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Assessment and valuation of ecosystem services from peri-urban forests: the case of Oslomarka, Norway

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Abstract

Peri-urban forests provide many ecosystem services that contribute to human well-being including provision of food and fresh water, recreational opportunities, climate regulation and habitat provision. This study examines ecosystem services delivered by a peri-urban forest in a Nordic context: the case of *Oslomarka,* the peri-urban forest of Oslo, Norway's capital city. First, we identify and characterize ecosystem services delivered by Oslomarka. Second, we measure flows and assess trends in these ecosystem services over the past 50 years. Third, we explore the importance of Oslomarka and its ecosystem services as perceived by its recreational users through a socio-cultural valuation survey (n=95). Based on our results, we find that i) Oslomarka provides a wide range of critically important ecosystem services to the urban population of Oslo, with freshwater supply and outdoor recreation being of particular prominence, ii) provisioning and supporting services have declined over the past fifty years while regulating and cultural services have increased during the studied time period, iii) ecosystem services provided by Oslomarka are highly valued by its recreational users, with the cultural service 'outdoor recreation' perceived as the most important ecosystem service, iv) overall, supporting services are given the highest average value, followed by regulating services and cultural services.

Contents:

1. Introduction

For the first time in history, more than half of the global human population live in cities (UNDESA, 2018). The expected growth rates of world population and urbanization will add another 2,5 billion people in urban areas worldwide by 2050 (ibid.). This presents major challenges to achieving sustainable, resilient and safe cities for all (UN, 2020). As people increasingly live their lives surrounded by technological landscapes, humans become less likely to interact with nature in their everyday lives (Soga & Gaston, 2016). Moreover, human dependence on nature to provide life-supporting conditions for human life become less visible as food and other vital resources are increasingly associated with supermarkets and stores rather than their 'hidden' origin from natural ecosystems (Gómez-Baggethun, 2017). Studies find that lack of interaction with nature make people less likely to appreciate and value the many benefits to human well-being nature provides, in turn leading to lower motivations for visiting and protecting natural areas (Bixler et al., 2002; Wells & Lekies, 2006; Thompson et al., 2008). This phenomenon is commonly referred to as the 'extinction of experience', hypothesized to worsen over time as each generation live in deeper separation from nature (Miller, 2005).

Due to the negative health consequences of human-nature separation (Shanahan et al., 2015; Soga & Gaston, 2016) and the ongoing environmental degradation typically driven by the undervaluation of nature (MEA, 2005; TEEB, 2010; IPBES, 2019), reconnecting humans with nature is of vital importance. In this context, a helpful tool in recognizing and giving visibility to societal dependence on functioning ecosystems can be that of applying the concept of ecosystem services (de Groot et al., 2002; Gomez-Baggethun et al., 2010), now also referred to as Nature's contributions to people (Pascual et al., 2017; Diaz et al., 2018). Ecosystem services is defined as "the benefits people obtain from ecosystems" (MEA, 2005, p. v) and is used to describe the "flows of value to human societies as a result of the state and quantity of natural capital" (TEEB, 2010, p. 7).

Ecosystem services are the outcomes of biophysical structures and processes taking place within an ecosystem that enable different ecosystem functions that might provide useful services to humans (Haines-Young & Potchin, 2010). These in turn give benefits that contribute to human well-being. As defined by the Millennium Ecosystem Assessment (MEA, 2005), ecosystem services can be divided into four main categories: (1) provisioning (e.g. wild foods, timber, fresh water), (2) regulating (e.g. climate regulation, air quality regulation,

water filtration), (3) cultural (e.g. recreation, education, spiritual and aesthetic values) and (4) supporting (e.g. soil formation, nutrient cycling, photosynthesis).

With their proximity to cities, urban and peri-urban forests are increasingly recognized for their ability to (re)connect urban people with nature and play an essential role in meeting the global goals on urban sustainable development (FAO, 2018). Studies of ecosystem services provided by these ecosystems contribute to recognition and visibility of the importance of these forests for the provision of climate regulation (Nowak & Crane, 2002; Nowak et al., 2013; Escobedo et al., 2010; Liu & Li, 2012; Chen, 2015; Baró et al., 2014), microclimate regulation (Bolund & Hunhammar, 1999; Krieger, 2001), air purification (Baró et al, 2014; Yang et al., 2005; McPherson et al., 1997), assistance in food, energy and water provision (Shackleton et al., 2015), recreational spaces, stress relief and social cohesion (Jim & Chen, 2009; Brack 2002). Hence, urban and peri-urban forests are increasingly being managed to provide nature-based solutions to a range of urban challenges such as mitigation of impacts of climate change, enhancement of human physical and mental health, reduction of air pollution, maintenance of water quality and preservation of biodiversity (FAO, 2018).

Using *Oslomarka*, the peri-urban forest of Oslo (Norway's capital city), as a case study, the aim of this research is to synthesize knowledge on the values of forest ecosystem services in a Nordic context. In doing so, we assess what ecosystem services Oslo's peri-urban forest provide, and what values users attribute to these services.

The research questions for this study are:

1. *What ecosystem services do Oslomarka provide, and what are their state and trends?*
2. *What socio-cultural values do people attribute to the ecosystem services of Oslomarka?*

The thesis is organized as follows: chapter 2 presents an overview of forest ecosystem services and values in Norway. Chapter 3 provides a site description and background information about historical forest use at the study area. Chapter 4 presents the research methods used in this study and the results are presented in chapter 5. Chapter 6 discusses the main findings and finally chapter 7 provides concluding remarks.

2. Ecosystem services and values of Norwegian forests

In Norway, forests cover an area of about 120 000 km^2 which is the equivalent of 37 % of the total land area (Norwegian Agriculture Agency, 2018; see figure 1). About 68 % of the total forest area is productive forest[1] (Statistics Norway, 2020a). There are mainly three forest types in Norway, boreal deciduous (40 % of forest area), pine (30 %), and spruce (27 %) forest (NIBIO, 2020a). More than 90 % of the standing forest volume (defined here as cubic mass of trees) consists of three tree species: spruce, pine and birch (NIBIO, 2020b). During the past hundred years, there has been an increasing growth of Norwegian forests while the volume of felling has remained fairly constant (Lindhjem & Magnussen, 2012). Forest growth has been particularly high since the 1980s, much due to a long-term investment in increasing the timber volume in the forestry sector, a warmer climate, and the encroachment of forest on land used for grazing and agriculture (ibid.).

