Universität für Bodenkultur Wien

Natural capital, ecosystem services and their inclusion in corporate decision making – The economic valuation of ecosystem services from a business perspective

Masterarbeit

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Eingereicht von: Constantin SALETA

Matrikelnummer: 0752452

Email: constantin.saleta@gmail.com

Betreuer:

Univ.-Doz. Mag. Dr. Christine Jasch

Institut für Agrar- und Forstökonomie

Department für Wirtschafts- und Sozialwissenschaften

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Executive Summary

The concepts of natural capital (NC) and ecosystem services (ES) combine an economic perspective with a natural science perspective on ecosystems and the goods and service they provide. This thesis introduces into these concepts from a business perspective. The focus is on the economic valuation of ES and how this information can be used by business. Main approaches, instruments and frameworks are introduced and analysed for their relevance for business.

The research questions of this thesis are centred around the question whether common approaches and methodologies for the economic valuation of ES are applicable and generated information useful for businesses. These questions can be answered with 'yes, but…'.

Economic valuation techniques for ES as defined by TEEB are generally applicable by business. It was found that direct market valuation techniques and benefit transfer might be more useful than other techniques. Regarding value categories as included in total economic value (TEV), it was found that use value categories are relevant for all companies, but non-use and option values might only be relevant in specific circumstances and for certain companies.

In a case study the main concepts of NC and ES and their assessment including economic valuation are applied using the Natural Capital Protocol as framework. All steps of the Protocol have been performed and thus a structure for future, more comprehensive assessments provided.

This thesis concludes that NC and ES are relevant concepts for business and their structured assessment and economic valuation can support companies in basing decisions on a broader understanding of the company's interdependency with nature. While this research area is relatively new, the necessary frameworks, concepts and methodologies exist to enable NC and ES assessments and economic valuation in a corporate context.

Executive Summary - Deutsch

Die Konzepte Naturkapital (NK) und Ökosystemleistungen (ÖSL) kombinieren eine ökonomische mit einer naturwissenschaftlichen Perspektive auf Ökosysteme und die Güter und Leistungen die diese produzieren. Diese Masterarbeit führt in diese Konzepte aus der Unternehmensperspektive ein. Der Fokus liegt auf der ökonomischen Bewertung von ÖSL durch Unternehmen und wie diese Information genutzt werden kann. Die wichtigsten Zugänge, Instrumente und Rahmenwerke werden vorgestellt und hinsichtlich ihrer Relevanz für Unternehmen untersucht.

Die Forschungsfragen der Arbeit konzentrieren sich auf die Frage, ob die gebräuchlichen Zugänge und Methodologien in der ökonomischen Bewertung von ÖSL auch für Unternehmen geeignet sind und für diese nützliche Information generieren können. Die Forschungsfragen können mit ‚ja, aber' beantwortet werden.

Ökonomische Bewertungstechniken für ÖSL, wie von TEEB definiert, sind generell für Unternehmen anwendbar. Es wurde festgestellt, dass direkte Marktbewertungsmethoden und Benefit transfer nützlicher sein könnten als andere Techniken. Bezüglich der Wertkategorien des Total Economic Value (TEV) wurde festgestellt, dass Nutzenwerte für alle Unternehmen relevant sind, während Nicht-Nutzenwerte und Optionswerte nur für bestimmte Unternehmen relevant sein könnten.

In einer Fallstudie wurde Analyse von NK und ÖLS inklusive einer ökonomischen Bewertung durchgeführt. Hierzu wurde das Natural Capital Protocol als Rahmenwerk genutzt.

Die Arbeit schließt mit der Feststellung, dass NK und ÖSL für Unternehmen relevante Konzepte sind und deren strukturierte Analyse inklusive einer ökonomischen Bewertung Unternehmen dabei unterstützen kann Entscheidungen zu treffen, die auf einem breiten Verständnis der Wechselwirkungen zwischen der Organisation und der Umwelt beruhen. Obwohl dieses Forschungsgebiet relativ neu ist, existieren die für Unternehmen benötigten Rahmenwerke, Konzepte und Methodologien um Analysen von NK und ÖSL durchführen zu können.

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1. Introduction and problem definition

Economic development has increased nearly 60-fold between 1820 and 2003 (Maddison, 2007), increasing human well-being and average living standards significantly. However, this economic expansion had large implications on our natural environment, leading some researchers to see our planet Earth in a new geological period, the Anthropocene, in which human influence on the Earth System has reached a scale at which "*humanity itself has become a global geophysical force*" (Steffen et al. 2011; 741). At this scale, negative impacts of human economic activities on planet Earth, our natural environment and the ecosystems which constitute it, are becoming a risk for future human well-being, as ecosystems and their services build the foundation for human activities (Guerry et al., 2015; MEA, 2005; Steffen et al., 2015; TEEB, 2010a; World Economic Forum, 2015).

As Rockström et al. (2009; 1) found in their eminent article on planetary boundaries, „*anthropogenic pressures on the earth system have reached a scale where abrupt global environmental change can no longer be excluded*". They identified nine planetary boundaries, within which humanity can live safely. Of these nine, seven could be quantified by Rockström et al. (2009), and of these four have already been overstepped (climate change, rate of biodiversity loss, land-system change and changes in the global nitrogen cycle) (Steffen et al. 2015). In other words, the world's ecosystems are deteriorating at an unsustainable rate (WWF, 2014), which may have severe consequences on humanity (MEA, 2005).

However, there is a lack of understanding and acknowledging the relevance of nature in economic thinking (Guerry et al., 2015). Guerry et al. (2015) found an asymmetry in our economic systems, which incentivizes short-term production and consumption instead of long-term stewardship and conservation of the natural basis that underpin human existence.

The ecological economic concepts of natural capital and ecosystem services have been introduced to combine an economic perspective with a natural science perspective on ecosystems and their goods and services (Turner and Daily, 2008). Natural capital is understood as the stock of natural ecosystems, renewable and non-renewable, including air, land, soil, biodiversity and geological resources, which underpin the global economy and society by producing value for people, both directly and indirectly (Natural Capital Coalition, 2016a). Ecosystem services are the services and goods of ecosystems, which are based on natural capital, and which result in a direct or indirect benefit to human well-being (TEEB 2010; 33). They are commonly divided into regulating, supporting, provisioning and cultural services (MEA, 2005). Biodiversity is an important driver for the quality and quantity of ecosystem services (Natural Capital Coalition, 2015).

These concepts are anthropogenic in their nature, focussing on the benefits people derive from nature, and not on the intrinsic value of nature. By focussing on nature's goods and services as a contribution to human well-being, nature can be understood as natural capital, making it in economic thinking comparable to other asset classes, such as human capital (such as skills, knowledge or experiences of people), manufactured capital (such as machinery or buildings) or even financial capital (Guerry et al., 2015). While natural capital is used to assess the stock of natural ecosystems, biotic and abiotic (Natural Capital Coalition, 2015), human benefit is derived generally from nature's goods and services, the so called ecosystem services (Kareiva, 2011). This concept offers the opportunity to quantify, assess and value nature's benefit to humanity, thus providing important information for public and private decision makers (Guerry et al., 2015).

Some researchers have tried to bridge the gap between natural sciences to the economic and business world, by calculating and attributing estimated economic or monetary values to the services of ecosystems in order to translate the understanding of value between both worlds (Helm 2015; 4). For example, Costanza et al. (2014) estimate that the global value of ecosystem services is between USD 125 trillion and USD 145 trillion per year (both in 2007 USD). From this base, they estimated the value of the global loss of ecosystem services from 1997 to 2011 due to human-induced land use change at up to USD 20 trillion.

While studies on global level, such as the aforementioned by Costanza et al. (2014), (De Groot et al., 2010; Groot, 1992), and economic valuations of ecosystem services or accounting of natural capital on national or regional level are increasing in number (Götzl et al., 2015; Hein, 2011; Schwaiger et al., 2015; WAVES Partnership, 2014), there are only few cases of scientifically conducted and published ecosystem service valuations by organizations and companies. Yet, there is increasing business interest into this topic (Bonner et al., 2012), which is met by emerging initiatives such as the Natural Capital Coalition[1], which has the intention to generate a generally accepted structured framework for including information on natural capital in corporate decisions, the Natural Capital Protocol.

1.1. Combining the ecological and economic perspectives on ecosystem services

An ecosystem is a dynamic system of plants, animals, and micro-organisms and their abiotic environment, which interact together as a functional unit (MEA, 2005). This includes not only natural systems, but also agricultural and semi-natural systems (Hein, 2010). In an anthropogenic, economic perspective, ecosystems can be defined as the biotic components of natural capital (Natural Capital Coalition, 2015).

Ecosystem functions are „*the capacity of natural processes and components to provide goods and services that satisfy human needs, directly or indirectly*" (Groot 1992; 7). Therefore, they represent the capacity to supply ecosystem goods and services, but do not take demand after these into account (Hein, 2010).

Ecosystem services are the services and goods of ecosystem functions, which are based on ecosystems, and which result in a direct or indirect benefit to human well-being (TEEB 2010; 33). They are commonly divided into regulating, supporting, provisioning and cultural services (MEA, 2005). There are different perspectives on defining biodiversity as ecosystem service (Hein, 2010) or seeing it as an important driver for the quality and quantity of ecosystem services (MEA, 2005; Natural Capital Coalition, 2015).

In an economic perspective, ecosystems are components of natural capital, which have the capacity to supply biotic, i.e. ecosystem services, and abiotic services, which are not dependent on ecological functions and ecosystems, but rather on non-living component of the environment, such as minerals, fossil fuels, metals (Natural Capital Coalition, 2015).

1.2. The European political agenda on ecosystem services

The European Environmental Agency has found in a status report, that in 2010 "*the majority of ecosystem services show either a degraded or mixed status across Europe"* (EEA, 2015a, p. 9). Furthermore, researchers of the Joint Research Centre of the European Union (Maes et al., 2015) have found that under current trends in demography, economic development and agriculture, ecosystem services across the European Union will decrease by up to 5% by 2020 and 10%-15% by

[1] The Natural Capital Coalition is a unique global multi-stakeholder collaboration that brings together leading global initiatives and organizations to harmonize approaches to natural capital. The Coalition is made up of organizations from research, science, academia, business, advisory, membership, accountancy, reporting, standard setting, finance, investment, policy, government, conservation and civil society. These organizations have united under a common vision of a world where business conserves and enhances natural capital. The Natural Capital Coalition is the successor organization of the TEEB for Business Coalition. (Natural Capital Coalition, 2016b)

2050, compared to 2010 as baseline. The findings for 2050 are shown for the different NUTS 2 areas in figure 1. They also found that for securing the level of ecosystem services at levels of the year 2010, every 1% increase of human-build non-natural land, such as buildings or infrastructure, has to be compensated by an increase of 2.2% of natural or semi-natural land cover, i.e. green infrastructure (Maes et al., 2015).

To improve the long-term situation of ecosystems and their goods and services in the European Union, the European Union has included in its Biodiversity 2020 strategy the headline target of *„halting the loss of biodiversity and the degradation of ecosystem services in the EU by 2020, and restoring them insofar as is feasible"* (European Commission, 2011, p.2).

The European Union formulated its 2050 vision of the state of biodiversity and ecosystem services in the EU Biodiversity 2020 strategy as follows:

"By 2050, European Union biodiversity and the ecosystem services it provides — its natural capital — are protected, valued and appropriately restored for biodiversity's intrinsic value and for their essential contribution to human well-being and economic prosperity, and so that catastrophic changes caused by the loss of biodiversity are avoided."
(European Commission, 2011, p.2)

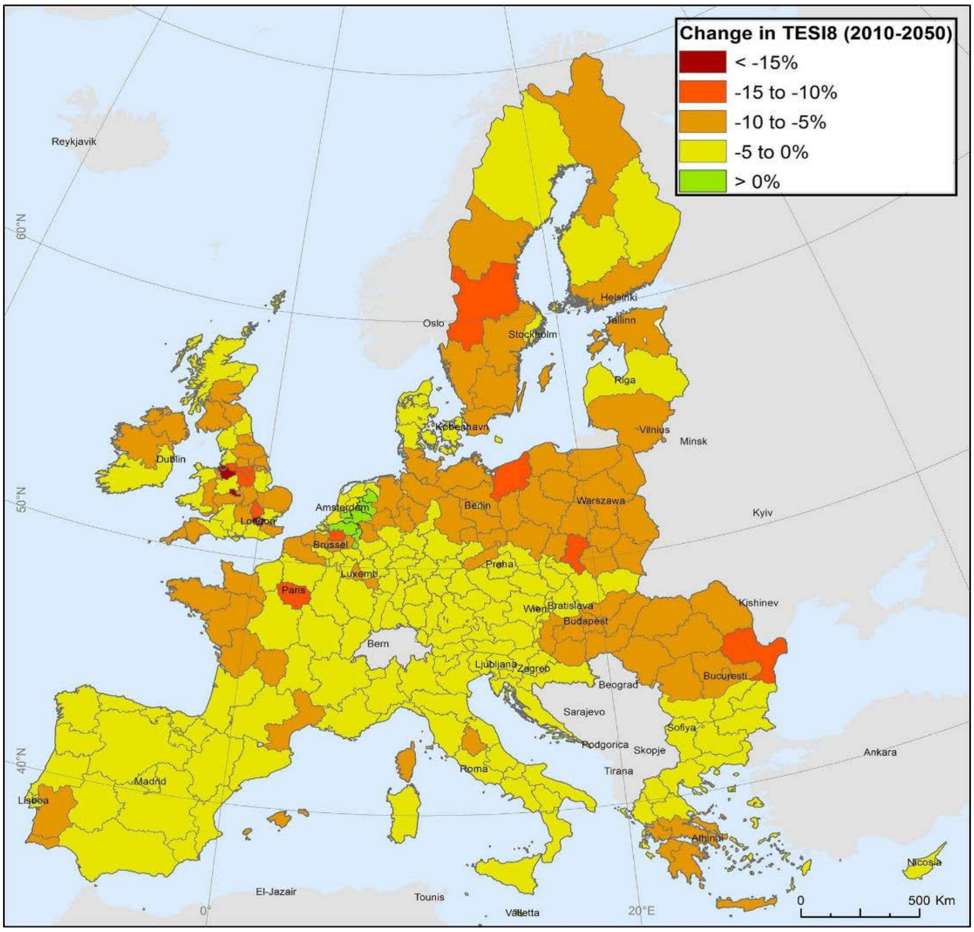

Figure 1: Relative changes in ecosystem services shown by an ecosystem service index (TESI8) between 2010 and 2050 (Maes et al., 2015)

2. About this master thesis

This master thesis gives an introduction into the concepts of natural capital and ecosystem services. It focuses in detail on economic valuation of ecosystem services in a business context, available methods and frameworks, and assessments of natural capital.

The assessment of natural capital including an economic valuation of ecosystem services by companies has hardly ever been performed adhering to scientific standards and publicly published. Still, there is an ever growing number of tools and instruments which aim to support it. This thesis introduces into some of the proposed tools and scientific methods for valuing ecosystem services and puts them in a corporate context. The results of the analysis shall be useful for companies in their internal decision making, especially in business applications such as risk management or supply chain management, but also for external reporting.

In the theoretical part, the current state of the science on the valuation of ecosystem services is presented and reflected against developments of the private sector. By interviews with subject matter experts and business representatives, the applicability of the commonly used methods and approaches, such as proposed by TEEB (2012), is discussed in a corporate context. In addition, examples of corporate ecosystem service assessments including economic valuation are presented.

In the practical part, in a case study with an Austrian company the concepts of natural capital and ecosystem services are assessed from a corporate perspective with a focus on the economic valuation of ecosystem services. Through a transparent documentation of this assessment, challenges and other learning effects experienced during conducting the assessment can serve other practitioners performing similar assessments. The case study demonstrates how natural capital assessments including an economic valuation of a company's natural capital can support the company in improving business planning and decision making based on scientific information and methodologies.

This master thesis shall serve to fulfil the following objectives:

- Provide an overview of current approaches and methodologies in assessments of natural capital including the economic valuation of ecosystem services,
- Analyse these approaches and methodologies from a corporate context, and assess their applicability for businesses,
- Conduct a case study in which these concepts and methods are applied.

2.1. Research questions

The research question of this master thesis is:

- Are common approaches and methodologies for the economic valuation of ecosystem services and natural capital assessments applicable and useful for assessments done by companies?

Under this main research question, following sub-questions are proposed:

  - How can results of such assessments be useful for corporate decision-making?
  - How can ecosystem services and corresponding risks, opportunities and impacts be assessed, valued, accounted for and managed by companies?
  - Which techniques and tools are available for companies to perform such analysis, and how could the generated information affect corporate decisions and corporate management of their impacts on the environment?

2.2.Methodology

The research questions of the thesis shall be answered using qualitative research methods.

An in-depth literature review of papers from academic journals, academic text books and grey literature shall provide an overview of the current state of knowledge of the assessment and economic valuation of natural capital and ecosystem services with an emphasis on the business perspective. Grey literature shall, inter alia, include relevant reports from businesses, business associations, consultancies, non-governmental organizations, public agencies and non-academic research institutes.

The knowledge of existing academic and grey literature shall be complemented by information from interviews with academic and non-academic subject matter experts and company representatives, which helped in further sharpening the focus on the Austrian context.

In a case study with an Austrian company, a natural capital assessment including economic valuation of the most material ecosystem services of this company has been conducted. In this case study, the knowledge from the theoretical part was used to adapt the valuation approach and methodology to the context of the company. It was expected, that through the case study challenges and opportunities for companies performing such an assessment can be observed and analysed.

3. Economic valuation assessments of ecosystem services

There is increasing awareness that human activities are having a significant deteriorating impact on the natural environment, but on the same time human wellbeing is dependent on nature's services (TEEB, 2012). But many of the benefits humans derive from ecosystems have not been assessed or valued, and can thus not be easily incorporated in decision-making processes (Guerry et al., 2015; TEEB, 2010a). There are a number of proposed approaches for incorporating nature and its services as an important dimension in public and private decision-making, such as natural capital accounting or ecosystem services assessments, which can include economic valuation.

Assessments of ecosystem services can be qualitative, quantitative or monetary (Kettunen and Vihervaara, 2012). In most cases, the assessment focuses on assessing flows of natural goods and services (ecosystem services), rather than their total stock (natural capital). Typically, an assessment includes the identification and analysis of ecosystem functions and services, their quantitative measurement in biophysical units and an economic valuation of their benefits to society or certain stakeholders as well as impacts of society on ecosystem services in monetary terms (MEA, 2005; TEEB, 2010b).

The economic valuation part of these assessments estimates the economic value of human welfare in monetary units which is derived from the ecosystem service assessed. Economic valuation of ecosystem services can be a helpful tool in making the value of nature more tangible for decision-makers (Guerry et al., 2015), and in estimating environmental externalities of economic activities which are at the moment only accounted for to a limited extend (Potschin et al., 2016). This is especially true for non-marketed ecosystem services for which no market prices exist, i.e. which can be consumed at no or low cost (Reddy et al., 2015). While the total value of an ecosystem service can be of interest for specific objectives such as awareness raising, valuation is generally used to assess the marginal value of a change in ecosystem services (Varcoe et al., 2015).

