of the environment or people's use of it can be measured and thereby reflect different ecosystem services' concrete contribution to human well-being. For example, the proportion of hectares with natural pastures in an area can provide an indication of the supply of biodiversity. By trying to identify good indicators, it is also possible to estimate the present value of a change by providing an ecosystem service (Swedish Environmental Protection Agency, 2015). An indicator is categorised according to complete, partial or direction indicators depending on how and to what extent it captures various values of the ecosystem service (Swedish Environmental Protection Agency 2012; Swedish Environmental Protection Agency 2015).

3.1 Economic valuation of ecosystem services

The theoretical foundation for an economic valuation of ecosystem services is economic welfare theory. By investigating individual preferences for the benefits ecosystem services contribute to mankind, their economic value can be obtained. This is interpreted as the ecosystem services' contribution to social benefit (well-being) and business profitability. Ecosystem services generate several kinds of economic values of which all are not represented in a market with an associated market price. Therefore, a framework is often used that describes Total Economic Value (TEV) in an economic valuation (Figure 4). TEV includes user values (direct and indirect) and non-user values. Non-user values do not arise through the use of an ecosystem service, but can e.g. be the value an individual receives merely from the knowledge that the earth's ecosystems are healthy. The breakdown has been done based on how mankind uses the goods that the ecosystem service contributes. To include the non-user values in an economic valuation, such as the existence value of salmon trout in a specific watercourse, which include the value people perceive as a result of the knowledge that salmon trout exist in the watercourse, surveys must be done since these are preferences that individuals do not reveal through actual behaviours. It can therefore be difficult to include non-user values in economic valuations of ecosystem services, but they should at least be illustrated in the analysis to be able to calculate TEV.

In addition, ecosystem services are often dependent on each other and the benefit of an ecosystem service may be due to an ecosystem service in an earlier stage (Fisher et al., 2009). There is therefore a clearer division of ecosystem services through the terms intermediate and final ecosystem services. For example, "retention of nutrients" can be interpreted as an intermediate service to "regulation of overfertilisation" in a wetland (Figure 3). An ecosystem service is intermediate or final depending on the context and, from an evaluation perspective, it is important to distinguish both of them to avoid double accounting. An example of double accounting in an analysis of summed socio-economic value is to combine both the value of feed, which is received through an intermediate service, and the value of the animal that eats the feed, which is a final service. This is not a problem in this report as only two ecosystem services are evaluated, which are linked to two different measures.

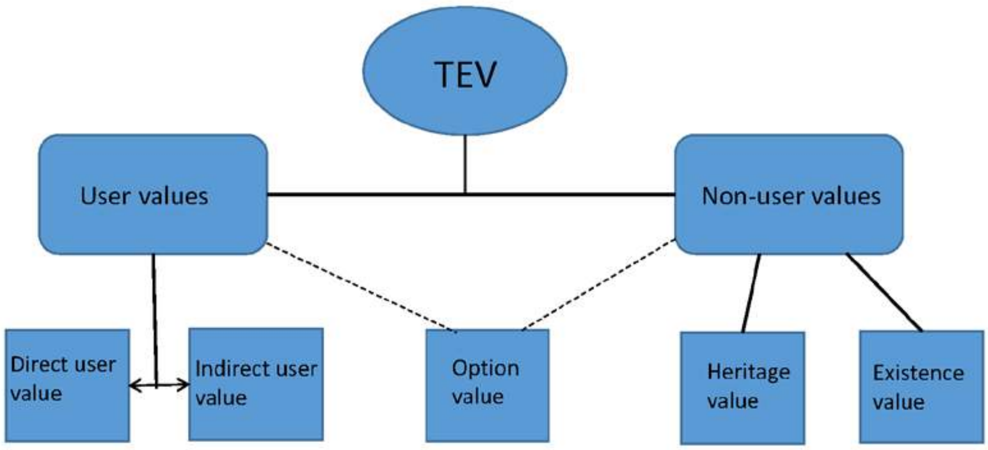


Figure 4. Structure of Total Economic Value (figure based on Swedish Environmental Protection Agency, 2012, p. 40).