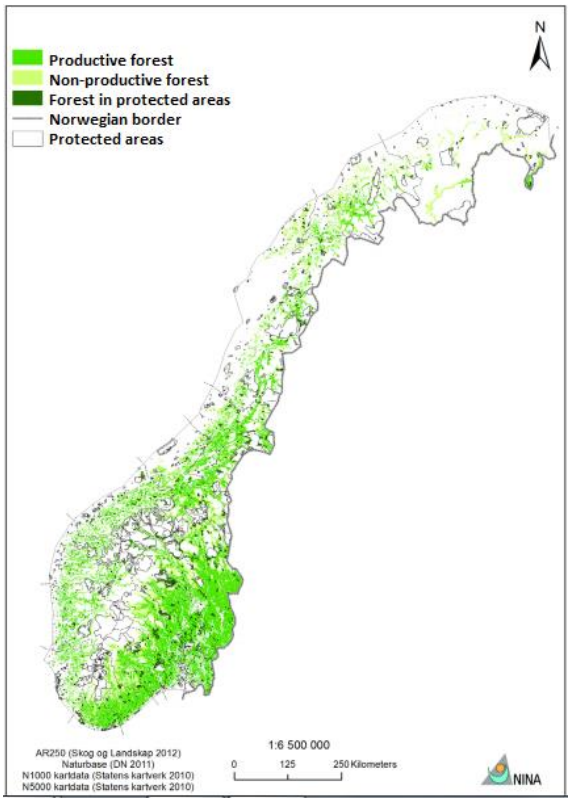

Figure 1: Forest distribution in Norway. Source: Lindhjem & Magnussen (2012), modified.

Forests are an important renewable resource contributing to value creation locally, regionally and nationally in Norway (Norwegian Agriculture Agency, 2018). However, from 1979 to 2009, the forestry sector experienced a sharp decline with the number of employees halving and its share of the Norwegian GDP declining from 2,5 % to 0,5 % (Lindhjem & Magnussen, 2012). This decline was largely driven by decreasing timber prices, technological development reducing the need for labor, and the larger contribution of the oil sector to the Norwegian GDP (ibid.). In the last decade, this development has turned with increasing timber harvest and rising timber prices. In 2018, timber harvest reached a record high of 10,8 million m^3 with a total timber value of about 4,4 billion NOK (around 440 million EUR) (Statistics Norway, 2020a). As the timber and wooden products travel through different value

[1] Productive forest is defined as forest that can produce a minimum of 1 m^3 wood with bark per hectare per year under favorable growth conditions (NIBIO, 2020a).

chains, it makes up a total production value of about 10-12 times the timber value (Ministry of Agriculture and Food, 2016). These value chains consist of forestry and its connected goods and services, including lumber- and wood products industry, wood processing industry and energy production (ibid.). The largest share of value creation comes from the part of the timber that can be used as saw logs, which is mostly used in the building sector.

Besides the contribution of forestry to the Norwegian economy, forests contribute to human and non-human well-being in many other ways. Forests are an important habitat for species. Forests host an estimated 60 % of Norway's 44 000 registered species[2] and are the homes of 48 % (1122) of endangered species (Henriksen & Silmo, 2015; Lindhjem & Magnussen, 2012; NOU 2013:10). Most (84 %) of these species are threatened due to the loss of natural forest[3] where these species have their habitat mainly driven by intensive forestry such as clear-felling practices put in place after the World War II (NOU 2013:10; Henriksen & Silmo, 2015). The share of natural forest that has been lost due to forestry since the World War II is at about 75 % (ibid.).

Another important contribution of forests to people is their role in carbon sequestration and storage. Forests in Norway offset about half of all Norwegian domestic greenhouse gas emissions and thus make an important contribution to climate change mitigation (Norwegian Environment Agency, 2018; Lindhjem & Magnussen, 2012). In 2017, this amounted to 29 million tons CO_2 equivalents (Norwegian Environment Agency, 2018). Carbon storage in Norwegian forest ecosystems is estimated at about 1500-2000 million tons where 75 % of this is stored in the soil (Grønlund et al., 2010; Haugland et al., 2011).

Forests are also key arenas for outdoor recreation in Norway facilitated by the undisputable principle of common access rights to all uncultivated land known as the 'right to roam' (*Allemannsretten* in Norwegian) (Outdoor Recreation Act, 1957, §2). 'Friluftsliv', the Norwegian term for nature-based recreation, is defined as "being outdoors and undertaking physical activities in the open air in one's leisure hours with the aim of experiencing a change in one's surroundings and encountering nature" (Ministry of Climate and Environment, 2015b, p. 10). It is strongly embedded in the Norwegian culture and identity, and 90 % of the country's population state that they do some form of nature-based recreation on a weekly

[2] According to the Norwegian Environment Agency, the actual number of species in Norway is assumed to be about 60 000 (Norwegian Environment Agency, 2019a).
[3] In Nowegian *naturskog/gammelskog*: forest with high biological age that is largely unaffected by human activities (Henriksen & Silmo, 2015).

basis (Statistics Norway, 2019; Norwegian Environment Agency, 2019b). 'Friluftsliv' in Norway has its roots in traditional rural employment activities and nature-related leisure activities over the last 150 years (Hofmann et al., 2018). It includes a range of different activities like hikes, sports activities (e.g. running, cycling, skiing), hunting, fishing, and wild berry- and mushroom picking, activities which are found to give important contributions to mental and physical health (Norwegian Environment Agency, 2019b; Lindhjem & Magnussen, 2012).

3. Study area: Oslomarka, Norway

The case study of this research is the forest known as *Oslomarka*, a relatively new term that evolved in the 1930s to refer to the hilly forested areas surrounding Oslo, Norway's capital city (Syse, 2016). The colloquial term for Oslomarka is simply *Marka.*

3.1. Site description

Oslomarka covers an area of approximately 1700 km^2 within the three counties Oslo (310 km^2), Viken (1175 km^2) and Innlandet (210 km^2) (Norwegian Environment Agency, 2020) stretching from 5 to 40 km from Oslo city Centre (Achin, 2018). Oslomarka is divided into eleven geographical areas, surrounding Oslo to the north, east and west, while to the south the city meets the sea (figure 2).