Economic valuation of ecosystem services is not perceived without critic in academic discussions (Kallis et al., 2013). As the lead author of the international study The Economics of Ecosystems and Biodiversity (TEEB, 2010a, p. 3), Pavan Sukhdev, wrote in the foreword:

"Valuation is seen not as a panacea, but rather as a tool to help recalibrate the faulty economic compass that has led us to decisions that are prejudicial to both current well-being and that of future generations. The invisibility of biodiversity values has often encouraged inefficient use or even destruction of the natural capital that is the foundation of our economies."

Before explaining in detail different frameworks and methods for the economic valuation of ecosystem services, the next sub-chapter introduces into the economic foundations of valuation of ecosystem services and the concept of value.

3.1. Economic foundations and understanding of value

Economics as a science is used to support the organization of societies in order to increase human well-being of the members of society (Freeman, 2014). Using neo-classical welfare economics as a framework, the welfare generated by ecosystem services, which is the aggregated utility of all beneficiaries of the service, depends on the producer and consumer surpluses[2] (Freeman, 2014). The

[2] Consumer and producer surplus are economic terms. Consumer surplus is difference between the willingness-to-pay of the consumer for a certain good or service and its price. In the context of ecosystem services, it corresponds to the aggregated utility of all consumers less the costs of harvesting or obtaining the service. The producer surplus is the welfare obtained by the producer for supplying a good or service. In the short term, it can be established by the difference between gross revenues and production costs of the producer. For the valuation of private ecosystem services, the producer surplus is to be considered in the case of harvesting or

utilities of the various individuals depend not only on the consumption of marketed private goods and services, on which traditional economics would focus, but also on the consumption of non-marketed goods and services and also public goods which are generated by nature, for example clean water or air, and on benefits derived from a non-consumptive usage of nature, such as the recreation or aesthetic value of nature.

The concept of value is used to assess the contribution of a good or service to human well-being. Applied to ecosystem services, their value equals the contributions of these goods or services to human well-being (Freeman, 2014).

Value, in an economic perspective, has traditionally captured the human benefits arising from the direct use of goods and services. However, in recent decades economists have broadened the scope of value and valuation to include indirect use values and non-use values, such as existence, bequest or option values (Chee, 2004). Benefits derived from ecosystem services correspond to different types of values. (Farber et al., 2002) provide a comparison of the different understandings of value including economic and ecological concepts of value.

The different types of values associated with ecosystem services can be depicted using the Total Economic Value (TEV) framework (TEEB, 2010b). TEV is understood as the aggregate value of the various benefits derived from the ecosystem services of a given area (TEEB, 2010b).

The different kinds of values associated with ecosystem goods and services can be divided into two broad categories, use and non-use values, which are divided further into sub-categories (Freeman, 2014). Figure 2 gives an overview of the components of TEV.

Potschin et al. (2016) provide a concise overview of the different value components of TEV. Direct use values can either include the consumption of ecosystem services (e.g. timber or fish) or include the non-consumptive use of ecosystem services (e.g. recreation or aesthetic value). Indirect use values are derived from ecosystem services which are not directly used (e.g. water purification or many other regulating ecosystem services). Option values are related to the potential future use of ecosystems, but are often not in scope of economic valuation assessments. Non-use values are not related to the direct or indirect use of ecosystem services, but are directly linked to the existence of the ecosystem. They can be divided into altruistic, bequest and existence values. Altruistic values are related to the value generated by the knowledge that other humans in the same generation are potentially benefiting from ecosystem services. Bequest values are generated by the same scheme, but in relation to future generations. Finally, the existence values of ecosystem services is generated by the satisfaction of the sheer knowledge that ecosystems exist.

The applicability of the TEV framework to ecosystem service valuations done by companies is assessed in chapter 4.2 below.

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processing costs of the ecosystem good or service, or if the good or service is used as input for a production process (Hein, 2009).

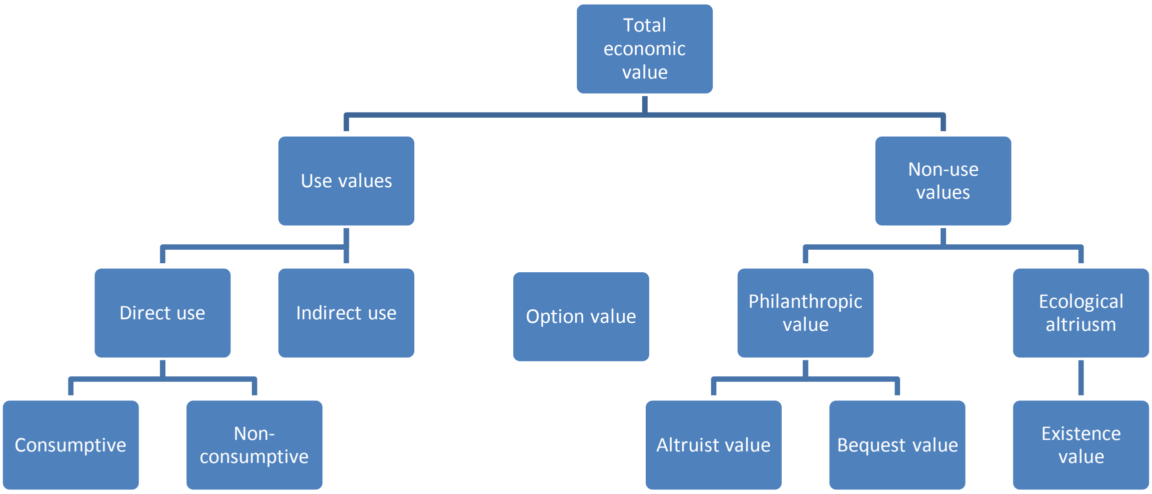

Figure 2: Total Economic Value of ecosystem services and it composition (own illustration based on (TEEB, 2010b)

3.2. Available methods for an economic valuation of ecosystem services

Various valuation methods can be used for assessing the economic value of ecosystem services. Choosing the appropriate method is depending on whether the ecosystem service in focus directly contributes to individual wellbeing, such as provisioning services used for consumption, or indirectly contributes via an input in a production process, such as intermediate goods. The international (TEEB, 2010b) is a reference work for scientific methods to economically value ecosystem services. In the study, four main categories of methods were distinguished (see Table 1below).

Table 1: Economic valuation methods for ecosystem services (TEEB, 2010b)

Valuation approaches	Valuation methods
Direct market valuation	Market price based
	Cost based
	Production function based
Revealed preferences / Indirect market valuation	Travel cost method
	Hedonic pricing
Stated preferences / non-market valuation	Contingent valuation method
	Choice modelling
	Group valuation
Benefit transfer	Benefit transfer

These methods will be presented in detail in the following sub-chapter.

3.2.1. Direct market valuation approaches

Direct market valuation methods are using information of existing markets for the economic valuation of ecosystem services. Actual market prices based on demand and supply of ecosystem services are used to indicate their economic value and of other non-marketed goods and services. These market prices can be derived from either consumption values (ecosystem services for direct consumption) or production values (ecosystem service as input in production process). Non-marketed goods and services can be assessed as inputs in a production process, or by using cost information, such as the marginal abatement cost curves for the reduction of greenhouse gas emissions (Potschin et al., 2016).

Despite the benefits of this approach, there is the limitation that it can only be used for marketed ecosystem services or ecosystem services which are inputs in the production of marketed goods or services. In other cases, indirect market or non-market approaches have to be applied (Potschin et al., 2016).

In TEEB, three different direct market valuation methods are distinguished, market price based, cost based and production function based approaches (TEEB, 2010b).

Market price based method

For ecosystem services traded on a market, it is possible to use market prices as an indicator of the economic value of these ecosystem services or goods. It is assumed that in well-functioning markets the market price of a good or service reflects consumer preferences and marginal production costs of suppliers, implying that market prices can be used as a good indicator of economic value (TEEB, 2010b). Market price based valuation methods are often used in the valuation of provisioning services, since for ecosystem goods such as timber or fish usually markets exist (TEEB, 2010b).

Table 2: Synoptic table for the market price based method

Valuation approach	Exchange value that ecosystem services and goods have in a market
Valuation type	Revealed willingness-to-pay
Value assessed	Direct and indirect use value
Ecosystem service applicability	Mainly provisioning services, but also selected cultural and regulating services
Example	Timber, fuel wood, fish (cf. (Pearce, 2001) for an overview of the economic value of non-forest timber products)
Advantages	This method can be applied quite easily and time-efficient, as it uses publicly available data and only requires few and simple calculation assumptions (Bouma and Beukering, 2015). In addition, market prices methods are transparent and defensible as they are based on market data and standard economic techniques, and in contrast to other economic valuation methods are able to reflect individual's willingness to pay.
Disadvantages	Despite the above advantages, (Potschin et al., 2016) found two problems which shall be discussed in a valuation assessment. First, market prices might be distorted by government subsidies, taxes or other market distortions. In such cases, the market prices have to be adjusted in order to serve as a good indicator of economic value.

	Second, ecosystem services may only constitute one of several inputs into the production of a marketed good or services. This can make it difficult to allocate the isolated value contribution of ecosystem services in complex production functions. However, (Potschin et al., 2016, p. 234) state various approaches for addressing this challenge.

Cost based method

In TEEB (2010b), three different cost based methods are distinguished, the replacement cost method, the damage cost avoided method and the mitigation cost method.

Using the replacement cost method, the costs of replacing ecosystem services (green infrastructure) with technical solutions (grey infrastructure) are estimated and used as a surrogate for the value (Freeman, 2014). For example, the capital and operating costs of a water treatment plant can be used as surrogate for the value of a wetland or forest, which would provide the same water purification services as the technical solution.

The damage costs avoided method estimates the costs that would occur in the absence of an ecosystem service, e.g. using estimated damages from flooding as a proxy for value of flood protection (Bouma and Beukering, 2015).

The mitigation or restoration cost method estimates costs associated with the mitigation of the loss of ecosystem services or the costs of restoration of ecosystem services.

Table 3: Synoptic table for the cost based method

Valuation approach	Use costs as indicator of ecosystem service value
Valuation type	Imputed willingness-to-pay
Value assessed	Direct and indirect use value
Ecosystem service applicability	Mainly regulating services
Example	Using water treatment cost for water from alternative sources to replace existing drinking water sources, e.g. groundwater (cf. (Hein, 2011)
Advantages	transparent and defensible as cost estimates are based on market data which is readily available;
Disadvantages	Can cause overestimation of values; does not consider consumer preferences for different ecosystem services; costs might only represent a proportion of the full value of an ecosystems service

Production function based method

For those ecosystem services, which are used as direct input into production functions of marketed goods, the economic value of these services can be assessed by analysing their contribution to the economic value (consumer and producer surplus) of the final good (Bouma and Beukering, 2015). Here the assumption was stipulated that an increase in the quantity or quality of ecosystem services may lead to lower production costs, thus decreasing market prices of the traded good and increasing produced and traded quantities, which ultimately leads to enhanced consumer surplus (income) and more producer surplus (productivity) (Freeman, 2014). This method uses information on the relationship between inputs and outputs of a production function. Data should be available on how changes in the quality or quantity of the ecosystem service impact the production process, including impact on production costs of the final good and ultimately impact on supply and demand of the final good (Bouma and Beukering, 2015). This approach shows consistency with the value creation model of the International Integrated Reporting Council (IIRC, 2013), as it shows the role that natural capital plays in a business model of a producing company, and how it interlinks with other forms of capital.

The production function method is usually applied in two step approach. First, the biophysical cause-effect relationship between changes in an ecosystem service and the production function has to be established. In a second step, the change in the traded final good is used to economically value the impact of the change in ecosystem service (TEEB, 2010b).

Table 4: Synoptic table for the production function based method

Valuation approach	Assess economic impact of change in ecosystem service as input in production process on the finally produced and traded goods
Valuation type	Revealed willingness-to-pay
Value assessed	Indirect use value
Ecosystem service applicability	To those services which are inputs in production processes of traded goods
Example	Estimating marginal value of water for irrigated olive grove with the production function method (cf. (Mesa-Jurado et al., 2010)
Advantages	relatively straightforward to apply; uses standard economic techniques
Disadvantages	limited to ecosystem services that are used as inputs in industrial production processes of marketed goods; data intensive; cause-effect relationship has to be understood; data availability is crucial

3.2.2. Indirect market valuation using revealed preferences

By using revealed preference methods, such as hedonic pricing or the travel cost method, the analysis of marketed goods or services is used to indicate the value of strongly linked non-marketed ecosystem services; thus these methods are labelled indirect market valuation methods.

In TEEB (2010b), a six-step approach is suggested for indirect market valuation approaches:

1. Define a surrogate market which can be linked to the ecosystem service
2. Select method (hedonic pricing or travel cost method)
3. Collect market data, which can be used to establish a demand function for the marketed good
4. Use this demand function to estimate the marginal value of a change in the ecosystem service
5. Aggregate the values across relevant scales
6. Discount where appropriate

In TEEB, two different indirect market valuation methods are distinguished, travel cost method and hedonic pricing (TEEB, 2010b).

Travel cost (TC) method

The travel cost (TC) method is mostly used to assess the recreational benefit of a specific site or landscape, based on the observed costs that visitors of the site are willing to pay for visiting the site. These cost can include direct expenses, such as transportation costs or entry fees, or opportunity costs of the time spent at the site (TEEB, 2010b).

TC is based on the assumption that recreational benefits of visitors are directly linked to the quality of the environmental area, such as provided by cultural ecosystem services, and that the value of the ecosystem service can be indicated by the number of visits to the area. Thus, travel costs occurred by visitors can indicate the implicit price visitors would be willing to pay for accessing the site. By using travel costs as a surrogate for value, revealed preferences of the visitors are analysed.

A typical application of the TC method would be in assessing the recreational economic value of a national park. Such an assessment can be performed by a visitor survey, asking for information on the number of visits, the expenditure for visiting the site, reasons for choosing this site over others and the role of environmental quality in deciding which site to visit (Bouma and Beukering, 2015).

Table 5: Synoptic table for the travel cost method

Valuation approach	Derive demand for ecosystem service by using data on travel costs
Valuation type	Revealed willingness-to-pay
Value assessed	Direct and indirect use values
Ecosystem service applicability	Typically applied for cultural ecosystem services, especially the recreational value of a specific site or landscape
Example	Recreational value of forest areas (cf. ÖBf, 2016)
Advantages	based on actual behaviour (revealed preferences); applies standard economic techniques; results are easy to interpret and explain; assumption that travel costs reflect recreational value is well founded

Disadvantages	limited to direct use of recreational benefits; data intensive; surveying can be expensive and time-consuming; interviewing can result in biases

Hedonic pricing (HP) method

The hedonic pricing (HP) method uses information on a good traded on a market (observed preference) to generate an implicit estimate of the value of a non-marketed ecosystem service, which can be linked to the traded good (Rosen, 1974). In general, two traded goods which are identical in most features, but different in certain environmental qualities, are used in the analysis. The difference in the market prices for these goods is interpreted as the revealed willingness-to-pay (WTP) for the ecosystem service (Bouma and Beukering, 2015). HP method can be used in the valuation of ecosystem services regarding certain environmental qualities, such as the level of air pollution, noise or water pollution, or in assessing the recreational or aesthetic value of cultural services.

A typical application of HP is based on property prices. Under the assumption that any non-environmental features of two properties are identical, the difference in the market price of the two properties can be linked to the difference in environmental quality of the area surrounding the property. Thus, the value of the ecosystem services of the area is indicated by the difference in price. Furthermore, by estimating a demand function for a specific property, a change in ecosystem services composing the environmental quality of the area can be linked to a changing demand and market price for the property, thus assessing the marginal value of the ecosystem service.

Table 6: Synoptic table for the hedonic pricing method

Valuation approach	Derive effect of ecosystem services on price of marketed goods that include those ecosystem service as constituent of market price and demand
Valuation type	Revealed willingness-to-pay
Value assessed	All
Ecosystem service applicability	Various
Example	Estimating the value of urban green space (cf. Wüstemann and Kolbe, 2015)
Advantages	transparent and defensible as based on market data and WTP (revealed preferences); property markets are usually good indicators of values
Disadvantages	largely limited to benefits related to property; property market is affected by number of non-environmental factors, which need to be discounted (e.g. number of rooms, property size etc.); high data requirements; highly dependable on model specifications; value assessed is location specific and can to be easily transferred to other locations

3.2.3. Non-market valuation using stated preferences

The creation of hypothetical markets and market prices for ecosystem services in survey or interview settings allows to ask participants for their hypothetical willingness-to-pay for a certain ecosystem service, which is defined as stated preference. This allows to estimate both use and non-use values of ecosystem services, which would not be possible using direct or indirect market valuation approaches (Bouma and Beukering, 2015).

In TEEB, three different non-market valuation approaches are distinguished, contingent valuation, choice modelling and group valuation (TEEB, 2010b).

Contingent valuation method

In the contingent valuation method (CV), participants are interviewed with the objective to establish their willingness-to-pay (WTP), or alternatively willingness-to-accept-compensation (WTAC), for an increase or decrease in the hypothetical provision of an ecosystem service (TEEB, 2010b). The underlying theory is that a hypothetical market for the ecosystem service in scope is generated in the survey context, which allows the estimation of economic welfare of not-marketed ecosystem service without the actual existence of these markets. These surveys can be conducted as face-to-face interviews, by printed questionnaires send to selected households or web-based (Bouma and Beukering, 2015).

For a step-wise process to perform a CV see for example Kontoleon and Pascual (2007).

Table 7: Synoptic table for the contingent valuation method

Valuation approach	Estimation of use and non-use values by directly asking target group representatives in surveys/interviews
Valuation type	Stated willingness-to-pay
Value assessed	All
Ecosystem service applicability	All
Example	Ask visitors of a national park how much they would be willing to pay to uphold the status of the national park (cf. (Hackl and Pruckner, 1995)
Advantages	captures both use and non-use values and can be used to estimate the value of marketed and non-marketed ecosystem services; applicable in many contexts and conditions;
Disadvantages	Results are hypothetical in nature and subject to bias (thus results might not be able to convince decision-makers); time- and cost-intensive method;

Choice modelling

Using the choice modelling (CM) method, the decision process of an individual is analysed. Participants are asked to choose between a set of hypothetical alternatives, which are inter alia described by different attributes of the ecosystem services in scope. For example, a certain area might show a mixture of different types of land use, e.g. forest land, agricultural land and nature conservation areas. Different alternative hypothetical scenarios with varying levels of these land uses are generated and participants asked to choose their preferred alternative. By asking for the WTP or WTAC in relation to these choices the relative value of different land uses can be assessed which then is used to assess the value of the associated ecosystem services (Bouma and Beukering, 2015).

In many features, it is similar to the CV method, with the main difference being that CM generates hypothetical alternatives and lets participants select their favourite choice, instead of directly asking for values (Bouma and Beukering, 2015).