When it comes to the selection of evaluation methods, which method is the most relevant to apply differs. Such factors that can determine the selection of method are e.g. the purpose of the evaluation, what analysis resources are available and if there are indicators for the selected ecosystem services. In this report, the quantitative evaluation of the chosen ecosystem services has been done using available standard values for physical reduction of nitrogen and phosphorous in the Water Information System Sweden (WISS). To estimate the value of the reduction in monetary terms, standard values based on the Swedish Environmental Protection Agency (2009) and Ahlroth & Finnveden (2011) were used. Within the scope of this limited study, there was no room to do a primary evaluation study. Nor has a proper benefit transfer study from earlier studies been able to be done where the value of the corresponding ecosystem services has been calculated.

4 Evaluation of prioritised ecosystem services

In this chapter, an attempt has been made at the evaluation of the ecosystem services "retention of nutrients" and "regulation of overfertilisation". Initially, a quantitative estimation is done of how the provisioning of the ecosystem service will change as a result of the measure in question and this is followed by a monetary valuation. At the end of the chapter, a section is added on continued evaluation of ecosystem services in the case study area. Table 2 lists the ecosystem services chosen for evaluation and what measure they result from.

Table 2. Selected ecosystem services and method approach for evaluation

Type of ecosystem service	Ecosystem service	Linked to measure	Indicator	Evaluation method
Supportive	Retention of nutrients	Nutrient trap	Amount of nitrogen and phosphorous taken up, kg	Standard values
Regulating	Regulation of overfertilisation	Edge zones	Amount of phosphorous taken up, kg	Standard values

4.1 Retention of nutrients

4.1.1 Quantification

To quantify the nutrient trap's cleaning of nitrogen and phosphorous, there are multiple standard values to work from and the values from the literature vary to a large degree. A wetland's effect depends on multiple factors; for example, the retention effect is greater in high flows than in low flows, which affects the results. The quantification of the ecosystem service "retention of nutrients" was done in this study based on the standard values in WISS[5], which are developed for wetlands with nutrient retention as the primary purpose. The standard values are based on two reports from the Swedish Board of Agriculture that evaluated the effects of wetlands resulting from the Rural Affairs Programme (Weisner & Thiere, 2010; Weisner et al., 2015).

Table 3. Standard values for nutrient retention of nitrogen and phosphorous in wetlands

Nutrient	kg/hectare per year
	Standard values
Nitrogen N	200
Phosphorous P	5

The reduction amount is obtained by multiplying the size of the nutrient trap by the standard value from WISS. Since the planned nutrient trap will be around 1 hectare large, the retention of nitrogen is estimated at 200 kg/year and the retention of phosphorous is estimated at 5 kg/year.

4.1.2 Monetary valuation

The monetary valuation of the ecosystem service was done using the standard values from the Swedish Environmental Protection Agency (2009) and Ahlroth & Finnveden (2011). The Swedish Environmental Protection Agency's values are developed through a

[5] http://viss.lansstyrelsen.se/Measures/EditMeasureType.aspx?measureTypeEUID=VISSMEASURETYPE000725

compilation of earlier studies. All studies applied scenario valuation methods to trace people's payment willingness for the reduction of nitrogen and phosphorous in marine waters. These included both user and non-user values, i.e. Total Economic Value (Figure 4). As the standard value is developed for reduced input of nitrogen and phosphorous to the coast, it is used in this report as an approximation of reduced input of nitrogen and phosphorous to fresh water. In addition, the standard values from Ahlroth & Finnveden (2011) are also a compilation of results from earlier literature. However, a different method approach is used here. In addition to an average for people's payment willingness for the reduction, a market value approach was included, which affects the standard value. The standard value for phosphorous applies for overfertilisation in fresh water and the value for nitrogen applies for coastal waters. With regard to the applicability of the standard value for nitrogen for this report's case study area, the same reasoning is used as for the values from the Swedish Environmental Protection Agency (2009), i.e. that the value can be used as an approximation for fresh water.