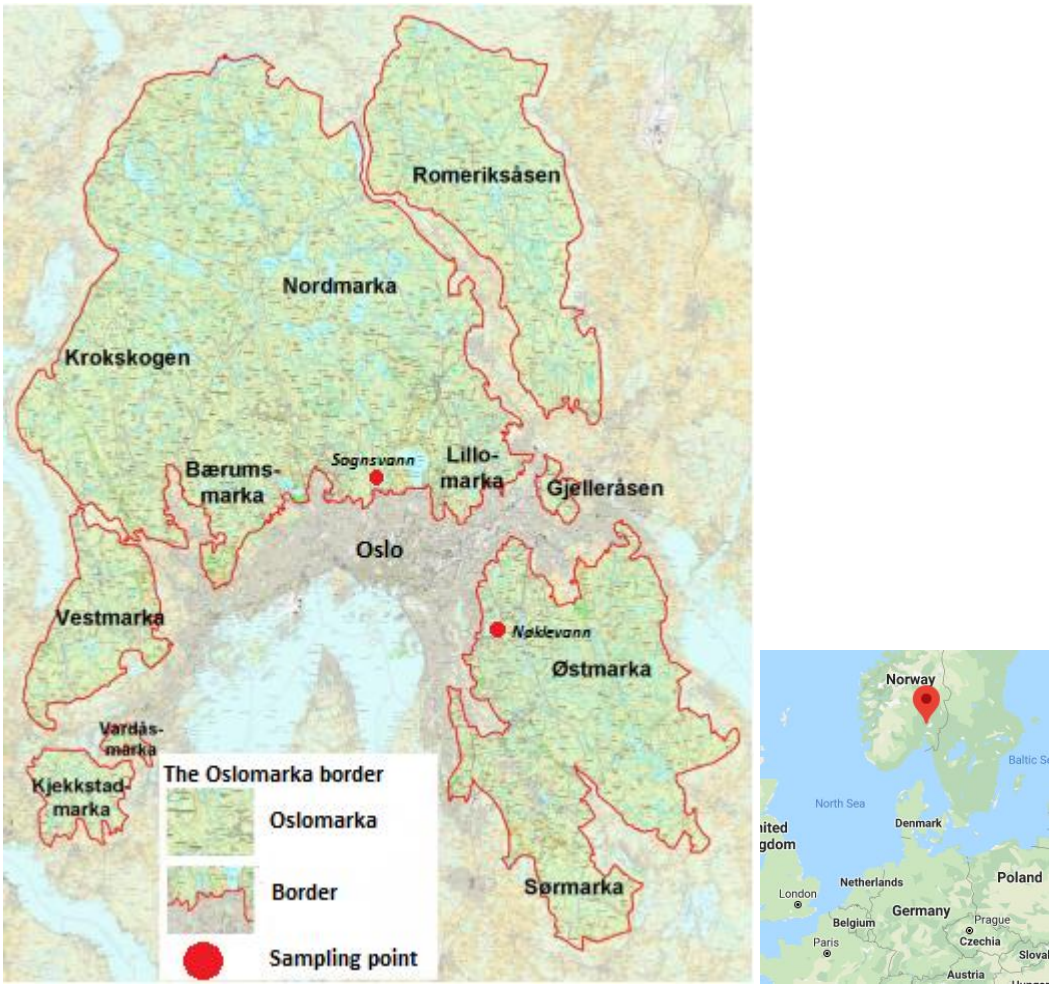

Figure 2: Geographical location and borders of Oslomarka
Source: Anchin (2018, modified)

Oslo is the largest city in Norway. It has a population of 693 494 inhabitants which is expected to increase to 759 158 by 2030 (Statistics Norway, 2020b). Oslomarka makes a large contribution to the access of green space for people living in Oslo. Green space per inhabitant in Oslo is 39,05 m^2, of which 26,81 m^2 is forest and woodland (Statista, 2020). By comparison, the World Health Organization recommends a minimum level of 9 m^2 per inhabitant with an ideal level of 50 m^2 of urban green space per inhabitant (Russo & Cirella, 2018). Oslomarka is the largest peri-urban forest in Norway (Norwegian Environment Agency, 2020). A mere 1600 people live within the borders of Oslomarka (Gundersen et al., 2015). However, it is surrounded by urban areas comprising more than 1,2 million people (about 25 % of the Norwegian population), for which Oslomarka is the closest outdoor recreational area (ibid.; Ministry of Climate and Environment, 2015a). No other capital city in the world has a comparable peri-urban forest in terms of size, quality and use (Oslo municipality, 2005). Its large number of users is facilitated by a total of 166 stops for public

transport suitable as access points to Oslomarka making the area highly accessible (OOF, 2014).

Oslomarka is divided in about 2000 properties. The largest owner is Løvenskiold-Vækerø (430 km^2), followed by Oslo municipality (167 km^2)[4], and Losby Bruk (43 km^2) (Borges et al., 2015; Oslo Municipality, s.a.(a), Bugge & Reusch, 2010). About 70 % of Oslomarka is private property. Apart from the private properties owned by Løvenskiold-Vækerø and Losby Bruk, private properties in Oslomarka are on average 2000-3000 m^2 in size (Heyerdahl, 2011). The land that is not privately owned (about 30 %) is approximately equally divided between municipalities and commons (Borges et al., 2015). Around 20 % of the Oslomarka forest is protected for biodiversity purposes (Gundersen et al., 2015).

3.2. Historical background

Historically, Oslomarka has been owned by many different actors. The main ownership types have been and are still municipal, private and common property (Syse, 2016; Borges et al., 2015). Generally, the western parts of the forest have been (and are still) owned by many small landowners whereas the northern part (Nordmarka), privatized in the 1600s, is owned as a large family estate by Løvenskiold-Vækerø. The southern and eastern parts have a more complicated ownership history with owners ranging from the church, municipality, central state, and small and large landowners (Syse, 2016). Oslo's City Council has since 1889 purchased strategic areas of Oslomarka to ensure clean drinking water and recreational areas for its inhabitants, and in more recent years, also to preserve biodiversity (ibid.; Oslo Municipality, 2005).

1500 years ago, most of the forest called Oslomarka today was commons where local inhabitants had the right to collect wood, hunt, fish, harvest wild plants and berries and use the land as pasture for livestock (Gangdal, 2011; Jerman, 2004). This right was regulated through local agreements with low levels of conflict, and one was only allowed to gather and use what was needed to cover one's own use (Gangdal, 2011). In the late 800s, as most parts of today's Norway was assembled in one kingdom, property rights were transferred to the king (Gangdal, 2011; Holmen, 1973), although local people retained their use rights. This situation persisted for centuries, and even as the king started selling parts of the land to private

[4] Oslo municipality owns parts of Oslomarka in Oslo and six other municipalities.

buyers in the 1600s to cover state debt, local people kept their rights to the land. However, these rights were now limited to certain farms and people that had gained a prescriptive right to the area (Gangdal, 2011).