Table 8: Synoptic table for the choice modelling method

Valuation approach	Asking participants to choice among different alternatives with varying attributes of the underlying ecosystem services
Valuation type	Revealed willingness-to-pay
Value assessed	All
Ecosystem service applicability	All
Example	Estimate the avalanche protection function of forests under different scenarios (Olschewski et al., 2012)
Advantages	captures both use and non-use values and can be used to estimate the value of marketed and non-marketed ECS; useful to find preferred option among set of alternatives
Disadvantages	results are hypothetical in nature and subject to bias (thus results might not be able to convince decision-makers); time- and cost-intensive method;

Group valuation

The group valuation (GV) method combines stated preference techniques with methods from other fields of science, such as the deliberative economic valuation approach as used in political science, in order to overcome limitations of other traditional economic valuation methods. This approach does not survey individuals but groups of stakeholders and their WTP or WTAC are established through group discussion processes (TEEB, 2010b), which can have several advantages over the other stated preference approaches (cf. Spash, 2008).

Table 9: Synoptic table for the group valuation method

Valuation approach	Ask a group of participants for their WTP or WTAC for an ecosystem service through group discussions
Valuation type	Revealed willingness-to-pay

Value assessed	All
Ecosystem service applicability	All
Example	Estimate the WTP for ecosystem restoration by discussions in focus groups (Gregory and Wellman, 2001)
Advantages	captures both use and non-use values and can be used to estimate the value of marketed and non-marketed ECS; Allows to overcome limitations of other stated preference methods;
Disadvantages	results are hypothetical in nature and subject to bias (thus results might not be able to convince decision-makers); time- and cost-intensive method;

3.2.4. Benefit transfer

Valuation assessments of ecosystem services usually involve comprehensive ecological and economic studies, however, conducting such primary research can oftentimes be an expensive endeavour. Benefit transfer, or value transfer as it is known as well, is a secondary research method which can be applied in instances where the costs of conducting a valuation of ecosystem services outweigh the benefits. It uses results of valuation assessments at other locations and, after a possible adaption to the study context, transfers these values to the study site (TEEB, 2010b).

While choosing benefit transfer over the application of primary valuation methods is appealing as for the costs and time savings, there are some risks involved regarding data validity and reliability (Bouma and Beukering, 2015). Bouma and Beukering (2015) found several conditions, which need to be met if benefit transfer shall be applied correctly. They found that it is essential, that local circumstances of the primary study site and the site in focus of the current study need to be closely related in order to create reliable results.

Table 10: Synoptic table for benefit transfer

Valuation approach	transfer of values (and benefits) from existing studies with similar context to the site in scope
Valuation type	Secondary research, relying upon different primary valuation types
Value assessed	All
Ecosystem service applicability	All
Example	Studies estimating the global value of ecosystem services, such as Costanza et al. (2014) or de Groot et al. (2012)
Advantages	low cost, rapid method for estimating values; can be used as pre-assessment for more detailed valuation study
Disadvantages	results are questionable if not carefully applied; different ECS are differently covered by existing valuation studies;

3.2.5. Overview of the available methods for an economic valuation of ecosystem services

For a better overview, in this chapter the valuation methods are linked to the respective ecosystem services and the values created.

In Table 11, an overview of economic valuation methods for ecosystem services and their applicability for different ecosystem services based on Bouma and Beukering (2015) is given. It shows that while some methods are applicable to various kinds of ecosystem services, especially revealed preference methods are only can only be used with selected ecosystem services.

Table 11: Linking ecosystem services to economic valuation methods (based on Bouma and Beukering, 2015)[3]

	Valuation methods	**Direct market valuation**			**Indirect market valuation** **Revealed preferences**		**Non-market valuation** **Stated preferences**		**Benefit transfer**
ECS	**Examples of ECS**	Market price	Production function	Cost based	Travel costs	Hedonic pricing	Contingent valuation	Choice modelling	Benefit transfer
Provisioning services	Food	X	X				X	X	X
	Freshwater	X	X				X	X	X
	Wood and fiber	X	X				X	X	X
	Fuel	X	X				X	X	X
Regulating services	Climate regulation			X			X	X	X
	Water purification	X	X	X			X	X	X
	Flood regulation			X		X	X	X	X
	Disease regulation	X		X			X	X	X
Cultural services	Recreation				X	X	X	X	X
	Education						X	X	X
	Spiritual value						X	X	X

[3] Bouma and Beukering (2015) did not cover group valuation in their analysis. Therefore, this method is excluded from the overview.

	Aesthetical value					X	X	X	X
Supporting services	Primary production	X	X	X					X
	Soil formation	X	X	X					X
	Nutrient cycling	X	X	X					X

Kareiva (2011) made a similar analysis, but used a slightly different approach. They linked valuation methods to selected ecosystem services via the economic values these services created. While their results are consistent to Bouma and Beukering (2015), in linking valuation methods to economic values they provide an additional perspective. Their results are shown in Table 12.

Table 12: A combined view on ecosystem services, their economic values and valuation methods (Kareiva, 2011)

Ecosystem services	Economic values	Valuation methods
Provisioning ECS		
Sustenance of plants and animals	Direct use values (consumptive)	Direct valuation using market prices
	Direct use values (non-consumptive)	Indirect valuation using e.g. revealed preferences, contingent valuation
	Indirect use values	No valuation necessary, if plants or animals with direct values are counted
Regulating ECS		
	Direct and indirect use values	Estimation of ECS's contribution to profit (holding all else constant)
Other ECS		
Generation of spiritual, aesthetic and cultural satisfaction	Existence value	Indirect valuation using contingent valuation
	Direct, non-consumptive use value	Indirect valuation using revealed preferences / expenditure, contingent valuation

Recreational ECS	Non-consumptive direct use value	Indirect valuation using revealed preferences / expenditure, contingent valuation
Generation of option value	Option value	Empirical assessments of individual risk aversion

A third analysis of valuation methods is provided in Table 13. While the objective of Groot's analysis (1992) was identical, compare valuation methods to types of socio-economic value, he used different categories of methods and values; thus his results are only partly comparable to Kareiva (2011). Possibly the main difference is that Groot's analysis (1992) was not especially dedicated to ecosystem services, but to nature in environmental planning in general; thus the scope was broader. Still, his analysis is applicable to the field of ecosystem services and his categorisation of values into ecological, social and economic values links well to the three spheres of sustainability.

Table 13: Types of socio-economic value and corresponding valuation methods (Groot, 1992)

		Economic valuation methods						
			Shadow price					
Types of socio-economic value		Market price	Cost of environmental damage	Maintenance costs	Mitigation costs	Willingness to pay / accept compensation (WTP/WTAC)	Property pricing (Hedonic pricing)	Travel costs
Ecological values	Conservation value		x	x	x	X		
	Existence value			X[4]		X[2]		
Social values (valuation can be focused e.g. on securing minimum standards of ECS)	Health			X		x		
	Option value			x		X		

[4] In general, existence value of ecosystem services can be valued using economic valuation methods such as maintenance cost or WTP/WTAC approaches, but several authors have found ethical issues with the economic valuation of nature's existence (Groot, 1992; Clive L. Spash, 2008; SPERIshefuni, 2014).

Economic values	Consumptive use value	X				X		
	Productive use value	X					X	x
	Employment	X						

3.3.Choosing a valuation method

After the preceding chapters introduced into the valuation methods for ecosystem services, this chapter will provide some assistance in choosing a valuation method.

For example, Bouma and Beukering (2015) provide guidance for this problem. They found following key points to consider in choosing a valuation method:

- Type of ecosystem service in scope
  - Some ecosystem services can only be valued by a limited variety of methods, while for others a wider range of methods are applicable
- Type of economic value in scope
  - While use values can be assessed by all valuation methods, only stated preference methods can be used in the estimation of non-use values
- Purpose of the valuation
  - The objectives of valuation efforts can vary strongly, from the assessment of marginal values to the estimation of the total economic value. The valuation methods need to be chosen with the objective in mind.
- Data availability
  - While for marketed ecosystem services primary data will be more easily available, for other services it will be difficult to find available primary data at all.
- Required accuracy of the results
  - As the degree of uncertainty of results using different methods varies widely, this can be decisive in choosing the right method for securing the required accuracy in results.

An assessment of the available valuation methods has been conducted building on a meta-analysis of several reports (Bagstad et al., 2013; Hanson et al., 2012; Natural Capital Coalition, 2015; Spurgeon, 2014; UNEP et al., 2010; WBCSD, 2011, 2013). The objective of the assessment was to give an overview over advantages and disadvantages of the methodologies; not to prioritize them in any form. The application of the methodologies will depend largely on the valuation context and the ecosystem services in scope of the valuation effort. Common criteria in these studies, such as data requirements, duration of conducting a valuation, costs and required competencies, were used to compare the methods against each other.

From the results of the assessment (see Table 14) some interpretations can be deducted. It has been found that direct market valuation approaches can be conducted in a relatively short time frame and with little costs; with the restriction, that a market for the considered ecosystem services is needed in order for the required data to be available (TEEB, 2010b). The revealed preference approaches are generally more time and cost intensive, and in addition are largely limited to the valuation of selected ecosystem services, such as recreation using the travel cost method. Stated preference approaches are considered to be cost- and time-intensive as they are based on conducting interviews or other forms of surveys. While they are particularly well suited to value both use and non-use values, their results are by nature hypothetical and subject to bias.

Benefit transfer is no technique of primary data collection method and thus not directly comparable to the aforementioned techniques. It is a rather low-cost method, but largely dependent on the used primary data at hand.

Table 14: Overview and assessment of valuation methods for ecosystem services (own assessment based on Bagstad et al., 2013; Hanson et al., 2012; Natural Capital Coalition, 2015; Spurgeon, 2014; UNEP et al., 2010; WBCSD, 2013, 2011)

Methods		Assessed value	Required data	Required time	Costs	Required skills	Advantages	Disadvantages
Market valuation	**Market prices**	direct and indirect use	market prices of ECS or EC goods; production and distribution costs	days to weeks	low (€100 - €1,000)	basic understanding, econometrician	transparent and defensible as based on market data and standard economic techniques; can reflect individual's willingness to pay	only applicable where a market for ECS exists; market prices can be distorted by market imperfections (e.g. by subsidies) or do not present full value of the ECS (as not priced in)
	Change in productivity / production function approach	indirect use	data on production function; data on cause-effect relationship	days to weeks	low (€100 - €1,000)	basic understanding	relatively straight-forward to apply (if data available); uses standard economic techniques	limited to ECS that are used as inputs in industrial production of market goods; data intensive; cause-effect relationship has to be understood; data availability
	Replacement costs	direct and indirect use	costs (market prices) of replacing ECS with man-made alternative	days to weeks	low (€100 - €1,000)	basic understanding	provides surrogate measures of value for regulating services; transparent and defensible as based on market data; market data readily available;	can cause overestimation; does not consider social preferences for ECS; replacement service might only present a proportion of full value of ECS; assumes that costs match original benefit

	Methods	Assessed value	Required data	Required time	Costs	Required skills	Advantages	Disadvantages
	Damage costs avoided	direct and indirect use	data on costs incurred as a result of a loss of a ECS; damages under different scenarios	weeks	low (€100 - €1,000)	engineering knowledge, knowledge of biophysical processes	provides surrogate measures of value for regulating services	largely limited to services related to properties, assets and economic activities; can cause overestimation
Revealed preferences	**Hedonic pricing**	direct and indirect use	data on property prices and price changes due to changes in ECS (quality)	days to weeks	medium (€1,000 - €10,000)	econometric	transparent and defensible as based on market data and WTP; property markets are usually good indicators of values	largely limited to benefits related to property; property market is affected by number of non-envionmental factors, which need to be discounted (e.g number of rooms etc.); high data requirements; highly dependable on model specifications
Revealed preferences	**Travel costs**	direct and indirect use	data on duration, number of visits etc. of recreational activity; motivations of travel	weeks to months	high (€10,000)	questionnaires, interviews, econometric analysis	based on actual behaviour; results are easy to interpret and explain	limited to direct use of recreational benefits; some issues with travel costs; data intensive; interviewing can result in biases
Stated preferences	**Contingent valuation**	use (direct and indirect) and non-use	stated value asigned by target group to ECS	weeks to months	high (€10,000)	questionnaires, interviews, econometric analysis	captures both use and non-use values and can be used to estimate TEV of marketed and non-marketed ECS; extremely flexible; gives more accurate outcome that benefit transfer	results are hypothetical in nature and subject to bias; resource intensive method; results might not be able to convince decision-makers

	Methods	Assessed value	Required data	Required time	Costs	Required skills	Advantages	Disadvantages
	Choice experiments	use (direct and indirect) and non-use	stated value asigned by target group to ECS for different alternatives	weeks to months	high (€10,000)	questionnaires, interviews, econometric analysis	captures both use and non-use values and can be used to estimate TEV of marketed and non-marketed ECS; more accurate than benefit transfer; useful to find preferred option among set of alternatives	results are hypothetical in nature and subject to bias; resource intensive method; results might not be able to convince decision-makers
Secondary research	**Benefit transfer**	use (direct and indirect) and non-use	valuations from comparable studies at other sides and their background info	days to weeks	low (€100 - €1,000)	econometric	low cost, rapid method for estimating values; can be used as pre-assessment for more detailed valuation study	results are questionable if not carefully applied; different ECS are differently covered by existing valuation studies

3.4. Available assessment tools for the valuation of ecosystem services

To support the widespread application of ecosystem service assessments, a number of tools have been developed. Their support can be delivered in various means, for example by recommending a structured approach for the valuation, by providing access to valuation databases or models, or by facilitating the prioritization among different ecosystem services. Some tools were originally developed for the public sector and later applied to private organizations, while others had companies as their target group from the beginning.

Bagstad et al. (2013) performed an assessment of available assessment and valuation tools. Their assessment included 17 instruments and was based on eight qualitative assessment criteria[5]. The results show a strong variation in the approach and structure of the tools. While some tools (e.g. InVEST by the Natural Capital Project, 2016) are based on a GIS[6] database and include a comprehensive modelling approach for the biophysical assessment of ecosystems and their services, other tools contain a database with valuation results which can be used for value transfer approaches.

Table 15: Comparison of tools for the valuation of ecosystem services (based on Bagstad et al. 2013)

Tools / Criteria	Quantification and uncertainty	Time requirements	Independent application	Development and documentation	Scalability	Generalizability	Nonmonetary and cultural	Integration
Ecosystem Services Review	qualitative	low	yes	fully	multiple	high	no	low-cost screening tool
Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST)	quantitative; varying inputs	moderate to high	yes	fully	watershed, landscape	high	biophysical values, can be monetized	spatially explicit ECS tradeoff maps
Artificial Intelligence for Ecosystem Services (ARIES)	quantitative; Bayesian networks and Monte Carlo simulation	low to high	yes	fully	watershed, landscape	low	biophysical values, can be monetized	spatially explicit ECS tradeoff, flow and uncertainty maps
LUCI	quantitative	moderate to high	ye	moderate	site to watershed or	high	tradeoffs between ECS,	spatially explicit ECS

[5] The criteria used by Bagstad et al. (2013) are quantification and uncertainty, time requirements, capacity for independent application, level of development and documentation, scalability, generalizability, nonmonetary and cultural perspectives and affordability, insights, integration with existing environmental assessments.
[6] GIS stands for geographic information system.

Tools / Criteria	Quantification and uncertainty	Time requirements	Independent application	Development and documentation	Scalability	Generalizability	Nonmonetary and cultural	Integration
					landscape		no valuation	tradeoff maps
Multiscale Integrated Models of Ecosystem Services (MIMES)	quantitative; varying inputs	high	yes	development fully; documentation low	multiple	low	Economic valuation via Input-Output analysis	dynamic modelling and valuation using Input-Output analysis
EcoServ	quantitative; varying inputs	low to high	yes	low	site to landscape	low	biophysical values, can be monetized	spatially explicit ECS tradeoff maps (in development)
Costing Nature	quantitative	low	yes	moderate	landscape	high	outputs indexed, bundled ECS values	rapid analysis of indexed ECS
Social Values for Ecosystem Services (ColVES)	quantitative	low to high	yes	fully	watershed, landscape	low	nonmonetary rankings of ECS values	maps of social values for ECS
Envision	quantitative	high	yes	fully (for case study sites)	landscape	low	nonmonetary tradeoff analysis, supports monetization	cost-effective in regions where already developed
Ecosystem Portfolio Model (EPM)	quantitative	low to high	yes	moderate	watershed, landscape	low	potential to support nonmonetary valuation	cost-effective in regions where already developed

Tools / Criteria	Quantification and uncertainty	Time requirements	Independent application	Development and documenta	Scalability	Generalizability	Nonmonetary and cultural	Integration
InFOREST	quantitative	low	yes	moderate	site to landscape	low	credit calculator, no valuation	cost-effective in regions where already developed
EcoAIM	quantitative	low to moderate	no	low	watershed, landscape	high	incorporates stakeholder preferences	spatially explicit ECS tradeoff maps
ESValue	quantitative; Monte Carlo simulation	high	no	low	watershed, landscape	high	incorporates stakeholder preferences	stakeholder-based ECS assessment
EcoMetrix	quantitative	low	no	low	site	high	credit calculator, no valuation	site-scale ECS assessment
Natural Assets Information System (NAIS)	quantitative; range of values	-	no	moderate	watershed, landscape	high	only monetization	point transfer for ballpark numbers
Ecosystem Valuation Toolkit	quantitative; range of values	low	yes	under development	watershed, landscape	high	only monetization	point transfer for ballpark numbers
Benefit transfer and Use Estimating Model Toolkit	quantitative; range of values	low	yes	fully	site to landscape	high	only monetization	low cost economic valuation

Most of these tools have been developed by scientific institutions and not primarily with companies as a target group. Still, most of them can be applied in a corporate context.

4. Putting the discourse into a business context

Companies are usually experienced in valuing and managing their financial or manufactured capital, but natural capital, neither the value of its stock nor the benefits its services provide, is often not adequately understood by business (Reddy et al., 2015). However, natural capital and ecosystem services are now perceived as potential material risks for many businesses, which underlines the need to be able to manage them from a corporate perspective (Bonner et al., 2012). The absence of markets, and thus costs and prices, for many ecosystem services poses a challenge as changes in the availability or quality of natural capital, usually indicated by changing market prices, cannot be detected as for marketed goods and services (Hanley and Barbier, 2009). Therefore, the economic valuation of ecosystem services can provide companies with a means to better manage their natural capital (Daily et al., 2009; TEEB, 2012).

While multiple corporate leaders have expressed their increasing interest in this area (Dow Sustainability, 2015; WBCSD, 2011), only few examples of scientifically conducted ecosystem service valuations from a business perspective have been conducted so far (Reddy et al., 2015).

4.1.Relevance of ecosystem services for business

According to a report commissioned by the Principles for Responsible Investment initiative and the UNEP Finance Institute (2010), more than 50% of company earnings could be at risk due to environmental externalities. The report estimated that global human activities in 2008 caused environmental costs in the amount of around 6.6 trillion US dollars. Of these costs, around one third (2.15 trillion US dollars) were caused by the world's 3000 largest publicly traded companies. Many of these costs are not accounted in companies' accounts (Principles for Responsible Investment and UNEP Finance Institute, 2010).