Table 4. The standard value for the monetary value of nitrogen and phosphorous reduction

Nutrient	SEK/kg	
	Standard values	
Nitrogen N	31*	90**
Phosphorous P	1023*	670**

* Swedish Environmental Protection Agency (2009)
** Ahlroth & Finnveden (2011)

By using the two different standard values, an estimate is obtained of how the value differs depending on the selection of method approach and what parts of the Total Economic Value are included. It is important as these factors may significantly affect the final value of the ecosystem service. The monetary value of the wetland's nutrient retention is obtained by multiplying kg of reduced nitrogen and phosphorous, respectively, per year by the standard value. The estimated economic value of the greater supply of the supportive service "retention of nutrients" as a result of the installation of the nutrient trap is presented in Table 5 below.

Table 5. Monetary value for the wetland's nutrient retention

Nutrient	SEK/year	
	Monetary value	
Nitrogen N	6,200*	18,000**
Phosphorous P	5,115*	3,350**

* Swedish Environmental Protection Agency (2009)
** Ahlroth & Finnveden (2011)

The value of the nutrient retention for the planned wetland is estimated to be between SEK 6,200 and SEK 18,000 for nitrogen and SEK 3,350 and SEK 5,115 for phosphorous per year. The value should be interpreted as an absolute minimum value for the ecosystem service "retention of nutrients" partly because it is uncertain if the Total Economic Value has been captured by the standard values from Ahlroth & Finnveden (2011) and that the standard values from the Swedish Environmental Protection Agency (2009) were adjusted due to the risk of hypothetical bias. Despite these factors, the chosen indicator succeeded in capturing the change in the supply of the service "retention of nutrients" relatively well. The economic value of this ecosystem service therefore also sheds light on the value of the wetlands as one of its main purposes is the reduction of nitrogen and phosphorous. Furthermore, the supply of other ecosystem services such as flow and flood regulation increases as a result of installed wetlands (see Table 1). So the total value of the measure is expected to be higher if the value of all services could have been calculated. In summary, it should be noted that the ability of wetlands to reduce nutrients is not yet fully investigated and may therefore differ from the values applied in this case study.

4.2 Regulation of overfertilisation

4.2.1 Quantification

The quantification of the ecosystem service "regulation of overfertilisation" was done based on calculations for phosphorous reduction in WISS[6] for the measure of grass covered protection zones along watercourses without required harvest of the plant material. The information on potential edge zone length in the partial catchment area is obtained from the FyrisSkz[7] model, which was made by the Swedish University of Agricultural Sciences (SLU) on behalf of the Water Authorities. The partial edge zone length in the partial catchment area is 24,670 m. To do the quantification, information is necessary about how many hectares of edge zones will be installed in the case study area. This is not currently established, which is why an estimate is done to be able to show the value of the ecosystem service. At present, the width of the edge zones along the arable land varies between 0-2 m. In the calculations, a width of 2 m for all edge zones was assumed. To obtain the number of hectares of edge zones, the potential edge zone length of 24,670 m is multiplied by the edge zone width of 2 m, which provides a total edge zone area of 4,934 hectares.

The reduction for a 2 m wide edge zone is estimated at 0.45 kg phosphorous/hectare and year, which is an average based on an interval for phosphorous reduction/hectare and year for edge zones (with an average width of 6 m) prepared by Uusi-Kämppä et al. (2000). As a result of many edge zones being placed where there is no surface run-off or the surface run-off is limited, the effect of the measure was reduced by 20% of the ground effect in the calculations for the standard value in WISS. If the edge zones are installed in an optimal

[6] http://viss.lansstyrelsen.se/Measures/EditMeasureType.aspx?measureTypeEUID=VISSMEASURETYPE000926
[7] http://fyrisskz.slu.se/daro/103000/

location, i.e. with a high incline, a lot of grain cultivation and high surface run-off, the installed zones will have a significantly higher effect. The standard value for the reduction of phosphorous/hectare and year is presented in Table 6 below.