In the 1600s, with the new private owners and the growing European and Norwegian demand for timber, large scale commercialization of Oslomarka took place for the first time (Gangdal, 2011). The introduction of commercial forestry and sawmills was then followed by the production of charcoal to fuel the iron industry (Syse, 2016; Jerman, 2004). This turned forests into important economic resources, bringing about large expansions of the Norwegian timber trade (Syse, 2016).

As the timber industry grew, more labor was needed and people living in Oslomarka shifted their condition from subsistence farmers to workers with the status as crofters (*husmenn*) in a condition of serfdom to the estate owners (Gangdal, 2011; Syse, 2016; Jerman, 2004). Workers in the timber industry - loggers felling the trees, drovers transporting the timber by horse to a river and floaters floating the logs to a port – were supervised by these crofters. Additionally, engineers diverted rivers and streams into a network of waterways to transport the timber (Syse, 2016).

In areas of Oslomarka owned by large estates, such as in Nordmarka, a network of tenant farmers living in the forest worked for the landowners to provide a steady supply of timber workers (Syse, 2016; Holmen, 1973). Horses were needed to drive the timber. This required farms to produce fodder and this partly explains the diverted farms and smallholdings in Oslomarka. At this time, the peasants who lived and worked in Oslomarka with their livestock of horses, sheep and cattle were the main occupants of the forest.

It was not until the late 1700s that urban people discovered Oslomarka as an area of recreational interest. In this period, there is evidence of a certain longing and admiration for a rural life. This is evident through the contemporary group of Norwegian intellectuals called ‘det Norske Selskab’ (the Norwegian Society), who believed that the true Norwegian identity laid in the free Norwegian farmer (Syse, 2016). A few decades later, Norwegian writers and artists inspired by the Romantic Movement headed towards what was perceived as the wild, wonderful and exotic forests surrounding Oslo and wrote about their explorations (ibid.; Jerman, 2004). Among these were the well-known writers Peter Christian Asbjørnsen (1812-1885) and Jørgen Moe (1813-1882), who gathered Norwegian stories and fairytales about trolls and other supernatural beings in the Norwegian lore. These were written and illustrated

in folklore collections that are to this day commonly found in bookshelves in Norwegian homes (Gangdal, 2011).

In the 1870s, new visitors entered Oslomarka following the new trend of going for walks in the countryside for pleasure and recreation (Gundersen et al., 2011). These visitors were mainly from the middle- and upper class, males, and were called tourists, connected to the Norwegian expression of going for a *tur* (hike) (Syse, 2016). The Norwegian Trekking Association (DNT) was formed in 1868 and had by 1870 marked the first trekking route in Oslomarka (Oslo Municipality, 2005). Over the next decades, the network of marked tracks and trails expanded, and more people incorporated a Sunday walk in Oslomarka into their lifestyles (Gangdal, 2011). Skiing, which up until then had mainly been a means of transport, also became a key recreational activity. The first skiing competition was arranged in 1886 in Nordmarka and by 1900, 22 skiing clubs had been established in Oslomarka (Syse, 2016).

Hence, since the late 19th century, the life for the people living and working in Oslomarka was increasingly influenced by the demands of the urban population (Syse, 2016). During weekends, recreational forest visitors from the city would seek accommodation and meals from people living in the forest. Moreover, as the population of Oslo grew (from about 100 000 in 1875 to 250 000 in 1900 (Myhre, 2020)), the city needed more fresh water. This set-in motion large engineering projects that changed the course of the waterways through the forest to secure drinking water (Jerman, 2004). As a compensation for the loss of waterways to transport timber, roads were built through the forest. After the World War II, with the use of new technology like the chainsaw and motor vehicles, this road network expanded further to accommodate the need to transport timber from the forest to the sawmills (Syse, 2016; Jerman, 2004). The increasing road network made the forest more accessible for people while at the same time decreased the number of areas viewed as ‘inaccessible wilderness’. It also accommodated bikers as a new group of users of Oslomarka.

From 1900 onwards, the use of Oslomarka for recreation gained enormous popularity across social classes and gender. More routes were developed, and cabins were built to accommodate day and overnight visitors (Syse, 2016). At the same time, population growth in Oslo and the surrounding region increased the need for better transport (roads and railways) and raised demand for better and larger water and power supplies (Gangdal, 2011). Moreover, technological development after the World War II intensified forestry practices from selection felling to clear-felling transforming large tracts of old multi-aged forest into uniform clear-cuts and even-aged stands (Gundersen et al., 2011; Gundersen et al., 2015). These

developments presented conflicts of interest with recreational users who wanted to preserve Oslomarka for leisure activities. By the 1970s, this had grown to a fierce public debate resulting in several proposed solutions by the government, including multiple use plans and a special statute to govern and manage Oslomarka (Gangdal, 2011). In 1976, the forestry act was modified, imposing restrictions on forestry and road construction in Oslomarka, and since then the forest has in effect been legally managed as an urban forest for recreational purposes (Gundersen et al., 2015). Several attempts were made the following decades to pass a specific law for the legal protection of Oslomarka and finally, in 2009 the 'Marka Act' was passed (Gangdal, 2011). The purpose of the Act is to "promote and facilitate outdoor activities, nature experiences and sports. The Act shall ensure Markas borders and preserve the rich and varied landscape and natural and cultural environment with monuments. At the same time, sustainable use for other purposes shall be considered" (Markaloven, 2009, §1, translated from Norwegian). The Act defines the borders of Oslomarka (figure 2).

4. Methods

4.1. Classification and categorization of ecosystem services

Initially, a preparatory categorization of forest ecosystem services at the study area was developed. In line with established international classifications, ecosystem services were divided into four main categories (provisioning, regulating, cultural and supporting services) and sub-services specific to forest ecosystems (MEA, 2005; TEEB, 2010). Then, a review of the literature on forest ecosystem services studies in general and in Norway specifically was conducted (see Lindhjem & Magnussen, 2012; NOU 2013:10). To identify and assess the ecosystem services provided specifically by Oslomarka, we conducted a literature review of scientific papers, policy and business documents, books, webpages of Norwegian public institutions and organizations associated with Oslomarka, master theses and media documents. As few of these documents use the ecosystem services term explicitly, the identification involved the translation of information into the language and framework of ecosystem services.