ACCA, the world's leading body for professional accountants, asked its members whether natural capital is a material issue[7] for their business. 49% of respondents identified natural capital as material issue. For businesses actively considering natural capital in their assessments of materiality, the reasons were operational, regulatory, reputational and financial risks (Bonner et al., 2012). However, as Bonner et al. (2012) found, natural capital and ecosystem services are issues which are not included in most companies' materiality assessments, due to non-existing or low market prices of many services and goods which are provided by natural capital.

In addition, there are a number of cases where companies faced financial losses or risks due to natural capital issues (Bonner et al. 2012). For example, the oil spill in the Gulf of Mexico had large financial implications for BP, which were in part caused by clean-up costs and compensation claims for ecological damages to natural ecosystems. As a result, in 2010 the company had to include 3.5 billion US dollars provision related to clean-up costs and 7.8 billion US dollars provision related to litigation and claims associated with the spill in its balance sheet (BP, 2011). In December 2015, BP and the US government agreed to a final settlement of more than 20 billion US dollar[8] (Kasperkevic, 2016). After the oil spill in the Gulf of Mexico, an academic discussion emerged on how to account for environmental damages at such a large scale. The US Congress commissioned a report on this matter using an ecosystem services approach (National Research Council, 2013). The report found that "the full value of losses resulting from the spill cannot be captured … without consideration of changes in ecosystem services – the benefits delivered to society through natural processes" (National Research Council, 2013, chap. Abstract). The authors asserted that the current approach in accounting for environmental damages, which is focused on calculating restoration costs for individual ecosystems, is not able to account for the full loss of value to humanity. Rather, the

[7] A material issue in financial reporting and auditing is an issue, which if omitted or misstated could influence the decisions of shareholders, lenders or investors (Bonner et al., 2012).
[8] This is the largest settlement for environmental damages in US history (Kasperkevic, 2016).

application of an ecosystem services approach was welcomed, which helps in assessing the changes in economic value of the ecosystem in a broader context taking into account different forms of value (National Research Council, 2013).

In another case, a mining company lost more than 50% of its share value following losing the development permission for one of its gold mines in South America due to potential negative environmental impacts (Bonner et al. 2012).

The daily operations of almost any business is impacting the natural environment; on the other hand many companies are dependent on services and resources provided by natural ecosystems (TEEB, 2012). Besides natural capital, other forms of capital, such as manufactured capital, social capital or human capital are essential factors in companies' the value creation process (IIRC, 2013). But as depicted in figure 3, natural capital is the foundation on which the other forms of capital are built upon (Forum of the Future, 2016). However, most companies, just as nation states, are confronted with the challenge to assess the natural capital which is material to their business in order to be able to deduct respective decisions based on this knowledge.

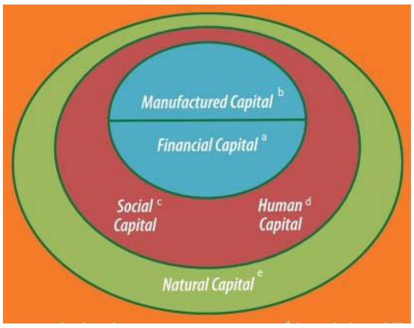

Figure 3: The five capitals model (Forum of the Future, 2016)

The World Resource Institute (Hanson et al., 2012) found several types of business risks and opportunities in relation to natural capital and ecosystem services (see figure 4 below).

Type	Risk	Opportunity
Operational	• Increased scarcity or cost of inputs • Reduced output or productivity • Disruption to business operations	• Increased efficiency • Low-impact industrial processes
Regulatory and legal	• Extraction moratoria • Lower quotas • Fines • User fees • Permit or license suspension • Permit denial • Lawsuits	• Formal license to expand operations • New products to meet new regulations • Opportunity to shape government policy
Reputational	• Damage to brand or image • Challenge to social "license to operate"	• Improved or differentiated brand
Market and product	• Changes in customer preferences (public sector, private sector)	• New products or services • Markets for certified products • Markets for ecosystem services • New revenue streams from company-owned or managed ecosystems
Financing	• Higher cost of capital • More rigorous lending requirements	• Increased investment by progressive lenders and socially responsible investment funds

Figure 4:Natural capital risks for business (Hanson et al., 2012)

However, recent research by the Cambridge Institute for Sustainable Leadership (CISL, 2016) show a transition in how companies perceive natural capital. It moved from a risk-focus perspective to one that puts opportunities from conserving the natural environment in focus. The report found that "this change reflects the shift from business decision-making being reactive and risk-based towards a more forward-looking, opportunistic approach when assessing natural resource challenges" (CISL, 2016, p. 8).

4.2. Are all value categories of TEV relevant for business?

The concept of total economic value (TEV) is commonly used in ecosystem service assessments as it includes different kinds of value thus allowing a broad and inclusive view of how ecosystem services contribute to human wellbeing. However, from existing literature it is unclear how it can be applied to a business context. While writing this thesis that question was discussed in expert interviews with business representatives and other experts in the areas of integrating nature into corporate thinking.

In general, it has been stated that all value categories of TEV can be relevant for companies. However, it was noted that there is a difference between companies with a long-term thinking and companies which are only interested in economic thinking. For the latter, use values are perceived as more relevant. Non-use values are seen as only partly relevant for companies as these cannot be directly linked to business thinking and do not directly generate revenues for companies. In addition, the valuation of non-use values can be a challenge, as required data and methods are often not established in many businesses.

Option value is perceived as important for any company with a focus on long-term thinking, as ecological factors such as ecosystem services and a company's natural capital will have long-term impacts on any business. However, it was noted that certain factors can have an amplifying effect on the relevance of option value. Mentioned factors were e.g. state-affiliation or public holdings in a company, companies active in natural resource management and companies which have integrated environmental risks in their risk management. In addition, it was mentioned that for companies with an environmental management system it can be easier to understand, assess and value the different values of TEV, as those companies usually perform an assessment of their direct and indirect environmental impacts, which can serve as a good data base for assessments of ecosystem services.

For companies in sectors which are subject to specific regulations, TEV categories can be implicitly relevant due to regulatory requirements. For example the Austrian forestry law (BMLFUW, 2016) obliges companies in the forestry sector to ensure the provision of non-use values by the forests under management. According to Austrian forestry law, a forest delivers four functions:

- Use function
    - A forest has to enable an economically sustainable production of timber.
- Protection function
    - A forest has to secure protection from certain environmental risks, such as avalanches or floods but also from light and noise disturbances.
- Welfare function
    - A forest has to contribute positively on its natural environment, especially regarding climate regulation, water flow regulation and air and water purification.
- Recreational function
    - A forest has to be a recreational area for visitors.

The four functions of forests link well to TEV, as different kinds of values are included, from use values (use function) over non-use values (recreational and welfare function) and option values (implicit in use function, as the forestry law requires that the productivity of the soil has to be secured).

An additional question discussed in the interviews was if there are certain factors which make a company especially interested in managing ecosystem services. Following factors had been discussed:

- State affiliation and public ownership
  - State-affiliated companies and companies which are publicly owned companies often have longer-term thinking embedded in their corporate culture, which makes non-use values and option values more applicable to them.
- Sector
  - Some sectors have been mentioned to be especially exposed to ecosystem services and natural capital. These are for example resource management (e.g. forestry, oil and gas, minerals, etc.), companies in production sector with ecosystem services as relevant inputs (e.g. clean water, clean air, timber), companies with large land holdings (e.g. real estate companies, infrastructure companies) and companies in sectors with specific regulations relevant to ecosystem services (e.g. forestry). Apart from single companies in specific sectors, sector associations or other business organizations could potentially be interested in ecosystem service valuations to show what the value of ecosystem services a sector contributes to human wellbeing.
- Companies with ambition to shape discussion around natural capital
  - Companies which want to proactively shape the agenda and regulation on how ecological issues are integrated into economic thinking.

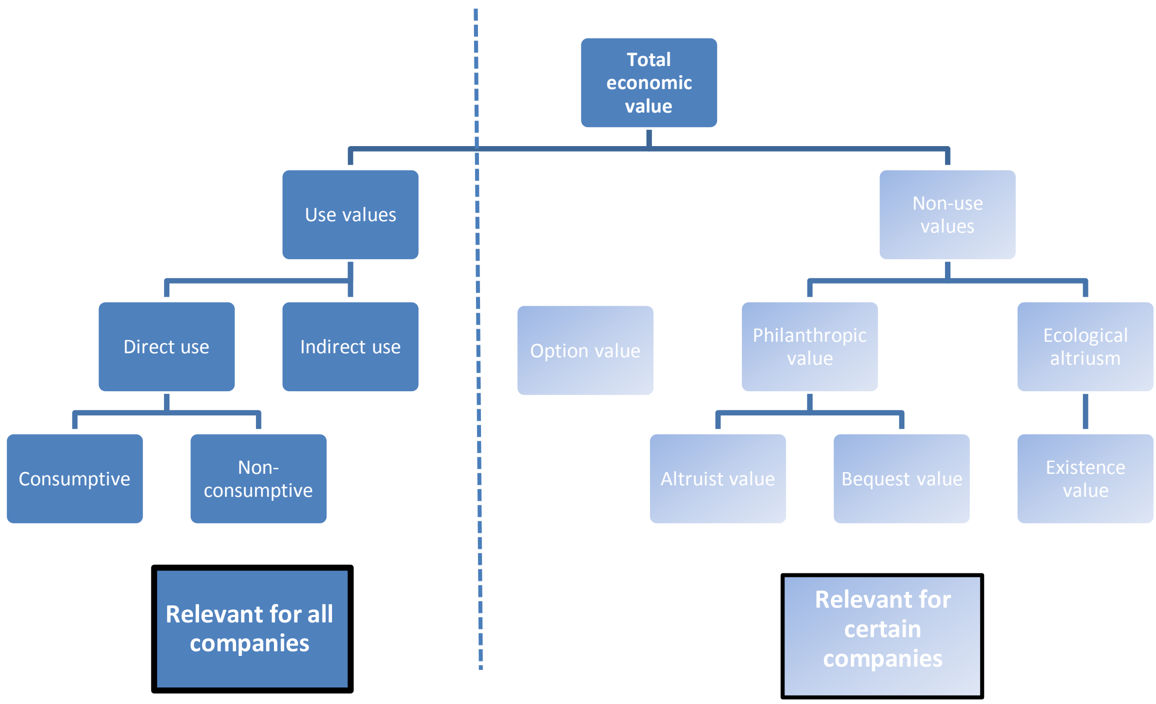

Figure 5: Overview of relevance of TEV components for companies (own illustration)

4.3. The European and Austrian perspective

To put a local perspective to the internationally discussed issue of ecosystem services and its valuation by companies, some relevant points of reference from Austria have been provided in this chapter.

On EU level, the EU biodiversity strategy is aimed at "reversing biodiversity loss and speeding up the EU's transition towards a resource efficient and green economy" (European Commission, 2011, p. 1). The strategy's headline target is *"halting the loss of biodiversity and the degradation of ecosystem services in the EU by 2020, and restoring them in so far as feasible, while stepping up the EU contribution to averting global biodiversity loss"* (European Commission, 2011, p. 2). More specifically, target 2 of the strategy states that

> *"By 2020, ecosystems and their services are maintained and enhanced by establishing green infrastructure and restoring at least 15 % of degraded ecosystems."*
> (European Commission, 2011, p. 12)

This shall be supported by mapping, assessing and valuing ecosystems and their services, and integrating these values into national and EU accounting and reporting systems (Action 5 of the strategy).

In a mid-term review of the EU biodiversity strategy the status of target achievement was evaluated. It was found that there is progress in achieving target 2, but at an insufficient rate (EEA, 2015b). It was stated that measures taken so far have "not yet halted the trend of degradation of ecosystems and services" and more specifically that "a lot remains to be done to halt the loss of ordinary biodiversity outside the Natura 2000 network" (EEA, 2015b, p. 1).

In relation to economic valuation of ecosystem services, the strategy explicitly mentions that "biodiversity and the services it provides have significant economic value that is seldom covered in economic markets" (European Commission, 2011, p. 2), which can lead to the risk of undervaluation of nature, and that "biodiversity loss itself is costly for society as a whole, particularly for economic actors in sectors that depend directly on ecosystem services" (European Commission, 2011, p. 3). As an example, the economic value of insect pollination as important ecosystem service to many farmers and businesses in the agri-business sector is stated as EUR 15 billion per year (European Commission, 2011, p. 3 based on Gallai et al., 2009). Furthermore, economic valuation of natural capital is expected to contribute to other strategic objectives of the EU, especially in the following areas:

- A more resource-efficient economy
- A more climate-resilient, low-carbon economy
- A leader in research and innovation
- New skills, jobs and business opportunities

In October 2010, the EU biodiversity strategy was implemented in Austria by the Austrian biodiversity strategy 2020+ (Bundesministerium für Land- und Forstwirtschaft, Umwelt und Wasserwirtschaft, 2014). The Austrian strategy includes 5 action areas, 12 targets and 140 measures. However, economic valuation of ecosystems and their services is, in contrast to the EU strategy, not included. Neither options to include the private sector are exploited in detail. Therefore, it can be interpreted that the Austrian strategy does not recognize the potential of economic valuation and the synergies of including the private sector in maintaining and improving the state of Austria's ecosystems and their services.

However, the Austrian environmental agency (UBA) has actively contributed to the enhancement of knowledge of Austria's natural capital by some research projects. In 2015 UBA published a theoretical report on the economic relevance of ecosystem services, which summarizes the methodology in economic valuation of ecosystem services and concludes with an analysis of inherent potentials and risks (Schwaiger et al., 2015). In addition, it discusses the possibility to include information on ecosystem services into Austria's national statistics. The report gives a good overview of the issue, but does not have companies as explicit target group.

Another UBA report developed an inventory for ecosystem services of Austria's forests (Götzl et al., 2015). In scope of the inventory are final ecosystem services which directly provide value to society. Ecosystem service classification is based on CICES (Common International Classification of Ecosystem Goods and Services)[9]. By developing indicators for the flow of ecosystem services, the report aims to make ecosystem services of Austrian forests better manageable. Thus, a clearer picture of the state of Austria's forest ecosystems and its services shall be enabled, from which the value of these services can be estimated. While the report does not include an economic valuation, the developed indicators can serve as a good starting point in ecosystem service assessments by companies in the forestry sector or companies for which forest products are relevant inputs in their value chain.

In addition, ENU, the environmental and energy agency of Lower Austria, has conducted a survey among local companies with biodiversity and ecosystem services as its objective (ENU, 2015). The most relevant results are presented below.

- 62% of surveyed companies think that they have a positive or rather positive impact on the environment, while only 6% think that the impact is rather negative. According to the study authors this unrealistic perception shows that companies have difficulties in assessing their impact on the environment.
- 90% of companies are in principle willing to adopt measures to make their use of natural resources more sustainable and minimize their negative impacts on biodiversity. Especially the promotion of biodiversity on company premises (66%) and the integration of biodiversity into current sustainability concepts have been mentioned.
- Companies expect that their business success will be increasingly influenced by ecosystem services and biodiversity.

To the knowledge of the author, there is only one example of an Austrian company which has performed an in-depth assessment of its ecosystem services, Österreichische Bundesforste (ÖBf), the Austrian federal forestry company. The company is Austria's largest ecosystem manager with 10% of Austrian territory and around 15% of Austria's woodland under management. As a company dedicated to sustainability, ÖBf wanted to know how much their natural areas contribute to Austria's welfare. The decided to take an ecosystem service based approach for the project. Selected ecosystem services should be quantified and their value and potential future development assessed. For the economic valuation, the difference between current level of ecosystem services (status quo) and a reference scenario (more intensified cultivation and forestry) has been evaluated.

In the first project phase, this has been performed for five ecosystem services, supply of drinking water, erosion control, local climate regulation, recreation and biological diversity. It was evaluated that the aggregate value of these ecosystem services is between EUR 92 million and EUR 114 million per year, which translates into between EUR 109 and EUR 135 per hectare per year.

Valuation methods used are diverse and depending on the ecosystem service in scope. While for water provision and local climate regulation[10], the valuation was performed using cost-based methods (market price method and replacement cost method), for recreation a stated preference method was chosen. A survey with around 1.500 participants across Austria was performed asking participants to assign a value of recreation to forests of ÖBf. Also biological diversity has been valued

[9] CICES is an initiative of the European Environmental Agency (EEA), which is intended to serve as a common European classification framework for ecosystem services. It is part of the EEA's contribution to support the revision of the System of Environmental-Economic Accounting (SEEA) by the United Nations.

[10] For water provision either the market price method or the replacement cost method was used. For local climate regulation, a cost based approach has been chosen.

using surveys asking for stated preferences of the willingness to pay for biodiversity. Interestingly the non-use value of biological diversity has been assessed higher (EUR 60,5 million per year) than the aggregated value of the other four ecosystem services (EUR 31,5 million to EUR 53,5 million), which deliver use values.

5. How business can value ecosystem services and integrate them into decision-making

This chapter provides an overview of management approaches for ecosystem services and introduce into available frameworks and concepts that can facilitate ecosystem service management for companies.

5.1. Corporate management approaches for ecosystem services

Ecosystem services are identified, quantified, monitored, valued and managed routinely by firms when the ecosystem services are directly used as inputs in the business model and if they are traded on market and thus have a price and implicit economic value (Schaltegger and Beständig, 2010). However, if ecosystem services are used indirectly, especially upstream in a company's supply chain, they are often not accounted for. Houdet et al. (2010) found that this is especially due to a lack of awareness by companies, but also of assessment and valuation tools tailored to the needs of business.

As a result, new business strategies and management approaches are needed, and are slowly emerging, for example in water intensive sectors, such as beverage production (Kissinger, 2013).

Ecosystem service quality, quantity in supply and demand are increasingly having an impact on companies' bottom lines, which creates an internal incentive for companies to adopt corresponding management approaches and strategies in order to reduce dependencies and benefit upon opportunities from ecosystem services (Houdet et al., 2010, 2012; TEEB, 2012; WBCSD, 2011).

Martin-Ortega et al. (2015) describe approaches to analyse the human-ecosystem relationships in order to support decision-making as "ecosystem-service based approaches". These are based on four key elements:

- Focus on the status of ecosystems and the awareness of the impact on human wellbeing
- Understanding biophysical function and service delivery of ecosystems
- Interdisciplinary approach integrating natural and social sciences for a comprehensive understanding of ecosystem services
- Assessment of ES for integration in decision-making

The table below shows benefits for businesses adopting an ecosystem-service based approach in their environmental management.