Table 6. Standard value for reduction of phosphorous from edge zones

Nutrient	kg/hectare per year
	Standard values
Phosphorous P	0.1

To obtain the annual reduction of phosphorous that is obtained with the help of the edge zones, the number of hectares of edge zones is multiplied by the standard value, which provides an annual reduction of phosphorous of 0.4934 kg.

4.2.2 Monetary valuation

The monetary valuation of the phosphorous reduction is also done based on the standard values from the Swedish Environmental Protection Agency (2009) and Ahlroth & Finnveden (2011), which are found in Table 4. The monetary value of the edge zones' phosphorous reduction is calculated by multiplying the number of kg reduced phosphorous per year by the standard value. The estimated economic value of the edge zones is presented in Table 6 below.

Table 7. Monetary value of the edge zones' phosphorous reduction

Nutrient	SEK/year	
	Monetary value	
Phosphorous P	505*	331**

* Swedish Environmental Protection Agency (2009)
** Ahlroth & Finnveden (2011)

According to the calculations, the value of the ecosystem service "regulation of overfertilisation" is between SEK 331 and SEK 505 per year. So the socio-economic value of the ecosystem service is less than the cost of installing the edge zones by a large margin. The annual cost of installing edge zones is estimated at SEK 2,600/ha in WISS. An evaluation of the ecosystem service "erosion regulation" would probably be preferable to obtain a better estimate of the value of the edge zones. Reduced erosion is the main purpose of the measure (which in turn will positively affect regulation of overfertilisation). As a result of the lack of data, such estimates have not been possible, but a proposal on future evaluation of the service "erosion regulation" is provided in the next section. There are also several other ecosystem services (see Table 1) that will be affected positively by the measure and will reasonably contribute to a higher socio-economic value of it. These include for example the regulation of pests, recreation possibilities, habitats and biodiversity. If it is also possible to cultivate something that can be harvested and provide a yield on the edge zone, the cost for the allocation of arable land will be less for the farmers.

4.3 Continued evaluation of ecosystem services in the case study area

As previously mentioned, erosion is a noted problem in the case study area. It is therefore desirable to identify one or more indicators to estimate the measures' impact on erosion regulation and the value of the ecosystem service. A method to estimate the change in this service's function is the measurement of sediment transport at different points in time e.g. for different flows and climate conditions (Rydell & Lundström, 2013). The measurements can, for example, be made by investigating the sediment content, i.e. suspended material in the main flows and secondary flows. This was something that was discussed during the interview with Wanja Wallemyr and Peter Nolbrant, as a possible indicator (14 June 2017). Another possible indicator that could be easier to apply is to investigate how silting up is affected by broader edge zones as erosion causes sludge in the watercourses (Rydell & Lundström, 2013).

To estimate how the *Vartofta project's* measures affect the supply of ecosystem services in the partial catchment area, it is important to continue the work of finding indicators for the various ecosystem services so that they can be quantified and/or monetarised. By continuously performing monitoring in the course of the project through various kinds of testing, changes in the supply of ecosystem services can be mapped further and with greater reliability. This can illustrate the value of the measures and point out what measures provide the greatest benefits. The participants in the *Vartofta project* have already decided to use diatoms as an indicator for an estimate of the ecological status of the water (W. Wallemyr, personal message, 21 June 2017). Diatoms are growth algae that attach to and live in connection with e.g. stones in the water (Jarlman et al., 2016). The method, which means that diatoms are analysed, can be used to classify the status of the general water quality in watercourses and estimate how it is affected by e.g. overfertilisation and organic pollution. It is also well suited to localise point emissions and can be applied both in small and large areas, such as municipalities or counties. The first sampling of diatoms in the partial catchment area is planned for August and the results will serve as a starting point for the project. Diatoms can also serve as an indicator for the provisioning of the ecosystem services "water purification" and "regulation of overfertilisation".