For every ecosystem service category (e.g. provisioning services) and subcategory (e.g. fresh water supply), we defined indicators for measurement selecting those having the highest level of precision within the available data. In this study, we focus on measuring ecosystem services flow (actual use of the service) as opposed to capacity (potential to deliver) and

demand (human expectation) (Villamagma et al., 2013; Baró et al., 2016). When data measuring flow directly was missing, proxy measures were applied (see e.g. Gómez-Baggethun et al., 2019). For example, in the case of the supporting service 'habitat provision', 'share of natural forest' was used to indicate flow and trend. Similarly, when specific data for Oslomarka was not available, data covering parts of the area was used as proxies. We applied qualitative descriptions to the cultural services 'sense of place and community' and 'folklore' as quantitative information was unavailable and could not meaningfully measure the flow of these ecosystem services (Chan et al., 2012; Kaltenborg et al., 2017).

Following Gomez-Baggethun et al. (2019), we marked data uncertainty as i) low, ii) medium or iii) high for every identified ecosystem service based on the coarseness of the indicator, the quality of the information, and whether the information was concordant across the reviewed literature. Moreover, trends in ecosystem services were defined to assess overall change in the ecosystem service flow over time. The timeframe chosen was the period 1970-2020. Two main reasons motivated this choice. First, it covers the period of the so-called 'great acceleration' (Steffen et al., 2015), a period of rapid and intensive global change that has brought about large impacts on ecosystem services (MEA, 2005; IPBES, 2019). Second, this timeframe is of sufficient length to meaningfully aseess changes in ecosystem services and provide useful information to environmental management and planning (Gómez-Baggethun et al., 2019). In cases where data for these exact years was not available, available data with the best coverage of this time period was used and specified. In line with the general scheme of the Millennium Ecosystem Assessment (MEA, 2005) and the Intergovernmental Panel on Biodiversity and Ecosystem Services (IPBES, 2019), we labelled overall trends as increasing, stable, or decreasing. The classification of ecosystem services elaborated from the literature review was then used as input for a survey for valuing these services.

4.2. Ecosystem service valuation survey

In order to assess the importance users attribute to Oslomarka and its benefits to people, we conducted a socio-cultural valuation of ecosystem services (Iniesta-Arandia et al., 2014). Socio-cultural valuation "explores human attitudes and perceptions regarding ecosystem services for human well-being through (non-monetary) ranking methods" (Maestre-Andrés et al., 2016, p. 718).

The valuation was done through a face-to-face semi-structured survey conducted in March 2020, among 95 recreational users of Oslomarka. The survey was organized in three sections. Section one aimed to identify ecosystem services provided by Oslomarka as perceived by users using a free listing technique where the respondents were asked to list reasons why Oslomarka is important. We expected that the perception of Oslomarka's importance might vary across scales. Hence, following Camps-Calvet et al. (2016), we asked the respondents to identify ecosystem services provided by Oslomarka at individual, (*Why is Oslomarka important for you?*) and city scale (*Why is Oslomarka important for Oslo?*). Section two consisted of a Likert scale (Bryman, 2016) designed to assess the respondent's level of agreement with statements about the importance of the ecosystem services, using the pre-established classification elaborated from the literature review (Maestre-Andrés et al., 2016). The level of agreement followed a 1-5 scale where 1 denote "I completely disagree" and 5 denote "I completely agree". The regulating services 'air purification' and 'water filtration' were not included in our classification from the literature review due to that not enough data was found to assess flow and trend. However, these two services were added to the survey to give a better assessment of the value of regulating services and due to that these are found to be some of the most important ecosystem services of urban and peri-urban forests (FAO, 2018). The third and final section of the survey was designed to collect data on the socio-economic profile of the respondents with questions regarding sex, age, place of residence, education, professional status, and income. In order to make the term more understandable, the term 'ecosystem services' was always referred to in the survey as "benefits provided by Oslomarka to human well-being" (Maestre-Andrés et al., 2016) (see Appendix A for interview guide).

The survey was conducted in Norwegian. Respondents were thus restricted to being Norwegian speakers. In addition, we restricted our sample to recreational users (as this is the largest group of users) of Oslomarka over 18 years old. Two sampling points were used: Sognsvann (n=47) in Nordmarka and Nøklevann (n=48) in Østmarka (see figure 2 for their geographical location). These two sites were chosen because Nordmarka and Østmarka are the most popular areas of recreation in Oslomarka (Gundersen et al., 2011; Oslo municipality, 2005), are easily accessible by public transport, and thus ensured a higher probability of accessing a larger number of respondents. The sampling involved approaching people using the area at the two sampling sites and asking them if they would be willing to participate in the survey. People were approached irrespective of age and gender (apart from the 18-year-

old limit). As people jogging or biking were more difficult to approach, people who were sitting or walking are overrepresented in the survey. The answers were recorded by taking notes. Audio recording was not used due to that the survey was short (approximately ten minutes), two thirds of the survey (section two and three) consisted of filling out pre-established alternative answers, and due to wanting to make the threshold of agreeing to participate in the survey lower. Recording the answers by taking notes was tested in advance and was found to work well.

Once the survey was finalized, data from section one was sorted and coded according to Charmaz (2006) to categorize the information obtained through the free listing into different ecosystem services. The services were then coded into the four ecosystem service categories, provisioning, regulating, cultural and supporting services (MEA, 2005) and subservices following categories and their descriptions from Maestre-Andrés et al. (2016) as these were found to fit the data well. A statistical analysis was made of the results from the Likert scale in section two of the survey to obtain the average value users assigned to each ecosystem service. The data from the final section was used as a basis for descriptive statistics of the socioeconomic characteristics of the respondents.

5. Results

5.1. Ecosystem services of Oslomarka

A total of nine ecosystem services with additional five sub-services provided by Oslomarka were identified from the literature review. Table 1 provides a summary of the ecosystem services along with the indicators defined for their assessment, their current flow, their overall trend from 1970-2020, and the level of uncertainty in the information used for the assessment. In total, we identified and characterized four provisioning services, eight cultural services, one regulating service and one supporting service.

Table 1: Ecosystem services classification, description, indicators, current flow, overall trend, and level of uncertainty in data and information.