Table 16: Benefits to companies from adopting an ecosystem service based management approach (based on Spurgeon 2014)

General decision-making	Operational	Financial	Risk	Reputation	Strategy
• improved sustainability decision-making • integrated thinking and reporting • better stakeholder relationships • Capacity building around ecosystem services	• Cost savings • Enhanced supply chain management including long term stock security of natural inputs • Optimization of impact mitigation measures • more employee satisfaction and engagement • Meet regulatory and client requirements	• Maintain and enhance revenues • Benefit from new environmental markets • Maintain social license to operate	• Manage and reduce risk and exposure • Secure supply of critical natural resources • Increase awareness and understanding of environmental risks, including price increases • Reduce risk of future uncertainty • Reduce investment risk (of sunk costs and false investments)	• Maintain and enhance reputation • Demostrate the creation of shared value	• Anticipate and shape future regulation • Inform external and internal communication • Support in priorisation of risks and opportunities • Engage with stakeholders in managing ecosystems

Some governments are implementing approaches on ecosystem service and natural capital valuation, e.g. in the development of national natural capital accounts (see e.g. WAVES Partnership 2014). However, in the private sector there are only a handful examples of companies which are systematically assessing and valuating the natural capital on which they base their business model and which is potentially affected by their business activities (Chartered Institute of Management Accountants et al., 2014).

Natural capital and ecosystem services are often not considered in business decisions, because their use is not directly linked to costs to be borne by the company. Through the measurement and valuation of stock (natural capital) and flow (ecosystem services) of the natural goods and services material to the company, information can be generated which enables better informed business decisions. There are multiple approaches for companies for performing such an assessment. One recently developed framework on how to integrate nature into corporate thinking and decision-making is the Natural Capital Protocol (Natural Capital Coalition, 2016a). It will be introduced in more detailed in the next chapter, followed by information on other relevant approaches and initiatives linked to the Protocol.

5.2. An emerging framework - the Natural Capital Protocol

The Natural Capital Protocol (Natural Capital Coalition, 2016a) offers businesses with a framework on how to integrate nature, in corporate language natural capital, into decision making. The Natural Capital Protocol builds on a number of existing approaches, such as the Corporate Ecosystem Service Review (Hanson et al., 2012) or the Guide to Corporate Ecosystem Valuation (WBCSD, 2011). Its objective is to offer companies a relevant, rigorous, reliable and consistent framework in measuring and valuing their relationship with natural capital. Thus, information shall be created for business applications such as risk management in a company's supply chain, analysis of the dependency of business models on natural capital or the societal and environmental outcomes of business activities. Ecosystem services, as the biotic flows from natural capital to society, are an integral part of the Protocol.

In addition to the Protocol, the Natural Capital Coalition developed sector guides providing additional guidance and in-depth sector business insights. They do adopt the methodology as described in the Protocol and assist in implementing it in the specific sectors. Together with the Protocol sector guides for the food and beverage sector (Natural Capital Coalition, 2016c) and the apparel sector (Natural Capital Coalition, 2016d) have been published on the Coalition's web page[11].

The Natural Capital Protocol includes four stages and nine steps (see Figure 6 below). Economic valuation is described in step 07. Here, inter alia, an overview and analysis of valuation techniques is provided. In Annex B to the Protocol, relevant valuation techniques including value transfer are presented in more detail.

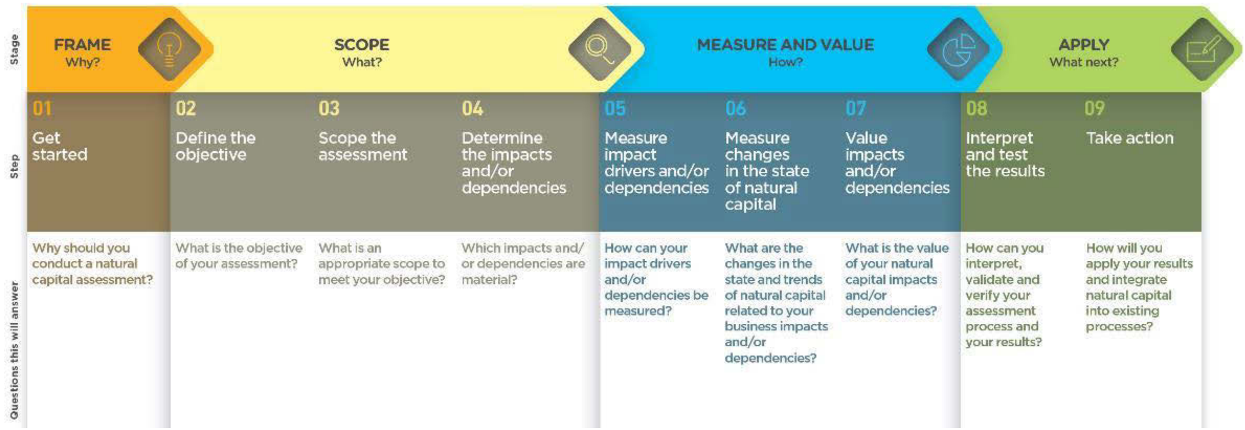

Figure 6: The Natural Capital Protocol framework (Natural Capital Coalition, 2016a)

In Figure 7 below, the conceptual model of the Protocol is presented. It shows the interactions between natural capital, society and business, costs and benefits resulting from impacting or depending with natural capital and the resulting risks and opportunities for businesses.

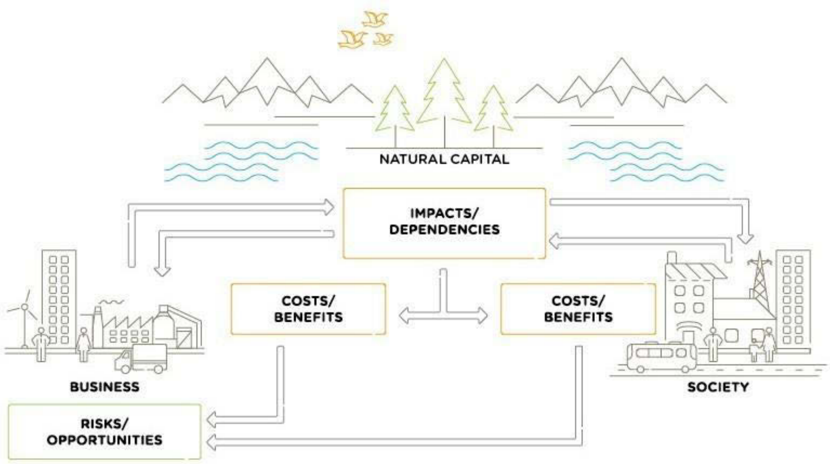

Figure 7: Conceptual model of the Natural Capital Protocol (Natural Capital Coalition, 2016a)

[11] http://naturalcapitalcoalition.org/protocol/sector-guides/

While the Protocol and the sector guides include hypothetical case studies on business implications from natural capital risks and opportunities, a growing number of real case studies can be found on the Natural Capital Hub[12]. Case studies in the food and beverage sector have been included in Figure 8.

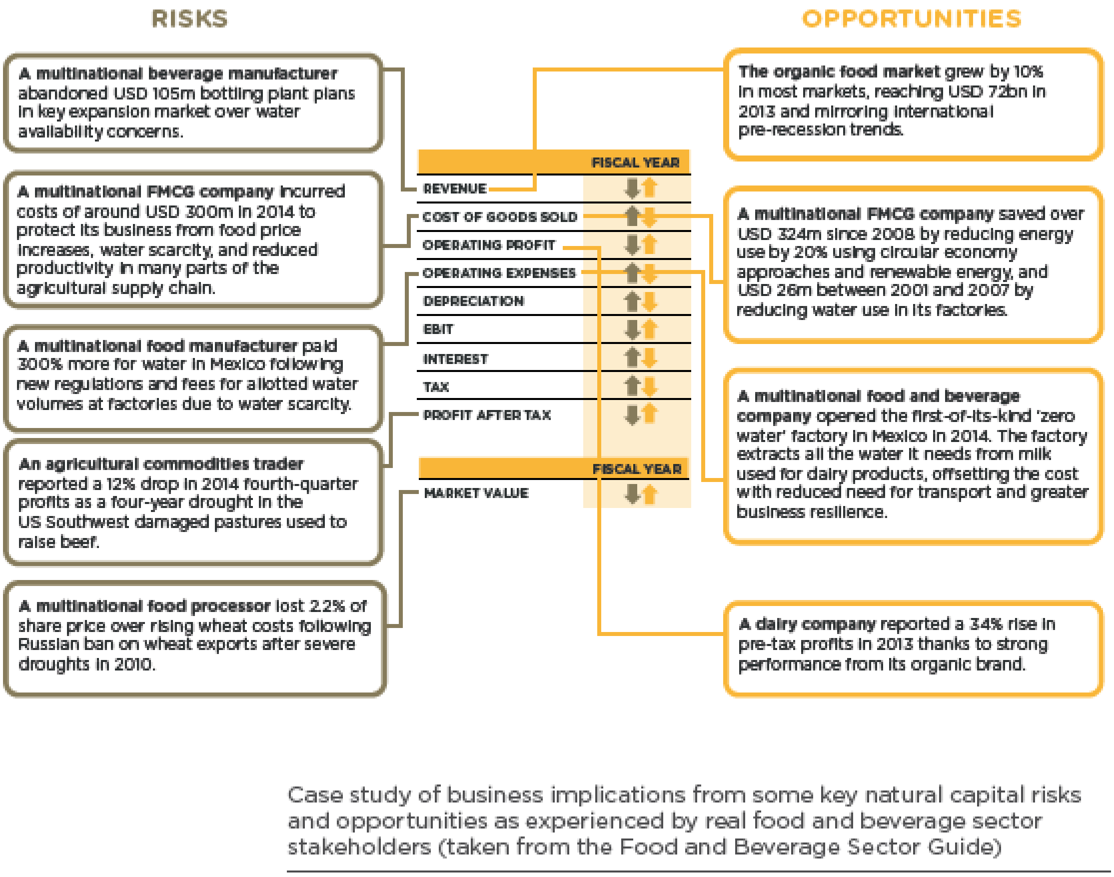

Figure 8: Real case studies on business implications from natural capital risks and opportunities (Natural Capital Coalition, 2016c)

For determining impacts and dependencies of a company to natural capital, the Protocol defines three important components of a natural capital assessment:

- Impact drivers

Impact drivers are understood as natural capital which is used as an input to a production (e.g. freshwater) or a non-product output (e.g. CO2 emissions) of the production of a business. Impact drivers are measured in quantitative units. In the understanding of an input-output-outcome-impact logic approach (cf. (Bertelsmann Stiftung, 2010), an impact driver is a result of business activity which leads to an impact in the quality or quantity of natural capital. Thus, it has to be differentiated from an impact-focused approach, such as impact pathways.

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[12] http://naturalcapitalcoalition.org/hub/

➢ Impact pathways

Impact pathways have a focus on the impacts of business activity on natural capital and how these changes in natural capital affect its beneficiaries or stakeholders. An impact pathway usually follows a logic as below:

➢ Dependency pathways

Those pathways assess the dependency of business activities on natural capital. They focus on how changes in natural capital impact company operations and the costs or benefits this change includes for the company and other stakeholders. A dependency pathway usually follows a logic as below:

To facilitate understanding of those concepts, following figure puts them into practice by the example of a plastic cup producer.

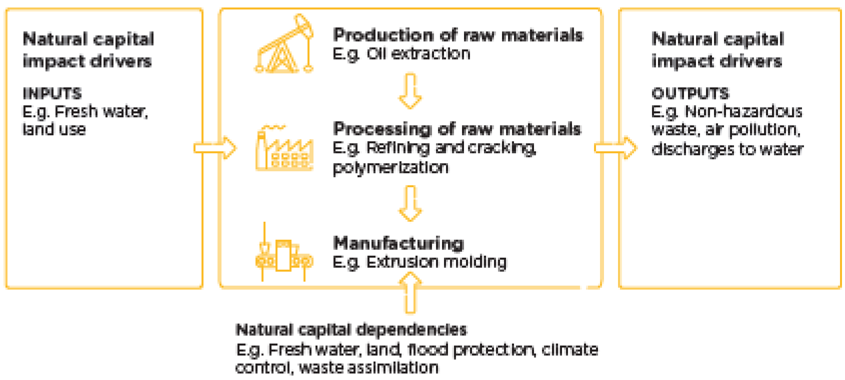

Figure 9: Impact drivers and dependencies for a producer of plastic cups (hypothetical example) (Natural Capital Coalition, 2016a)

In the Protocol, valuation is the process of estimating the relative importance, worth or usefulness of natural capital to people (or to a business), in a particular context (Natural Capital Coalition, 2015). Valuation involves a continuum of qualitative, quantitative and economic approaches, each a pre-requisite to the next.

➢ Qualitative valuation is descriptive and is normally performed by questionnaire surveys or expert opinion. It often serves as a first identification of material impacts or dependencies on ecosystem services. It can express relative value between different ecosystem services by assigning ranking values using defined categories.

➢ Quantitative valuation assesses the value of ecosystem services in quantitative non-monetary terms. It builds upon quantitative measurement[13], but goes further as it focuses on the benefits derived from ecosystem services, which can differ at the same output of an ecosystem depending

[13] Quantitative measurement focuses on the output of an ecosystem service, such as the carbon sequestered by a forest per ha per year, but does not put it into a bigger context.

on the context, e.g. demand after the ecosystem service. For example, a company consuming 1.000.000 m³ fresh water per day in a water abundant region can have a lower relative impact on the benefit of the ecosystem service than a company consuming 1.000 m³ in a region with high water stress. It can be implemented using questionnaire surveys, by developing indicators (e.g. Disability Adjusted Life Years (DALYs) (WHO, 2016)) or by ranking and scoring approaches.

- Economic valuation translates quantitative estimates of costs and benefits into a single monetary unit, such as Euros. It is often used to estimate marginal values of incremental changes in natural capital impacts or dependencies. Values can be estimated either at a point in time or over a period. By considering changes in supply and demand for ecosystem services, it can also be used to estimate trends in value. Choosing applicable valuation techniques depends on whether ecosystem services are traded on markets. Economic valuation enables to compare different ecosystem services as it allows to translate diverse values into a common unit, but also allows a comparison between natural capital and financial capital.

While the Natural Capital Coalition, the initiative behind the Natural Capital Protocol, has high ambitions to position the Protocol as the standard framework for companies for integrating natural capital into their decision making, there are a number of other interesting approaches supporting companies in ecosystem service assessments. The Natural Capital landscape (see Figure 10) shows how the Protocol is connected to other initiatives and approaches in the area of natural capital.

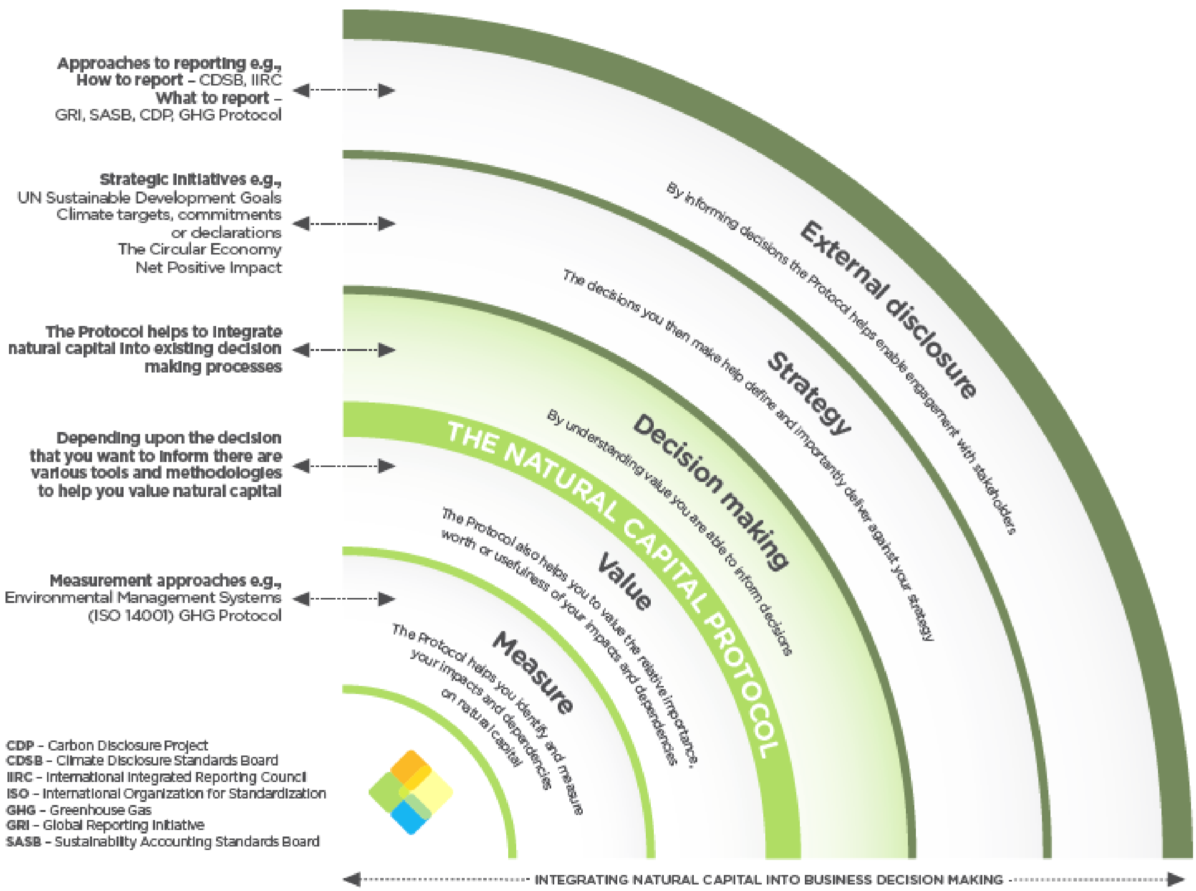

Figure 10: The Natural Capital landscape shows how the Natural Capital Protocol complements existing initiatives (Natural Capital Coalition, 2016a)

Consistent with the focus of this thesis on economic valuation of ecosystem services, special attention is given to approaches in the field of measurement and valuation, especially economic valuation. While economic valuation methods and basic economic foundations are already presented in chapter 3, other parts of the Natural Capital landscape in the area of measurement and valuation will be introduced in the following.

One current initiative is the development of ISO standard 14008 on the economic valuation of environmental impacts from specific emissions and use of natural resources (ISO, 2016). The standard aims to provide a common framework and terminology for economic valuation of environmental aspects and impacts, including human health and the built environment, to secure greater transparency in valuation assessments. The standard might support the uptake of economic valuation assessments, also by business, as it will provide a transparent and trustworthy source of common terminology and processes for such assessments. It aims to "*increase the awareness, understanding, comparability and transparency of monetary valuations of environmental impacts*" (ISO, 2016, p. viii). It will focus on values as included in the Total Economic Value (TEV) concept rather than being limited to private costs. However, it will not cover costing nor accounting approaches. According to the working draft, the crucial difference between valuation and costing is that "costing methods account for potential, not-yet-committed costs while valuation methods derive monetary values from already committed costs, such as those derived from legally binding targets, or already committed expenditures to prevent or reduce impacts" (ISO, 2016, p. 1). It will not be a certifiable standard and according to the proposed time plan the standard will be published in late 2018.