5 Conclusions

An important conclusion as a result of the case study is that the partial catchment area covered by the *Vartofta project* offers extensive natural value. Multiple ecosystem services are provided both by the watercourses and by the cultural landscape. They also overlap and are dependent on each other which is why it is important to apply a holistic perspective when an attempt is made to evaluate ecosystem services. It is therefore necessary to prepare listings of ecosystem services where water and cultural landscapes interact to enable an optimal ecosystem service approach. It is of major importance to find the right indicators for all ecosystem services that are positively affected by measures. Using the right indicator(s) for a given ecosystem service creates conditions to be able to measure the change in the supply of the ecosystem service. After quantification is done using indicators, it is possible in the next step to implement an economic valuation. Through an economic valuation of ecosystem services, the value of a measure for achieving improved ecological status in bodies of water can be illustrated. For the entire value of the measure to be included, all affected ecosystem services should be evaluated. This also contributes to greater motivation for those involved in the project to undertake measures that may be costly. An investigation like the one done above can also serve as a basis for deciding on which measures provide the greatest benefit and should therefore be prioritised.

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Appendix 1 Gross list - Ecosystem services in the case study area

The gross list is compiled based on Gisselman et al., (2015), Swedish Agency for Marine and Water Management (2017) & Swedish Environmental Protection Agency (2012).

Type of ecosystem service	Ecosystem service	General description	Where is the ecosystem service?
Supportive	Maintenance of the soil's fertility	The soil's capacity to provide large and certain harvests	Agricultural land
	Soil formation	Is affected by multiple animals and organisms, strongly linked to bio-geochemical ecocycles and regulating services	Agricultural land
	Retention of nutrients	Denitrification, sedimentation and uptake in plants of nutrients	Existing river basin, open trenches, wetlands and floodplains (Bredska Kvarn and Öjevalla)
	Primary production	Photosynthesis conversion of carbon dioxide (CO_2) and energy (sunlight) to carbohydrates (biomass) and oxygen	Plants, existing river basin, open trenches, wetlands and floodplains (Bredska Kvarn and Öjevalla)
	Bio-geochemical cycles	Among others, Carbon's, nitrogen's, oxygen's and phosphorous' cycles	Plants, existing river basin, open trenches, wetlands and floodplains (Bredska Kvarn and Öjevalla)
	Biodiversity	Preservation of the gene pool and endangered species, variability through diversity on a genetic, species or habitat level, prerequisite for maintaining ecological systems	Existing river basin, open trenches, wetlands and floodplains (Bredska Kvarn and Öjevalla). Red listed species are at the river, in arable land and meadow/pasture land

	Ecological interaction	Nutrient weaver's dynamic, interactions between trophic levels (energy flow) and evolutionary processes	Whole case study area
	Water ecocycle	Water's circulation in the form of steam that condenses and falls to the ground as precipitation	Whole case study area
	Stability and resilience of the ecosystems	Ecosystems' ability to recover, strongly linked to ecological interaction and biodiversity	Whole case study area
	Habitats	Habitats that provide conditions for species to be able to develop and continue living	Existing river basin, open trenches, wetlands and floodplains (Bredska Kvarn and Öjevalla), red listed species at the river, in arable land and meadow/pasture land, existing edge zones, pastureland, stone walls, crop islands and boulder ridges, etc.
Regulating	Regulation of air quality and local climate	Regulation via uptake of the greenhouse gases carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O), deposit of airborne pollutants an regulation of temperature difference	Vegetation-rich land, primarily pastureland
	Flow/flood control	Contribution to reduced flood and draught risks, transport of water from	Existing river basin, open trenches, wetlands and