Ecosystem service category	***Sub-category***	***Description***	***Indicator***	***Current flow (year)***	***Overall trend 1970-2020***	***Source of current flow***	***Level of uncertainty***
Provisioning services		*Physical goods obtained from nature*					
Food production 		Land used for pasture and production of food and fodder	Actively driven agricultural land (ha)	**759 ha (2019)**		Statistics Norway (2020c)	+++
	Animal farming	Animal raising in farms and pastures for production of meat and dairy products	Number of farmed animals	**432 (2019)**		Statistics Norway (2020d)	+++
Freshwater supply 		Precipitation collected by rivers and lakes for water supply	Extracted water (m^3/y)	**92 m^3/y (2018)**		Oslo municipality (2020)	+
Timber production 		Timber production for direct use or processing.	Timber harvest (m^3/y)	**234 373 m^3/y (2019)**		NOA (2020)	++
Cultural services		*Immaterial benefits obtained from interaction with nature*					
Outdoor recreation 		Spending time in nature in one's leisure hours for physical and mental recreation	Share of Oslo population visiting the area per year Total number of visits per year	**86 % (2015)** **23,4 million visits (2015)**		Synnovate (2011); Barton et al. (2015)	+

	Fishing	Fish from inland waters for personal use	Number of fish permits sold	**8072 (2019)**	⇧	OFA (2019)	++
	Hunting	Felling of wild animals	Number of felled elk and roe dear	**153 (2018)**	⇧	Naturdata (2019)	+++
	Wild berries and mushrooms	Wild berries and mushrooms collected for personal use	Share of users of Oslomarka picking wild berries and mushrooms per year	**45 % (2011)**	⇔	Synnovate (2011)	+
Cultural heritage 		Buildings and other monuments with historical value	Number of registered cultural heritage sites	**986 (2020)**	⇧	Norwegian Environment Agency (2020c)	++
	Folklore	Traditional beliefs, customs and stories of a community	Folklore in literature ‘Fairy-tale forests’	**N/A**	?		N/A
Sense of place and community 		Identifying oneself in relation to a place and community contributes to strengthening social cohesion	Markers of cultural identity Social cohesion	**N/A**	?		N/A
Science and education 		Education, knowledge creation, and scientific development	Number of publications on Oslomarka per decade	**297 (2010-2019)**	⇩	Norwegian National Library database (2020)	++
Regulating services		*Benefits humans derive from ecological regulation processes*					

Climate regulation	Carbon sequestered and stored in soil and vegetation	CO_2 sequestered (t/y) CO_2 stored (t)	**175 000 t/y** **17,5 million t (2016)**	↑	The County Governor of Oslo and Akershus (2016)	+++
Supporting services	*Provision of habitat for species along their life cycle*					
Habitat provision 	Provision of habitat for plants and species	Share of natural forest	**14,3 % (2016)**	↓	Mathismoen (2018); National Forestry Inventory (2017)	+++

Source: Own elaboration based on tables, categories and descriptions from Gomez-Baggethun et al. (2019). Icons by Jan Sasse for TEEB (except icons for 'sense of place and community' and 'science and education' which are from Gomez-Baggethun et al., (2019)).

Arrows indicate trend: ↑ = increased; ↔ = remained stable; ↓ = decreased; ? = not assessed due to lack of data. Large arrows in colour = trend in ecosystem service category and smaller arrows in grey = trend in sub-category.
+ indicate level of uncertainty in the data, + = low, ++ = medium, and +++ = high level of uncertainty.

5.1.1. Food production

As described in chapter 3.2, the forested areas surrounding Oslo has historically been a place of small-scale farming and keeping of livestock. Today, the largest remaining agricultural areas within the Oslomarka border are Maridalen, Sørkedalen, Losby and areas by the lakes Dælivann and Stovivann (Norwegian Environment Agency, 2020b (map); Ministry of Environment, 1976). Maridalen is a valley in Nordmarka connected to Maridalsvannet with 280 ha of agricultural land (the County Governor of Oslo and Akershus, 2002). Fifteen farms are actively driven at present which mainly cultivate grain. Grass, vegetables and berries are grown on a smaller scale. The keeping of livestock and milk production was common in this area until it became illegal in 1967 due to the strict protection of the lake Maridalsvannet as a source of drinking water (ibid.; Oslo Byleksikon, 2020). Drinking water regulations has moreover driven a reduction of 100-120 ha of cultivated land replaced by forest since the 1970s (ibid.). Sørkedalen is another valley located in Nordmarka with 350 ha of agricultural land (Solbakken, 2007). 31 farms are actively driven in the area and a total of 30 cows, 99 sheep, 25 goats and 281 horses were raised in this area as of 2017 (Sørkedalen Vel, 2017). Similar data were not found for the other areas.

As data on agricultural production, total area of agricultural land and/or the number of livestock kept in Oslomarka was not found, data of actively driven agricultural land (land used for pasture, food and fodder production), and livestock in Oslo municipality was chosen as a coarse indicator of flow and trend. Of the mentioned agricultural areas in Oslomarka, Maridalen and Sørkedalen lie within the borders of Oslo municipality. Figure 2 show data from Statistics Norway (2020c) of ha of actively driven agricultural land and its distribution of this land used for food production, and pasture and fodder production from 1969 to 2019. Figure 3 show the number of livestock (cattle and sheep) kept in Oslo municipality for the same time period (Statistics Norway, 2020d). The overall trend for both figures is decreasing.

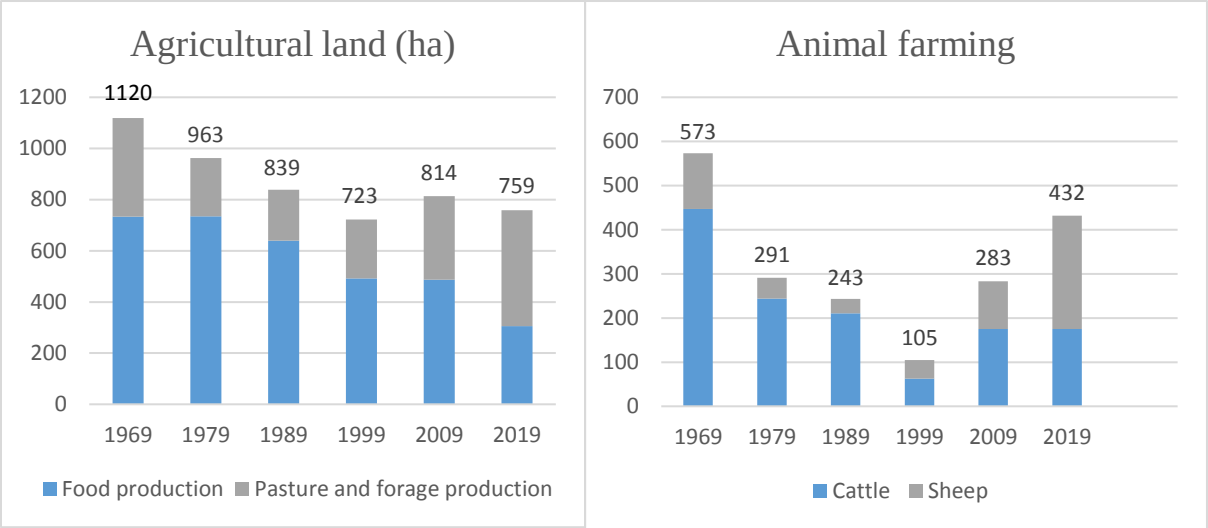

Figure 2 & 3: Agricultural land (ha) and animal farming in Oslo municipality, 1969-2019.
Source: Own graphs based on data from Statistics Norway (2020c; 2020d).