5.3. How can companies implement these concepts into their management and disclosure?

As ecosystem services and natural capital are new issues for most companies, their adoption in corporate management and reporting can be facilitated by guidance documents and academic recommendations. **Error! Reference source not found.** provides an overview of relevant papers and reports structured around key corporate activities in the management and reporting of nonfinancial information.

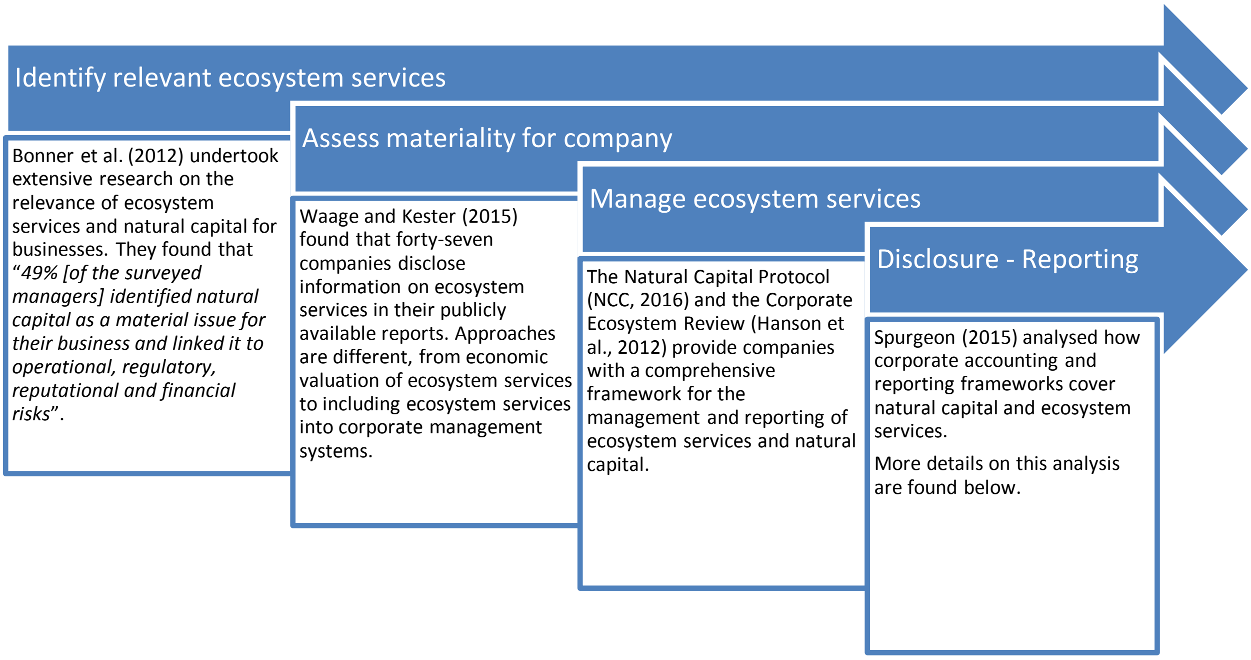

Figure 11: Insights into how to embed ecosystem services into corporate management (own compilation)

Spurgeon (2015) analysed how corporate accounting and reporting frameworks cover natural capital and ecosystem services. Assessed components of natural capital and ecosystem services are environmental outputs or residuals, environmental inputs and environmental expenditure. It was analysed how sub-categories of these components are covered by nonfinancial accounting and reporting frameworks. For reporting, GRI[14] and CDSB[15] were chosen as frameworks. Accounting approaches analysed were the environmental profit and loss account approach[16] and the corporate natural capital account approach[17]. Figure 12 provides an overview of the assessment results.

[14] Global Reporting Initiative. The current version GRI G4 sustainability reporting guideline (GRI, 2013) has been included in the assessment. For more information, see: https://www.globalreporting.org

[15] Carbon Disclosure Standards Board. The current version of the CDSB framework for reporting environmental information and natural capital (CDSB, 2015) has been included in the assessment. For more information, see: http://www.cdsb.net/

[16] For setting up an environmental profit and loss account (EP&L), there is no standardized framework applied internationally. Yet some corporate leaders have begun to set up such accounts and provide the methodology they used. For example, Kering, holding company behind international apparel and accessories companies such as PUMA, Gucci or Stella McCartney, disclosed the methodology behind their 2013 EP&L (Kering, 2015). For more information, see: http://www.kering.com/en/sustainability/epl

[17] The Corporate Natural Capital Accounting (CNCA) approach, developed by (DEFRA, 2015), has been included in the assessment.

Parameter			Business/Private FI			
			Reporting		Sets of accounts	
			CDSB	GRI	EP&L	CNCA
Outputs/ Residuals	GHG		P	P	M	
	Other air emissions		P	P	M	
	Waste and spillages		P	P	\M	
Inputs (capital and/or flows from)	Renewable energy		P	P	n/a	M
	Non-renewable energy (fossil fuels)		P	P	n/a	n/a
	Land use & ecosystems		P	P	M	M
	Renewable resources	Agriculture	P	P	n/a	M
		Forests	P	P	n/a	M
		Fish	P	P		M
	Non-renewable materials (minerals, metals)		P	P	n/a	n/a
	Water		P	P	M	M
	Soil					M
	Marketed biological resources				n/a	M
	Protected species & habitat status			P		Partial
	Other NC/ecosystem services		P		Partial	M
	Environmental expenditures			M		M

P	Covered in physical/quantitative units
M	Covered in monetary values (and physical/quantitative)
Partial	Partially covered in monetary values
n/a	Not applicable because covered by financial accounts
	Not covered

Figure 12: How natural capital and ecosystem services are considered in corporate nonfinancial accounting and reporting frameworks (analysis by (Spurgeon, 2015)

It was found that reporting frameworks focus mainly on quantitative information, while GRI includes environmental expenditures as well. In contrast, accounting approaches for natural capital focus on economic valuation of non-marketed values.

The analysis includes a list of relevant indicators as included in the GRI G4 guidelines (GRI, 2013) in Annex 2 to the study (Spurgeon, 2015). The analysis also examined the IIRC framework for integrated reporting (IIRC, 2013), in which natural capital is explicitly included as integral part of the value creation model, which is the centre-piece of the framework. While the IIRC framework does not specify particular indicators for natural capital, it recommends that, if an aspect of natural capital is assessed as material for the business, the value created or destroyed should be quantified.

Also the Natural Capital landscape (Figure 10 above) includes references to approaches for disclosing information on natural capital. It includes approaches on what to report (e.g. GRI, SASB[18] or GHG protocol[19]) and how to report (e.g. IIRC[20] and CDSB).

A number of companies go further than reporting on their impacts on ecosystem services and natural capital and dedicate themselves to long-term targets or commitments. For example, one of Dow Chemical's sustainability goals towards 2025 is to "deliver $1 billion in value through projects that are good for business and good for ecosystems" (Dow Chemical, 2016). As part of their efforts, Dow Chemical have entered a long-term corporate with NGO The Nature Conversancy to measure the value of ecosystem services. As part of this cooperation, (Reddy et al., 2015) valued the natural capital assets of a Dow Chemical facility. Based on the assessment, Dow Chemical now uses

[18] Sustainability Accounting Standards Board. For more information, see: http://www.sasb.org/

[19] The Greenhouse Gas (GHG) Protocol develops global standards for how to measure, manage and report greenhouse gas emissions. For more information, see: http://www.ghgprotocol.org/

[20] The International Integrated Reporting Council (IIRC) is a global coalition of business, regulators and accountants. It developed the Integrated Reporting framework, which includes the fundamental concepts for developing an integrated report. For more information, see: http://integratedreporting.org/

reconstructed wetlands for their waste water treatment, which saves the company more than $280 million in net present value (Dow Chemical, 2016).

Another example is international forestry and timber product company Weyerhaeuser, which has set the target to “recognize ecosystem services and share publicly” (Weyerhaeuser, 2016). The company identified 18 ecosystem services, structured them based on the Millenium Ecosystem Assessment categories, developed suitable indicators to monitor them and report on an annual basis on their performance. Instead of monetary values, Weyerhaeuser use quantitative indicators. For example, they report that in 2015 almost 200.000 visitors visited their forests which is seen as education and allocated to cultural ecosystem services. For provisioning ecosystem services, asides timber production they report on a range of non-timber forest products (NTFP) such as grazing livestock, bee hives or fur production.

Apart from single organizations, business associations and coalitions are a major driver for the ecosystem service and natural capital agenda. For example, the Science Based Targets initiative helps companies to set adequate targets for combating climate change (Science Based Targets initiative, 2016). Targets are considered science based “if they are in line with the level of decarbonization required to keep global temperature increase below 2 degrees Celsius compared to pre- industrial temperatures, as described in the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC AR5)” (Science Based Targets initiative, 2016). While many companies commit to greenhouse gas emission targets, the level of ambition has to be raised in order for business to attribute a fair share of effort in the international combat against climate change. According to data by CDP (2015), 81% of the world’s 500 largest companies had emission or energy reduction targets in 2014. However, the majority of these targets is based on existing or expected regulation or projects and investments that are planned or in the pipeline, and not on the fair share that the respective company should reduce its emissions. The initiative supports companies in setting emission reduction targets in accordance with scientific evidence.

6. Case study – Ecosystem service assessment including economic valuation of Austrian brewery

The case study demonstrates how economic valuation of a company's natural capital can support the company in improving business planning and decision making for its material ecosystem services based on scientific information and methodologies. The focus is on creating shared value (Porter and Kramer, 2012) for both the company and society by optimizing benefits derived from ecosystem services.

6.1.Case study objective

The initial objective of the case study was to demonstrate how a company can use economic valuation of ecosystem services to produce information which can support business planning and risk management. This should have been achieved by the economic valuation of key ecosystem services using InVEST as valuation software.

Due to unavailability of sufficient and adequate data and small size of the research area[21], the objective had to be adapted. The adapted objective is to perform a natural capital and ecosystem service assessment using the Natural Capital Protocol as framework. Due to the novelty of the Protocol, this case study contributes to the knowledge on how companies can manage natural capital and ecosystem services.

6.2.Case Study context

6.2.1. Brau Union – a sustainability frontrunner

Brau Union is the biggest brewery company in Austria. It operates eight major breweries across Austria and sold more than 5 million hectolitres of beer in 2015 (Brau Union, 2016). Since 2013, Brau Union is part of Heineken group, a major global breweries group. Brau Union has implemented an comprehensive sustainability strategy, which is centred around six key areas. Two of these are directly addressing the company's natural capital and ecosystem services, namely protecting water resources and reducing CO2 emissions.

A brewery has multiple connections with ecosystem services. Its operations have impacts on the natural environment, e.g. through fresh water consumption and emissions of greenhouse gases. In 2015, Brau Union used more than 250 tons of hop, almost 70.000 tons of barley and more than 1,6 million m^3 of water for its beer production (Brau Union, 2016). Although Brau Union has a strong focus on energy efficiency and use of renewable energy, greenhouse gas resulting from energy use were almost 13.000 tons CO2-equivalent. Figure 13 shows the company's carbon footprint allocated to the different steps of its product life cycle.

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[21] The initial idea was to assess the economic value of the well protection forests owned by the Brewery Göss, as it was assumed that these forests are material natural capital to the company as they secure quantity and quality of the most important input resource of the brewery, freshwater in drinking water quality. However, this objective had to be adapted. The economic value of freshwater from these forest will still be valued in this case study, however in a much less detailed level as the adapted objective is on the process of conducting a natural capital assessment and not on the biophysical measurement and subsequent economic valuation of selected ecosystem services. The initial objective is still deemed as an integral part of such assessments by the author.

Figure 13: Brau Union's carbon footprint (Brau Union, 2016)

Breweries are also inherently dependent upon ecosystem services as critical inputs in their production. Water is the most important input in beer production, but also the other inputs are natural resources, which are indirectly dependent on ecosystem services (for Brau Union's input of natural resources in 2015, see above. Also climate change can impact beer production negatively, for example by changing vegetation patterns of grains used as ingredient in production, such as barley or hop. In its sustainability report 2015, Brau Union discloses that to mitigate risks from climate change, it had to change its supply of barley in order to hedge against increasing risks of failed crop harvests due to climate change.

6.2.2. Brewery Göss – world's first large-scale carbon neutral brewery

Brewery Göss is one of the major Brau Union breweries and one of the largest breweries in Austria. It is located in Styria at the heart of Austria in the town of Leoben. Annual production in 2015 was almost 1 million hectolitres of beer (Brau Union, 2016).

Through a series of energy efficiency measures and the extensive use of energy from renewable sources, Brewery Göss' beer production is carbon-neutral making it "the first carbon-neutral large-scale brewery in the world" (Heineken, 2016a).

Brewery Göss is the focus of this case study.

6.3. Application of the Natural Capital Protocol

In the following, the steps as provided by the Natural Capital Protocol (Natural Capital Coalition, 2016a) are applied to the context of Brewery Göss. Each step is supported by a key question to be answered during conduction the step and actions which facilitate applying the Protocol. These key elements are presented at the beginning of each step in a separate box.

6.3.1. Step 1: Get started

Stage	Step		Questions	Actions
FRAME - Why?	1	Get started	**Why should you conduct a natural capital assessment?**	Apply the basic concepts of NCP to the business context
				Identify potential application for assessment results
				Prepare for the assessment

In this step it is important to clarify the reasons for conducting a natural capital assessment and identify potential business applications for the assessment results. Therefore, the relationship of a brewery's business model with ecosystem services has been analysed and potential business implications highlighted.

Due to the close relationship with nature, natural resources being the major input into many production systems, companies in the beverage sector have a considerably high impact and dependency upon ecosystem services (KPMG, 2011)[22]. The Natural Capital Coalition choose the food and beverage sector for one of its two sector guides to the Natural Capital Protocol (Natural Capital Coalition, 2016a)[23]. The sector guide provides a tailored approach for natural capital assessments for companies in the selected sectors, which includes brewing companies.

Potential business implications from natural capital risks and opportunities have already been presented in Figure 8. The business application for this assessment is to test the Protocol as framework for natural capital and ecosystem service assessment for businesses and provide a structured approach for more comprehensive assessments to be conducted in the future.

The theoretical part of the thesis is the content-wise preparation for this case study.

6.3.2. Step 2: Define the objective

Stage	Step	Steps	Questions	Actions
SCOPE - What?	2	Define the objectives	**What is the objective of your assessment?**	Define audience for the assessment and its results
				Define stakeholders and appropriate level of engagement for the assessment
				Define the specific objective of the assessment

The objective of this case study is to test the application of Natural Capital Protocol as suitable framework for ecosystem service valuation and natural capital assessments by business. It is intended as internal assessment and not assessment results are not primarily edited for external disclosure. However, as this thesis is published, the public will have access to the case study. It has to be emphasised that this assessment is limited to a pilot project in the analysis of natural capital and

[22] Examples of risks and opportunities arising from natural capital and ecosystem services can be found in figure 8 above.
[23] The second sector guide is dedicated to the apparel industry (see Natural Capital Coalition, 2016c).

ecosystem service for brewery Göss. For the generation of clear and in-depth results on which to base informed management decisions, a more comprehensive analysis and assessment process is recommended.

In the course of writing this case study, there was exchange with company representatives from Brewery Göss and Brau Union. Although engagement with external stakeholders is seen as valuable in different phases of a natural capital assessment and for the usage of different methods in valuing ecosystem services, such as contingent valuation, it has not been done for this assessment.

6.3.3. Step 3: Scope the assessment

SCOPE - What?	3	Scope the assessment	**What is an appropriate scope to meet your objective?**	Define organizational focus (corporate, project, product)
				Define value chain boundary (upstream, direct operations, downstream)
				Define value perspective (business value, societal value, both)
				Define which impacts and/or dependencies to consider (impacts on business, impact on society, business dependencies)
				Define which type of value to consider (qualitative, quantitative, monetary)
				Consider other technical issues (i.e., baselines, scenarios, spatial boundaries, and time horizon)
				Address key planning issues (timescale, funding and resources, capacity, data availability, stakeholder relationships)

The organizational scope for this case study is Brewery Göss; a corporate-level scope has been chosen. The entire value chain is considered for natural capital impacts and dependencies, however, the focus sharpened on the key activities for the material ecosystem services as defined in step 4.

In this assessment, the general focus was on the value created for business. However, for greenhouse gas emissions as impact drivers, for which a direct and clear chain of impacts is difficult to constitute, the focus has been broadened to include societal value as well. For future assessments it is encouraged to widen the value perspective and include value for society and key external stakeholders for all impacts and dependencies assessed.

While all types of values (quantitative, qualitative and monetary) have be included in the assessment, the focus has been set on the monetary value of the most material ecosystem services, as these represent the key parts of biotic natural capital for the company. For performance indicators used in the assessment, data from the business year 2015 are used.

6.3.4. Step 4: Determine the impacts and/or dependencies

SCOPE - What?	4	Determine the impacts and/or dependencies	**Which impacts and/or dependencies are material?**	List potentially material natural capital impacts and/or dependencies
				Identify the criteria for your materiality assessment
				Gather relevant information

				Complete the materiality assessment and consider generating materiality matrix for material impacts and/or dependencies

For narrowing the scope of the assessment, the materiality of different relevant ecosystem services for Brewery Göss have been analysed. For this step, an interview with the representatives of Brewery Göss and Brau Union has been held. The Corporate Ecosystem Service Review (Hanson et al., 2012) was used as tool to assess the materiality of different ecosystem services to Brewery Göss from a dependence and impact perspective. The results are shown in Figure 14.

ECOSYSTEM SERVICES DEPENDENCE AND IMPACT MATRIX

Ecosystem services		**Dependence**	**Impact**	
Provisioning				
	Crops	○	●	-
	Aquaculture		○	-
	Timber and other wood fibers	○	●	-
	Biomass fuel	○	●	-
	Freshwater	○	?	-
	Genetic resources			-
Regulating				
	Maintenance of air quality	○	●	-
	Global climate regulation		?	-
	Regional/local climate regulation		●	-
	Regulation of water timing and flows		●	-
	Water purification and waste treatment		○	+/-
	Pollination		?	+/-
Cultural				
	Recreation and ecotourism		?	+/-
	Educational and inspirational values		●	-
Supporting				
	Habitat		●	-

Legend
● High + Positive impact
○ Medium - Negative impact
Low
? Don't know

Figure 14: Ecosystem service dependence and impact matrix for Brewery Göss (results of own assessment based on Hanson et al., 2012)

The ecosystem service dependence and impact matrix shows that a medium dependence for the brewery has been assessed for the provisioning services crops, timber, biomass fuels and freshwater and the regulating service maintenance of air quality. These provisioning services are partly direct inputs into beer production. During the workshop, it was discussed that especially the provision of clean freshwater is a key dependency for a brewery.

On the other hand, it has been assessed that the brewery has multiple Impacts on ecosystem services with various impact directions (negative, positive) and intensities (low, medium, high). In the workshop, air emissions, waste water, sewage sludge and residuals from the brewery-owned biogas plant have been especially highlighted as direct impact drivers.