		the inland to the sea, water evaporation	floodplains (Bredska Kvarn and Öjevalla)
	Water purification	Purification of water through infiltration, cleaning via organisms in watercourses that through photosynthesis produce oxygen, retention via bacteria and algae and other particles that sink to the bottom and become sediment	Existing river basin, open trenches, wetlands and floodplains (Bredska Kvarn and Öjevalla), existing edge zones
	Regulation of pests	Natural production of organisms that eat plant-eating pests, e.g. hymenopter, ladybirds, spiders and ground beetles.	Existing edge zones, pasturelands, stone walls, crop islands and boulder ridges, etc.
	Biological post-treatment	Degradation of organic material done by terrestrial animals, fungi and microorganisms	Pasturelands
	Pollination	Provisioning of pollinators that pollinate beneficial plants	Existing edge zones, pasturelands, stone walls, crop islands and boulder ridges, etc.
	Erosion regulation	Counteraction/regulation of erosion (through various soil types) as a result of water movement (waves, wind, rapid water movements, acidified water)	Existing edge zones (0-2 metres in arable land)

	Regulation of overfertilisation	Retention of nutrients from arable land (reduced nutrient leakage of mainly nitrogen and phosphorous to watercourses)	Existing edge zones (0-2 metres in arable land), existing river basin, open trenches, wetlands and floodplains (Bredska Kvarn and Öjevalla)
	Biological regulation	Inland water's ability to limit the effect of pathogenic organisms (illness-related organisms or infectious matter, e.g. crayfish pest, Campylobacter, Salmonella)	Various bodies of water in the case study area
	Regulation of toxic substances	Regulation through degradation (bacteria), storage in biomass that is harvested (or otherwise leaves the ecosystem), sedimentation and permanent retention in deep sediment.	Existing edge zones (0-2 metres in arable land. Existing river basin, open trenches, wetlands and floodplains (Bredska Kvarn and Öjevalla)
Provisioning	Food from animals	Production of meat, milk and honey	Farms that conduct animal husbandry
	Food from wild land animals	Production of meat from hunted game	Various places in the case study area, e.g. around wetlands and watercourses
	Food from fish	Production of fish	Limited occurrence in the river
	Food from cultivated plants	Production of grains, oil plants and legumes	Agricultural land used for plant production

	Wild plants, berries and mushrooms	Production of mushrooms and berries for food	In edge zones and other vegetation-rich land
	Bioenergy	Utilisation of wood, grain and butcher remains for heating/fuel	Wood and butcher remains in a limited amount for energy
	Fertiliser	Production of fertiliser for arable land, own use or sale between farmers	Fertilisers from animals
	Feed	Production of crops and ensilage as animal feed	Agricultural land e.g. a lot of three-year fields
	Watering	Providing water for watering of plants and animals	Limited amount may be taken from watercourses for watering of agricultural land with plant cultivation
	Providing genetic resources	Supports production of all animals and plants, strongly linked to biodiversity	Endangered and very rare species are in the area, e.g. bird species, high biodiversity especially linked to meadow and pasture lands
Cultural	Recreation possibilities	Providing landscape that enables recreation, such as hunting, fishing, mushroom and berry picking, hiking and bicycling	The pilgrim path goes through the area, nature reserve with unique plants and bird species e.g. curlew and lapwing
	Aesthetic values	Providing beautiful natural settings both on land and in the water as well as open landscape	Meadow and pasture land and boulder ridges

	Cultural assets/heritage	Providing and preserving the historical landscape	Meadow and pasture lands, old school, hunting pavilion and church ruins
	Resources for education	Providing landscapes and natural settings used for educational purposes	Studies of floodplains and wetlands, boulder ridges and steppe-like grassland
	Science	Providing knowledge of both nature's indirect and direct benefits	Measures for reduced nutrient loading, holistic thinking and steppe-like grassland
	Inspiration	Inspiration for cultural phenomena, such as paintings and poems, as well as knowledge and science	Watercourses, meadows, cultural history, stories, curlew and the Water Council's work
	Natural heritage	Natural functions (habitats), formations and places of aesthetic and scientific value from earlier and to future generations	Steppe-like grassland and boulder ridges