5.1.2. Freshwater supply

Freshwater supply is defined here as water quantity from lakes in Oslomarka extracted for public, business and domestic use. Oslomarka has 2410 lakes covering a total area of 94,6 km^2 (OOF, 2014). A total of 83 lakes (45,4 km^2) are regulated for freshwater supply, of which 37 has restrictions on activities allowed in the area such as fishing, camping and bathing. These lakes provide freshwater to Oslo municipality and nine other municipalities surrounding the forest (OOF, 2014). The majority of these lakes (53 lakes, 35,9 km^2) provide freshwater to Oslo municipality only, which gets all of its water from Oslomarka (OOF, 2014; Water and wastewater agency, 2008). As no data was found for the total flow of freshwater from Oslomarka to the different municipalities, water flow to Oslo municipality was chosen as an indicator of freshwater flow and trend.

The supply of freshwater to Oslo municipality stems from four networks of lakes and rivers culminating in four main lakes: Maridalsvannet (90 % of water supply), Elvåga (10 % of water supply), Langlivannet (provides water to Sørkedalen in Oslo) and Alnsjøen (back-up) (Oslo municipality, s.a.(b); Water and wastewater agency, 2008).

Figure 5 shows data of the total freshwater withdrawal from Oslomarka to Oslo municipality and its distribution between public and business consumption, domestic consumption, non-registered consumption (water lost due to leakages) and water sold to neighboring

municipalities from 1980 to 2018 (Oslo municipality, 2020). Data was not found for the period 1970-1979.

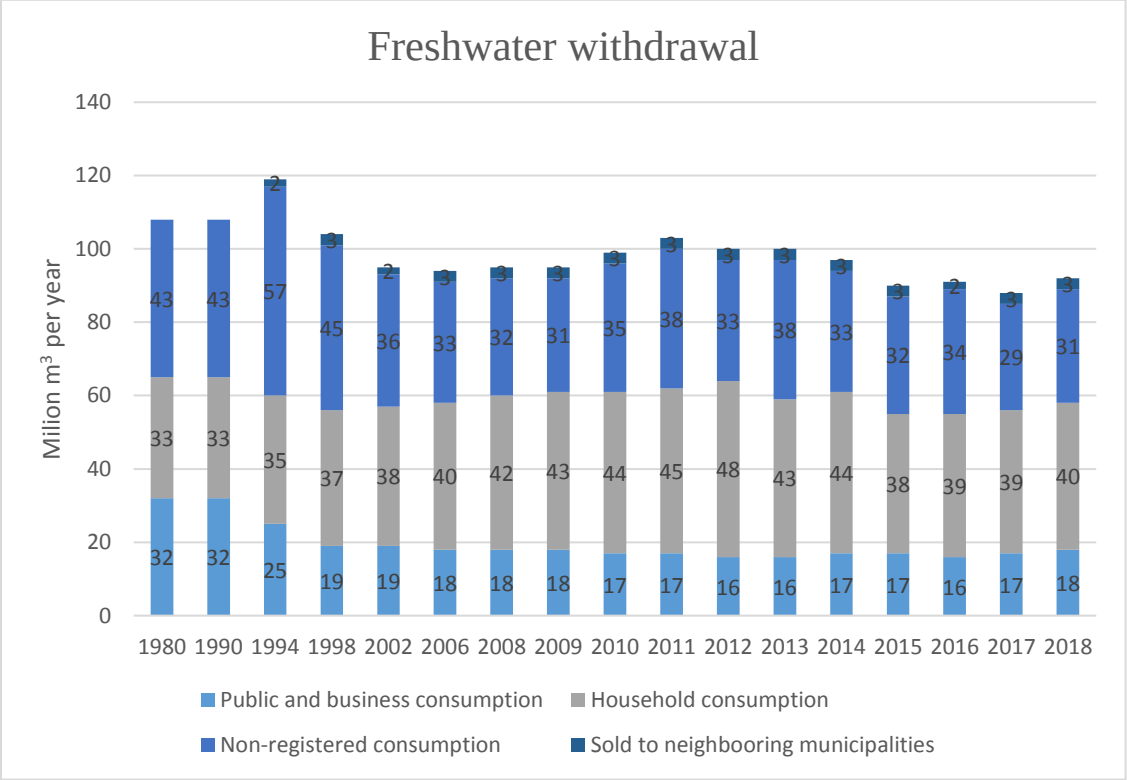

Figure 5: Total freshwater withdrawal from Oslomarka to Oslo municipality, 1980-2018.
Source: own graph based on data from Oslo municipality (2020).

The data shows a relatively stable flow of freshwater during this period with an overall decrease from a total of 108 m^3 in 1980 to 92 m^3 in 2019. Public and business consumption as well as non-registered consumption has declined while household consumption has increased. However, available data from Statistics Norway (2020e) from 2003 to 2016 shows that household consumption per capita has decreased from 206 liters per day in 2003 to 174 liters per day in 2016, indicating that the level of freshwater consumed by households has been driven by population growth and better water saving installations in recent years (Water and wastewater agency, 2019).

5.1.3. Timber production

A full overview of timber production in Oslomarka for the studied time period was not found. However, sources providing data for some individual years indicate an overall downward trend in timber harvested in Oslomarka in the time period under study (Table 2).

Table 2: Timber harvest in Oslomarka

Year	Timber harvest	Source
1970-1972	365 000 m^3 (average per year)	Ministry of Environment (1976)
1983	300 000 m^3	Christophersen & Svensson (1984)
2012	205 000 m^3	OOF (2014)
2018	345 063 m^3	NOA (2020)
2019	234 373 m^3	NOA (2020)

Data for 2018 and 2019 are uncertain as they are based on notifications of intended volume of logging in Oslomarka, which might differ from the actual volume felled. Moreover, the volume estimated for 2019 has 34 notifications that do not state the intended volume of felling.