Based on the results and on insights on the importance of ecosystem services for the brewing industry (Natural Capital Coalition, 2016c; WBCSD, 2013), the focus of the natural capital assessment of this case study was set on the dependence on freshwater as critical input in the brewery's operations and the impact on climate change by the emission of greenhouse gases from the brewery.

While the selection of two key ecosystem services is suitable for this case study, for a comprehensive natural capital assessment including economic valuation of ecosystem services it is recommended to include more ecosystem services.

6.3.5. Step 5: Measure impact drivers and/or dependencies

MEASURE AND VALUE - How?	5	Measure impact drivers and/or dependencies	**How can your impact drivers and /or dependencies be measured?**	Map your activities against impact drivers and/or dependencies
				Define which impact drivers and/or dependencies you will measure
				Identify how you will measure impact drivers and/or dependencies
				Collect data

For the measurement of impact drivers and dependencies, performance indicators from Brau Union Sustainability Report 2015 (Brau Union, 2016) are used. This step is divided into two parts which correspond to the two selected material ecosystem services in focus of this case study.

Business dependence on freshwater

Figure 15 shows the exemplary water balance of a brewery as used in a Heineken presentation at the World Water Week 2014. It considers a specific freshwater consumption of 4 liter per 1 liter beer produced. This was the average consumption level for Heineken group in 2015 (Heineken, 2016b), however, Brau Union had a specific consumption of only 3.2 liters freshwater per 1 liter beer (Brau Union, 2016).

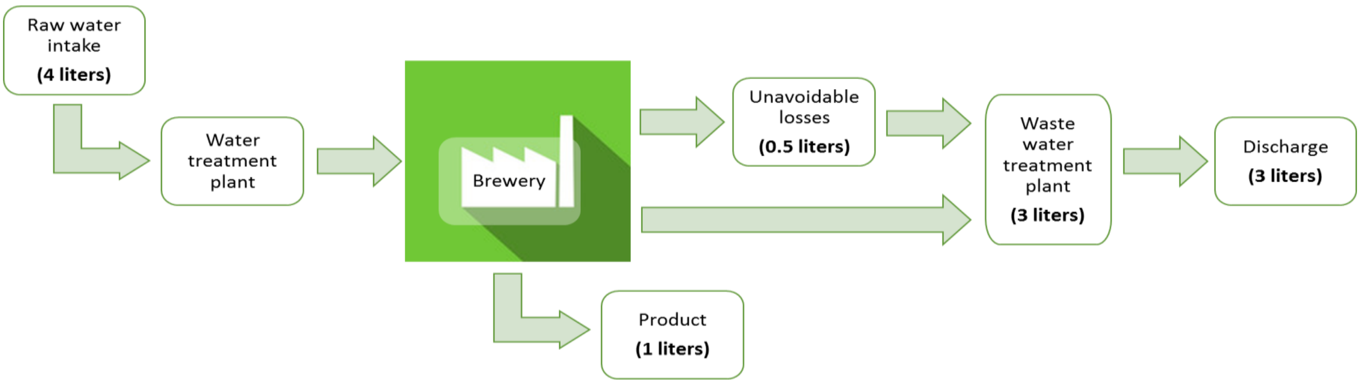

Figure 15: Average water flow in beer production (Ron Bohlmeijer, 2014)

For this assessment, the following data has been considered.

In 2015, Brewery Göss had a total water withdrawal of 306,593 m³. The majority of that water was from wells owned by the brewery. The brewery produced around 991,000 hectolitres of beer. The specific water consumption of freshwater is therefore around 3.1 liter per liter, which is even less than Brau Union average.

Business impact on climate change

Brau Union calculates its carbon footprint along the value chain of its beer production, also including downstream and upstream activities outside of the company's operations, such as agriculture or distribution. As shown in Figure 16, only 11% of the carbon emissions are directly from the production of beer.

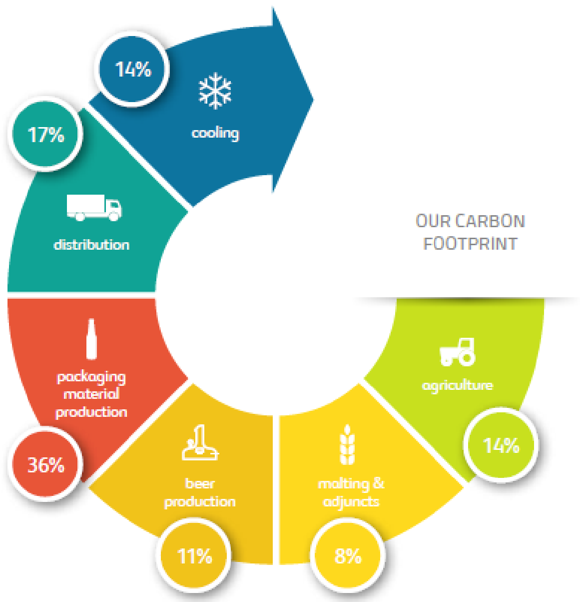

Figure 16: Carbon footprint of Brau Union in its beer production f0r 2015 (Brau Union, 2016)

For this assessment, the following data has been considered.

In 2015, Brewery Göss emitted 1.918.462,6 kg CO2-equivalents as direct greenhouse gas emissions (scope 1) (Brau Union, 2016). Herein carbon dioxide (CO2) emissions from the combustion of fuels and losses of refrigerants are included.

6.3.6. Step 6: Measure changes in the state of natural capital

MEASURE AND VALUE - How?	6	Measure changes in the state of natural capital	**What are the changes in the state and trends of natural capital related to your business impacts and/or dependencies?**	Identify changes in natural capital associated with your business activities and impact drivers
				Identify changes in natural capital associated with external factors
				Assess trends affecting the state of natural capital
				Select methods for measuring changes

				Undertake or commission measurement

As preparatory work for Step 7, Step 6 includes the establishment of an impact or dependency pathway between impact drivers and natural capital impacts or dependencies, respectively. In the terminology of an input-output-outcome(-impact) framework (Bertelsmann Stiftung, 2010), the impact drivers and dependencies measured in Step 5 are the inputs and outputs of Brewery Göss. In Step 6 these performance indicators are linked to the outcomes of business operation on natural capital and ecosystem services. Finally, Step 7 values the impacts on the company and society.

This step is divided into two parts which correspond to the two selected material ecosystem services in focus of the case study.

Business dependence on freshwater

A dependency pathway, as described in the Protocol in Step 4, for the dependence of Brewery Göss upon freshwater is shown in Figure 17. Ecosystems such as forest or wetlands filter water and provide it through wells or surface water sources to society and the economy. The ecosystem services are the provisioning of freshwater in drinking water quality for the consumptive use by humans and the maintenance or improvement of water quality as regulatory service. At the end of the pathway, the brewery is consuming freshwater, directly derived from its own wells, in its production processes.

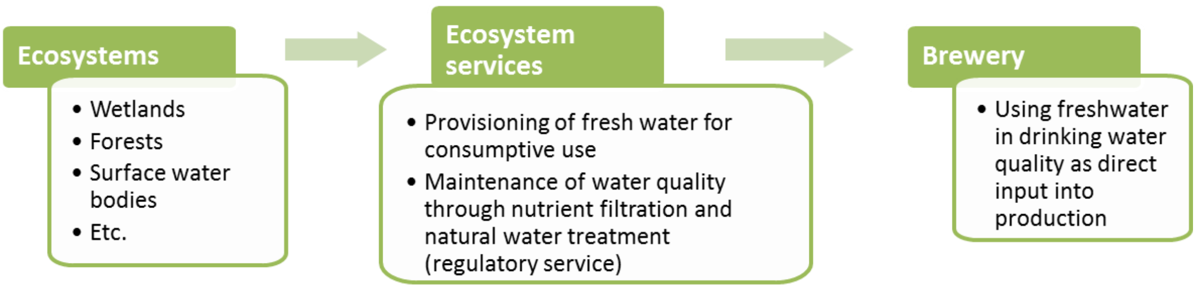

Figure 17: Dependency pathway for freshwater (own representation)

Although the state of water resources in the European Union is generally improving, "*more than half of the river and lake water bodies in Europe are reported to hold less than good ecological status or potential*" (EEA, 2015c). The state of Austria's natural water resources is generally good (EEA, 2015d), still there are diverse human activates, such as agriculture, land cover change or industrial activities, which create a range of potential pressures on water resources (EEA, 2015e).

The importance of water availability for breweries is highlighted in a case studies of Anheuser-Busch Inc. operations in the United States (Hanson et al., 2012). As in 2001 there was less rain which lead to water shortages in the region, barley prices increased which meant cost increases for one of the major inputs in beer production. Furthermore, prices from hydropower increased as less water was available for power production of hydroelectric dams, which increased the price of aluminium, a metal which needs a lot of energy in its production and processing, which resulted in raised price for aluminium cans. Therefore, the shortage of water had a significant price impact on two key inputs in beer production.

Another major global brewery group, SABMiller, invested 150.000 U.S. dollars in a water protection fund in Colombia (The Nature Conservancy, 2016). The fund invests in the protection of ecosystem services upstream of the watersheds which supply the area of Colombia's capital Bogota with water. Through the initial investment in the establishment and enhancement of this green infrastructure, the provision of drinking water for the city and the brewery is secured. In the long term, the fund is intended to save costs as it substitutes the investment cost of the installation of water treatment facilities and flood protection systems.

Brewery Göss uses water from its own wells which are located in well protection forest. Therefore, it has certain influence on the ecosystems and their services which are securing a stable flow of freshwater in good quality. The company is conducting regular water control tests, based on stringent regulatory requirements but also on internal quality requirements.

One of the corporate responsibility focus areas of Brau Union is the protection of water resources. In line with this commitment, the company has implemented a range of targets and measures to reduce its water consumption but also to protect water resources, either through the reduction of wastewater or the support of nature protection projects in water bodies close to its breweries.

Business impact on climate change

The impact pathway of the emission of greenhouse gases is shown in Figure 18. The brewery is emitting greenhouse gases which contribute to global climate change, i.e. influence the natural capital's ability to regulate the global climate system.

Location of Brewery Göss

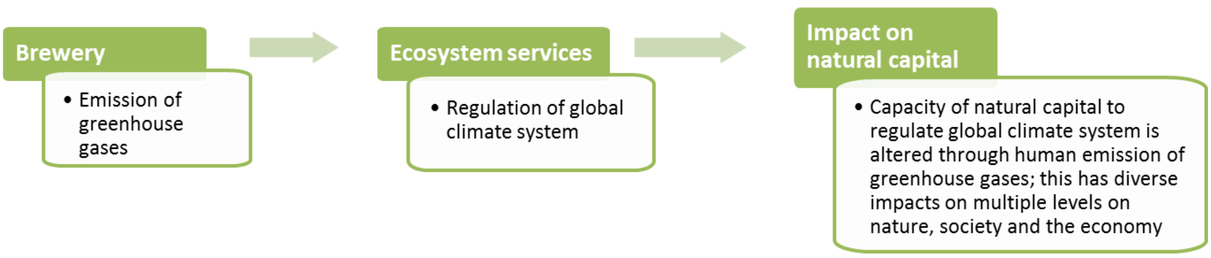

Figure 18: Impact pathway of emission of greenhouse gases (own representation)

Climate change can have diverse impacts on natural and socioeconomic systems. The European Environmental Agency (2015) has analysed these diverse impacts for main regions in Europe (see Figure 19). As Brewery Göss is located in the 'Mountain area', this impacts include above average increase of temperature, decrease in glacier and permafrost areas, increasing soil erosion and a high risk of species extinction in alpine regions.

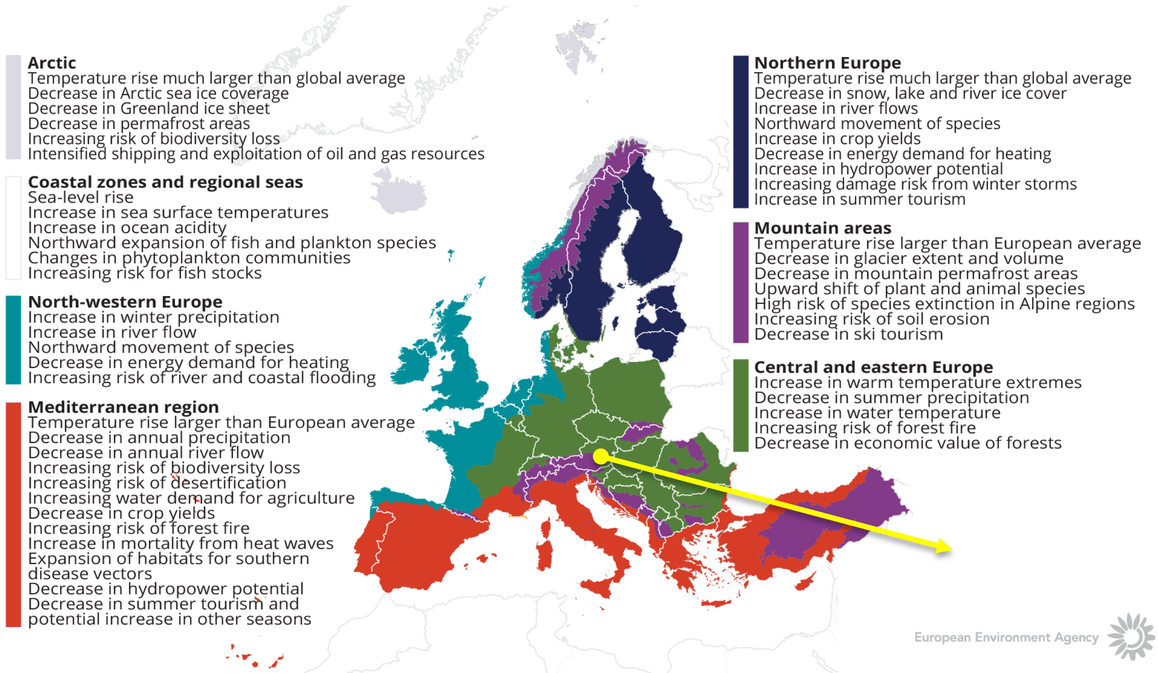

Figure 19: Observed and potential climate change impacts in Europe (EEA, 2015)

A direct link between greenhouse gas emissions of brewery Göss and climate change is hard to establish, as it is a global phenomenon and current emissions will lead to climate change in the future. Therefore, in the following the relevant scientific assessments of climate change, globally and in Austria, are introduced shortly, as those provide information on key current and future impacts of climate change on international and Austrian level.

The Intergovernmental Panel on Climate Change (IPCC), the international body for climate research, regularly publishes the state of international climate science in its reports[24], which also includes chapters on business impacts and adaptation potential. The Austrian Assessment Report Climate Change 2014 (Kromp-Kolb et al., 2014) is a comprehensive study on climate change in Austria. It follows the model of the IPCC reports and provides a comprehensive analysis of the state and outlook of climate change mitigation and adaptation in Austria. Its findings show that temperature increase between 1880 and 2014 in Austria is significantly higher than globally (2°C versus 0.85° C), precipitation patterns have changed significantly in spatial and temporal dimensions and temperature extremes are increasing.

6.3.7. Step 7: Value impacts and/or dependencies

MEASURE AND VALUE - How?	**7**	**Value impacts and/or dependencies**	**What is the value of your natural capital impacts and/or dependencies?**	Define the consequences of impacts and/or dependencies
				Determine the relative significance of associated costs and/or benefits
				Select appropriate valuation technique(s)
				Undertake or commission valuation

The initial objective of the case study was to concentrate on the valuation of selected ecosystem services. InVEST, the tool described in analysis of tools in chapter 3.4., was the initial choice to support the valuation. This objective could not be met, as it was not conductible given the available primary data, cooperation limits by Austrian companies and resources dedicated to the master thesis. Therefore, the objective was amended. In Step 7 of this case study, the valuation of the selected ecosystem services has been performed using secondary data from other valuation studies and other publicly available data. The results of these have been applied to the context of Brewery Göss and adapted where necessary. It was not a valuation exercise in the same depth as initially intended, but an analysis that delivers a first estimate for the economic value of the ecosystem services impacted by the business, or on which the business is dependent upon respectively.

This step is divided into two parts which correspond to the two selected material ecosystem services in focus of the case study.

Business dependence on freshwater

Freshwater in drinking water quality is one of the essential inputs into the brewing process, or as stated in Brau Union Sustainability Report 2015 (2016; 20), “*water is our most important raw material*”.

Brewery Göss is supplied with water from wells which are located in water protection forests. In 2015, the brewery had a total water withdrawal of 306,593 m³. As this water supply is vital to brewery operations, a potential loss of quality or quantity in water supply from its wells poses a major operational risk to the brewery. Therefore, the dependency of the brewery on the supply of freshwater from natural wells is a major natural capital dependency.

[24] More information on the IPCC can be found on its web page: https://www.ipcc.ch.

The focus was on valuing the business dependency on freshwater as a key input into beer production. The replacement cost method has been chosen for the valuation. The National Research Council (2004) recommends three conditions to be met for applying a replacement cost method, (1) the alternative should supply the same services as the replaced ecosystem service, (2) it is realistic that this alternative would be used in absence of the replaced ecosystem service and (3) the alternative is the least-cost option to choose from.

The average cost for communal drinking water for 2013 in Austria is 1.85 EUR per cubic meter, which includes fixed and variable costs as well as taxes (Österreichische Vereinigung für das Gas- und Wasserfach, 2016). As no details on other available alternatives and their costs is known, it is assumed that communal drinking water is a suitable alternative supply of freshwater for the brewery, should the quantity or quality of supply of its own wells decrease.

The estimation of economic value of the brewery's dependence on natural freshwater is shown in formula 1.

$$\boldsymbol{Value\ of\ water\ supply\ (in\ EUR) = water\ consumption\ (in\ m3) \times 1{,}85\ (in\ EUR)}$$

Formula 2: Valuation of water dependency of Brewery Göss

The dependence on natural freshwater of Brewery Göss is estimated to be 567.197 Euro[25]. Inflation-adjusted to 2015 Euros, this value is **584.341 Euro**[26].

For future assessments, it is recommended to conduct further research on which alternative sources are most feasible for the Brewery and how high the specific corresponding costs area.

Business impact on climate change

The focus of the valuation is on the consequences of the brewery's emissions on society. Therefore, the concept of 'societal or social cost of carbon' is used as proxy for the value of the greenhouse gas emissions of Brewery Göss. Fankhauser (1994, p. 86) defines the social costs of carbon (SCC) as "*the marginal global damage costs of carbon emissions*", which means "*the net present value of climate change impacts over the next 100 years (or longer) of one additional tonne of carbon emitted to the atmosphere today*". It is usually expressed in monetary unit per ton carbon emitted, but can also be presented as monetary unit per ton carbon dioxide emitted using the ratio of molecular weights between carbon and carbon dioxide (44/12) (Melaku Canu et al., 2015). There is a vast body of literature on the concept of SCC and a large range of value estimates, ranging from 14 to 300 Euros per ton CO2-equivalent (Tol, 2008). Van den Bergh and Botzen (2014) provide a theoretical overview and a critical evaluation of current estimates of SCC. They propose a lower bound value for SCC at 97 Euros per ton of CO2 emitted[27]. They base this estimate upon a meta-analysis of various studies and argue that it represents a conservative and realistic estimate of SCC.

Several governments have estimated a SCC to be included in the evaluation of policy options and investments. For example, the Environmental Protection Agency of the United States and other federal agencies have developed a methodology to estimate SCC for various time horizons and discount rates. The SCC for 2015 with a 3% discount rate, which has been used in policy appraisals, is 36 dollars per ton CO2 (in 2007 dollars) (US EPA, 2016). Also other countries, such as the UK, introduced a SCC (DECC, 2015).

Increasingly companies are introducing internal carbon prices, similar to SCC, into their risk management. Recent research by (CDP, 2016, p. 8) show that "*517 companies are already using*

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[25] Expressed in 2013 Euros.
[26] For the inflation adjustment, an average inflation rate for Austria at 1,5% was assumed.
[27] Expressed in 2011 Euros.

internal carbon pricing as an accounting and risk management tool … and an additional 732 disclose plans to implement one by 2018". The report shows in addition, that most companies disclosing their internal carbon price have set a price significantly higher as the current carbon costs due to regulative measures, i.e. in the EU the Emission Trading Scheme (ETS)[28]. The United Nations Global Compact, the world's largest business association for corporate sustainability, has called upon businesses to introduce an internal carbon price at a minimum of 100 dollars per ton CO2 emitted (United Nations Global Compact, 2016).

For the valuation of the greenhouse gas emissions of Brewery Göss, benefit transfer has been applied as method. The SCC as proposed by van den Bergh and Botzen (2014) has been used to estimate societal impact of the brewery's greenhouse gas emissions. This approach is similar to peer-researched papers in the field of ecosystem service valuation, such as (Melaku Canu et al., 2015). The calculation is presented in formula 2.

$$\textit{Value of GHG emissions (in EUR)} = \textit{GHG emissions (in tons CO2} - e) \times 97\ (\textit{in EUR})$$

Formula 2: Valuation of emitted greenhouse gases of Brewery Göss

With this approach, the value of Brewery Göss greenhouse gas emissions in 2015 is 186.091 Euro (expressed in 2011 Euros). In 2015 Euros, this value is 197.510 Euro[29]. For future assessments, it is recommended to conduct further research for a more specific SCC value for the context of Brewery Göss.

An overview on the valuation results, the applied methods and the aligned category of total economic value (TEV) is presented in Table 17. It was not an objective of this assessment to estimate a total economic value (TEV) of ecosystem services as an aggregate of all ecosystem services of a designated area owned by Brewery Göss. However, the value estimates for business dependence on freshwater and business impact on climate change have been aligned to the relevant category of TEV, which most represents its value to the company or society, respectively.

Table 17: Overview of valuation results, methods and TEV categories (own representation)

Impact / Dependency	Value estimates (2015 euro)	Valuation method	TEV category
Business dependence on freshwater	**584.341 Euro**	Replacement cost method – replacing freshwater supply from owned wells with communal freshwater	Direct use value
Business impact on climate change	**197.510 Euro**	Benefit transfer – using social costs of carbon as a surrogate to assess the impact of emissions on society	Altruist value & bequest value[30]

Figure 20 provides an overview of the measurement and valuation process as performed in Steps 5 to 7. Brewery Göss and the water it consumes or the greenhouse gas emissions it emits are the starting point. From there, the concerned ecosystem services and parts of naturel capital are

[28] The price of one carbon permit in the EU ETS per 1th April 2016 (in US dollars, converted with exchange rates as of 1th April 2016) is 5.92 dollar.

[29] For the inflation adjustment, an average inflation rate for Austria at 1,5% was assumed.

[30] It is assumed that current generations as well as future generations are impacted by climate change. Thus, the brewery's emissions are impacting both, altruist and bequest value.

detected as well as the company's impact or dependency defined. The last step is the economic valuation of this impact or dependency.

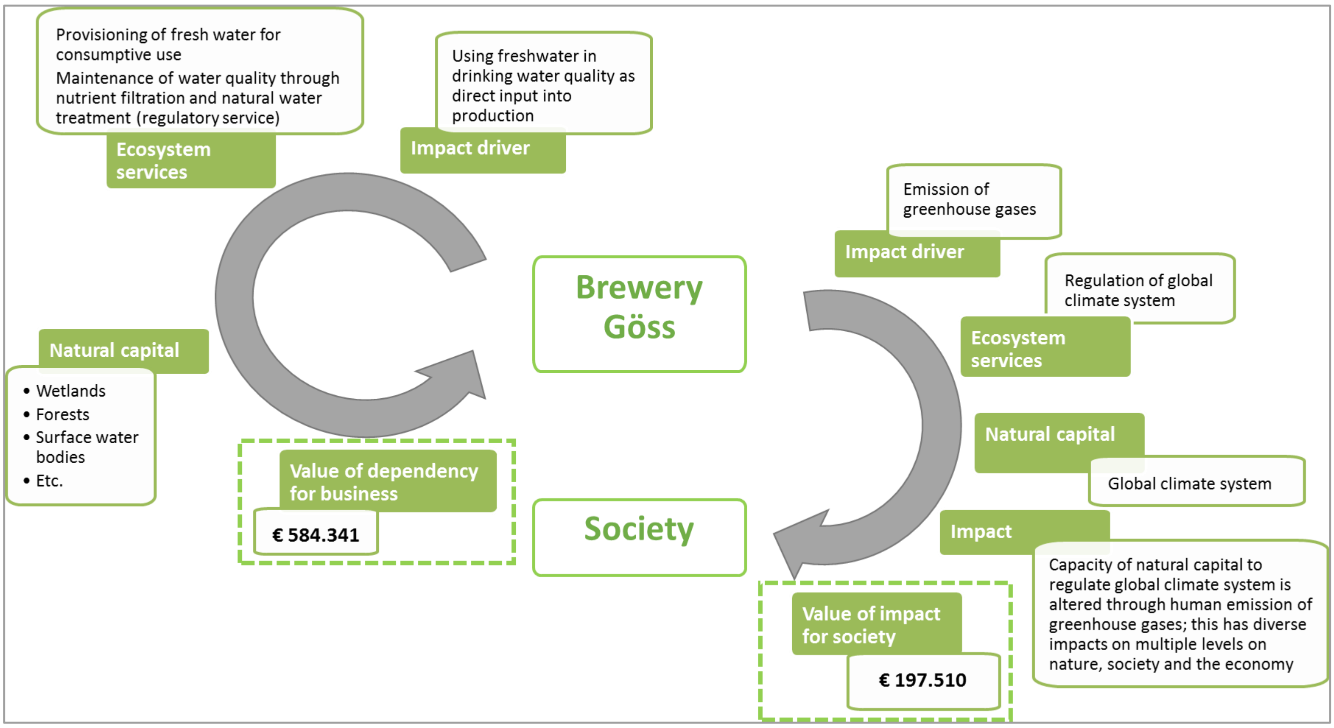

Figure 20: Overview of measurement and valuation process as performed in this case study (own representation)

6.3.8. Step 8: Interpret and test the results

APPLY - What next?	**8**	**Interpret and test the results**	**How can you interpret, validate and verify your assessment process and results?**	Test key assumptions
				Identify who is affected
				Collate results
				Validate and verify the assessment process and results
				Review the strengths and weaknesses of the assessment

The natural capital assessment as conducted in this case study is intended to be a pilot project for Brewery Göss in the application of the Natural Capital Protocol as a framework to assess impacts and dependencies on natural capital and ecosystem services. The outcome is a structured process which can be used as template for future assessments. As result of Step 7, the economic value of the business dependency upon natural freshwater supply and the business impact of emitting greenhouse gases has been estimated. These estimates rely upon assumptions, especially regarding the impact and dependency pathways on which the valuation has been based and the values used to estimate the economic value.

In the case of freshwater dependency, it is recommended to conduct future analysis of potential alternative freshwater supply sources as substitutes for the Brewery's wells and use the associated costs as component in estimating the economic value of the dependency.

For the estimation of the economic value of the Brewery's greenhouse gas emissions, a conservative lower-bound estimate of the Social Costs of Carbon (SCC) from a meta-analysis by (van den Bergh and Botzen, 2014) has been used as value indicator. As the value of SCC is a highly discussed topic in academia and the range of estimated values is very broad, ranging from 14 to 300 Euros per ton CO2-equivalent (Tol, 2008), the valuation results need to be seen as first estimate. The use of value transfer as valuation method is not seen as negatively impacting the valuation results in this context, as the calculation of marginal social costs of carbon for a specific company is not feasible and it is thought to be common practice to use SCC estimates from other sources. The estimate by (van den Bergh and Botzen, 2014) has been chosen as it is based upon a meta-analysis of different SCC estimation assessments and it is a conservative estimate.

This case study is a pilot project in assessing natural capital and ecosystem service impacts and dependencies for brewery Göss. A more comprehensive assessment is recommended in order to create robust and meaningful results on which informed management decisions can be based.

6.3.9. Step 9: Take action

Step 9 of the Protocol represents the concluding phase of a natural capital assessment. It is centred around applying the assessment results, integrating natural capital and ecosystem services into corporate processes and thinking and finally taking better informed decisions considering the company's natural capital impacts and dependencies. As these tasks are out of scope of this case study, recommendations have been provided on how it can be implemented.

APPLY - What next?	9	Take action	**How will you apply your results and integrate natural capital into existing processes?**	Apply and act upon the results
				Communicate internally and externally
				Make natural capital assessments part of how you make business

Before the assessment results can be embedded into corporate processes and decisions, it is recommended to conduct Step 8 of the Protocol in a company internal process in order to gain confidence in assessment results and detect areas in which the company sees need for further research. It might be necessary to perform or commission further research, including primary research especially on Steps 5 and 6 of the Protocol, to be able to receive in-depth results on the Brewery's relationship to its natural capital. Depending on the outcomes of this, valuation methods and assumptions from Step 7 will need to be adapted.

This case study provides a structure for future, more extensive natural capital assessments including ecosystem service valuation. The results can be an indicator for where to focus future corporate responsibility and environmental management activities and support in raising internal awareness for materiality of natural capital for business operations. Following business applications can potentially be supported by these assessments.

According to (CDP, 2016), Heineken, Brau Union's parent company, is considering introducing an internal carbon price in the coming two years. A natural capital assessment with a focus on greenhouse gas emissions could be a chance for Brewery Göss and Brau Union to anticipate this development and become a role model in the Heineken Group. This could further foster Brewery Göss reputation internally and externally as "green brewery" and frontrunner in environmental responsibility.

An in-depth assessment of the natural capital dependency of Brewery Göss, including the economic valuation of the ecosystem services it depends upon such as water or barley, could inform risk management and benefit-cost analysis of future investments, as well as supply chain management.

The disclosure of natural capital assessments and economic valuations of ecosystem services, for example in Brau Union's sustainability reporting, can increase the company's reputation as responsible company especially in the environmental field. Through the application of the Natural Capital Protocol in this assessments, the company has the potential to be one of the companies spearheading this emerging field of corporate sustainability.

7. Conclusion

The research questions, as proposed for this thesis, are centred around the question whether common approaches and methodologies for the economic valuation of ecosystem services are applicable and generated information i useful for businesses. These questions can be answered with 'yes, but…'.

This thesis concludes that generally natural capital and ecosystem services are relevant concepts for business to include information on the natural environment into business thinking. Through the structured assessment and economic valuation of ecosystem services, companies are able to base decisions on a broader understanding of the company's interdependency with its natural capital.

For the economic valuation of ecosystem services, the TEEB study (2010b) defines the commonly accepted methodologies. These techniques can be divided into three categories, direct market valuation, revealed preferences and stated preferences methods. While direct market valuation is based on market data such as prices and costs, revealed and stated preferences methods estimate a willingness-to-pay (WTP) or willingness-to-accept-compensation (WTAC) for the ecosystem service in focus and use this as a proxy for its economic value. Another option is the use of benefit or value transfer, a secondary valuation technique which consists of applying the results of other valuation assessments to the study context to derive an economic value for ecosystem services at the study site. It can be stated that companies will prefer to work with direct market valuation as primary research technique, as it uses market prices and costs as information in generating a value estimate. These kind of data is what companies are accustomed working with and which have a direct financial impact on the business. The other primary valuation techniques can be especially useful in assessments, in which the societal value of business impacts is in focus, as these techniques are usually performed using input from and engagement with external stakeholders which represent the impacted parts of society. Benefit transfer could be an appealing alternative form in valuation assessments for companies, as it is a rather low cost method requiring less expert knowledge than primary techniques, however, for the proper use of benefit transfer and the generation of robust economic value estimates, it needs to be secured that benefit transfer is applied correctly.

Valuation techniques are chosen depending on which forms of economic value, as represented by the total economic value (TEV) concept, is in scope of the assessment. As elaborated in this thesis, not all forms of value seem equally relevant for companies. The TEV concept has been adapted to represent the relevance for business, as shown in Figure 5 and further elaborated in chapter 4.2 of this thesis. It was found that use value categories of TEV are relevant for all companies, but non-use and option values might only be relevant in specific circumstances and for certain companies. Companies which have adopted a long-term thinking in their business processes and corporate identity might assess non-use values as more important. The same is true for option value, while here certain factors can have an amplifying effect on the relevance for businesses; these are for example state-affiliation or public holdings in a company, companies active in natural resource management and companies which have integrated environmental risks in their risk management.

Several case studies in other papers exemplify how natural capital and ecosystem service assessments are performed by or with companies. The case study in this thesis was initially intended to be primarily focused on an in-depth assessment of the economic value of ecosystem services for Brewery Göss. However, due to lack of data and insufficient size of the study site in focus, this objective had to be altered in order for the case study to provide added value. The adapted objective was to apply the Natural Capital Protocol (2016) as framework for a natural capital assessment from the perspective of Brewery Göss, which included the economic valuation of selected ecosystem services, however in a reduced extent as primarily intended. Based on an assessment of the relevance of natural capital impacts and dependencies, the impact on climate change from the company's emission of greenhouse gases and the business dependency on freshwater have been chosen as focus of the valuation. Replacement cost technique (freshwater) and benefit transfer (greenhouse gas emissions) have been used in the valuation exercise. The use of this techniques is in line with the general finding that direct market valuation techniques and benefit transfer are especially relevant as valuation techniques for companies. The Natural Capital Protocol (2016) does not directly adopt value categories of TEV; rather it distinguishes between value of impacts on the business, value of impacts on society and value of business dependencies. Depending on the scope of the assessment and the valuation approach selected, all TEV categories can potentially be covered by natural capital assessments. In the case study, the business value of the dependency on freshwater can be seen as consumptive direct use value in TEV. The business impact on climate change cannot directly be linked to a single TEV value; rather climate change can have an impact on all value categories, including option value and non-use values.

The application of the Natural Capital Protocol in the case study is considered especially valuable as the Protocol is a rather new framework and not many assessments have been disclosed in detail. While the immediate results of the case study are limited to the economic values of one business impact on society and one business dependency, it is expected that the detailed documentation of the process of applying the Protocol in this case study will support future assessments by Brewery Göss or other companies. In future assessments, a focus could be on the in-depth biophysical measurement and economic valuation of ecosystem services. While these are included as steps in the natural capital assessment of this case study, it might be worthwhile to invest more resources for these objectives in order to gain more robust biophysical and monetary results.

The major challenges of natural capital assessments including the economic valuation of ecosystem services as found in this thesis are presented below. These are also in line with challenges as emphasised by other authors (e.g. Guerry et al., 2015; Hein et al., 2015; Natural Capital Coalition, 2016a).

- **Availability of data**

Generating primary data is often resource and time intensive and corresponding cost constraints might limit the application of primary research methods. Therefore, value or benefit transfer might be a welcome alternative method in conducting a valuation project, however limitations as discussed in chapter 3.2.4 need to be considered carefully.

- **Technical expertise**

Assessments of nonfinancial impacts and dependencies are an emerging field in corporate responsibility research and practice. The basic methodologies in assessing the economic value of ecosystem services is provided by (TEEB, 2010b). The methods as provided by TEEB are applicable to all context, including assessments done by business. As the use of benefit transfer, due to it being a rather low cost methodology, might be an attractive alternative secondary research method for companies, it must be secured that it is applied correctly as otherwise results might not be satisfying scientific standards.

While some organizations provide specific guidance (DEFRA, 2015; Natural Capital Coalition, 2016a; WBCSD, 2011), the novelty of the subject implies that further research and corporate case studies need to be conducted in order to decrease the grade of uncertainty of assessment results. Only if companies can trust the results to be accurate and the assessment process behind has been conducted and documented transparently, will better informed decisions based on these results be incorporated into business.

- **Availability of resources**

Many companies do not have internal expertise on natural capital and ecosystem services; therefore, external assistance might be required to perform a natural capital assessment. Especially the economic valuation of ecosystem services can require time and financial resources and a certain level of expertise. This investment can be a challenge for many companies, especially small and medium enterprises. Limiting the scope of the assessment on what is most relevant for the company and choosing appropriate valuation techniques can help in limiting necessary resource inputs.

- **Integrating results into business**

Finally, more awareness building, internally and externally to applying companies and the specific research communities, needs to be performed. Especially corporate decision-makers will need to be introduced to the world of natural capital and ecosystem services, in order for them to integrate these concepts into their decisions. Case studies exemplifying the successful adopting of a natural capital and ecosystem service perspective in business context can be especially helpful in supporting uptake by other companies. Organizations such as the Natural Capital Coalition provides case studies on its website (NCC, 2016).

These challenges, combined with a currently rather low level of awareness on natural capital and ecosystem services by businesses, help in explaining why interest of companies in performing assessments of their natural capital and ecosystem services has been limited up to now. The emergence of the Natural Capital Protocol and other initiatives in the field create hope that companies' interest and awareness will be growing and more companies will assess their diverse relationships with nature and integrate the generated information into corporate decision making. To support this objective, future research in this area should concentrate on the value added businesses can derive from such assessments, on the refinement of tools available to businesses, on the establishment and further promotion of databases for valuation results and on the conduction and transparent documentation of case studies from which learning effects can be drawn. The Natural Capital Coalition and other initiatives can be a driver from the corporate side, but initiatives from academia will be needed to provide companies with scientific instruments and guidance.

Overall, it can be concluded that while ecosystem services, the biotic flows of natural capital, are among the most important aspects of natural environment for society and business, the research area on the connection of natural capital and ecosystem services with business and vice versa is relatively new for academia and companies alike. Therefore, each project and case study in this field will help advancing it and increase confidence in assessment processes and their results. As the science behind assessments and corporate integration of natural capital and ecosystem services matures, robust and meaningful results will be deducted from such analyses. These results will be able to inform corporate management decisions on broad interconnection between business and the parts of the natural environment they impact and depend upon, their natural capital.

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