Data of timber production for the two largest landowners in Oslomarka, Løvenskiold-Vækerø (430 km^2) and Oslo municipality (167 km^2) indicate a similar downward trend. Timber harvest in the forest owned by Oslo municipality over the studied period shows an overall decline with an average of 25 000 m^3 timber harvest per year from 1960-1993, followed by a decline down to 8500 m^3 per year from 1994-2009, followed by a rise up to 13 000-19 000 m^3 per year from 2010-2018 (Oslo municipality, 2005; Borges et al., 2015; Olsen, 2018). The large drop in volume in 1994 owes increasing considerations by local authorities for recreational use of the forest and to increase the forest's biological age (Borges et al., 2015; Røsjø, 1998).

Descriptions of timber production in the forest owned by Løvenskiold-Vækerø (430 km^2) indicate a similar trend (Jerman, 2004). In the 1950s, average timber harvest was 70 000-80 000 m^3 per year. In 2003, this volume had dropped to 67 000 m^3 year and current information shows a further drop to 65 000 m^3 per year (Jerman, 2004; Løvenskiold-Vækerø, s.a.). According to Jerman (2004) the decrease in the harvest volume since the 1950s owes the same reasons mentioned for Oslo municipality.

5.1.4. Outdoor recreation

Outdoor recreation in Oslomarka comprise a wide variety of activities and experiences amongst users of Oslomarka including hiking, skiing, cycling, running, bathing and camping (Gundersen et al., 2011). The share of the Oslo population visiting Oslomarka once or more

each year and the total number of visits to Oslomarka made by the Oslo population per year was chosen as indicators to assess flow and trend of the cultural ecosystem service 'outdoor recreation'. According to the Norwegian Ministry of Environment (1976), 400 000 people over the age of 15 living in Oslo commercial district[5] used Oslomarka each year, which at this time amounted to 62,9 % of its population (Statistics Norway, 1977). Two decades later, a study by Aasetre (1994) found that 80 % of the population of Oslo used Oslomarka at least once the past year (1993). A study conducted in 2005 found a similar share of 81 % of the Oslo population over the age of 15 visiting the forest at least once during the past 12 months (Oslo municipality, 2007). A more recent study finds this share to be 86 % (Synnovate, 2011). Measured in number of visits, Aasetre (1994) estimated that the inhabitants of Oslo visited Oslomarka 15.1 million times in 1993. Based on the study by Synnovate (2011), Barton et al. (2015) estimated that the inhabitants of Oslo visited Oslomarka 23.4 million times every year.

These studies indicate a rising trend in the use of Oslomarka for recreational purposes both in terms of the share of the Oslo population visiting Oslomarka each year and the total number of yearly visits. Comparing the increase from 1993 to 2015 in the share of people using Oslomarka each year (6 % increase) and the total number of visits per year (55 % increase) indicate that the total number of users has increased more than the equivalent increase in share, and/or that the average number of visits per person per year has increased.

The most popular activities in Oslomarka are short walks, daytrips on foot, skis or bicycle and bathing and sunbathing (OOF, 2014; Gundersen et al., 2011). Trends in later times find that many youths favor more specialized and action-driven activities like cross-cycling, snowboarding, kiting and different water activities (OOF, 2014). The most active users of Oslomarka are those with high education and income (Oslo municipality, 2007). Studies also show that use of the area varies throughout the year with a peak during the summer months and during weekends (Gundersen et al., 2011).

The use of Oslomarka for outdoor recreation is facilitated in many ways. Oslomarka comprises a network of 1400 km of forest roads, 2100 km of forest trails and 2800 km of prepped ski tracks in the winter (Oslo Municipality, s.a.(a)). There are 138 cabins open to the public out of which 95 offer some serving of food and beverages and 59 are available for accommodation (Skiforeningen, 2020). These are driven mainly by DNT, the Skiing Association and Oslo municipality as well as a range of other smaller actors like local skiing

[5] Comprising the municipalities of Oslo, Asker, Bærum Lørenskog, Nittedal, Oppegård and Nesodden.

and sport clubs and private owners. As for facilitation of sports and other specialized activities, there are 20 horseback riding routes, eight ski jumps, 11 alpine slopes, 24 cross-country skiing arenas and/or biathlon facilities, ten golf courses, ten climbing areas, one skating rink facility and one motor cross route (OOF, 2014).

5.1.4.1. Fishing

Studies indicate an increasing interest in fishing in Oslomarka during the last decades. Aasetre (1994) finds that 16 % of the recreational users of Oslomarka went fishing in Oslomarka within the past year. A study by Synnovate (2011) finds that the share of the users of Oslomarka that state fishing as an important reason for visiting the forest was 27 % in 2004 and 25 % in 2011.

Fishing has a long history in Oslomarka and has developed from being a crucial source of food to becoming mainly a recreational activity from the 1920s onwards (Christophersen & Svensson, 1984). The right to fish in Oslomarka belongs to the landowner, however, the purchase of a fish permit will grant permission to anyone. The sale of such permits is made by different fishing administrations of which the by far largest one is Oslomarka Fishing Administration (OFA) which administers 595 water bodies for fishing in Oslomarka (OOF, 2014). These water bodies include small swamp ponds, forest ponds, streams, rivers and larger lakes which are habitats for 36 species of freshwater fish (Heyerdahl, 2011; OFA, 2020).

OFA was established in 1936 to improve the fish stocks in Oslomarka, which were being depleted from increasing interest in recreational fishing at this time, and to secure fishing rights for everyone by taking on the administering of fishing rights from private and public landowners (Christophersen & Svensson, 1984; Heyerdahl, 2011). To increase fish stocks, OFA has driven their own hatchery since 1941, gathering trout roe from Nordmarka and releasing 30 000 1-3-year-old trouts every year back into the water bodies in Oslomarka (OFA, 2020).

The number of sold fish permits was chosen as an indicator for the ecosystem service recreational fishing in Oslomarka. As data for number of fish permits sold over time was not available for smaller fishing administrations, data from OFA was used to indicate flow and trend. Figure 5 presents data of the number of fish permits sold by OFA from 1970-2019

indicating an increasing trend over time. This trend may be even stronger from 1993 onwards due to that fishing for everyone under the age of 18 became free of charge (Heyerdahl, 2011).

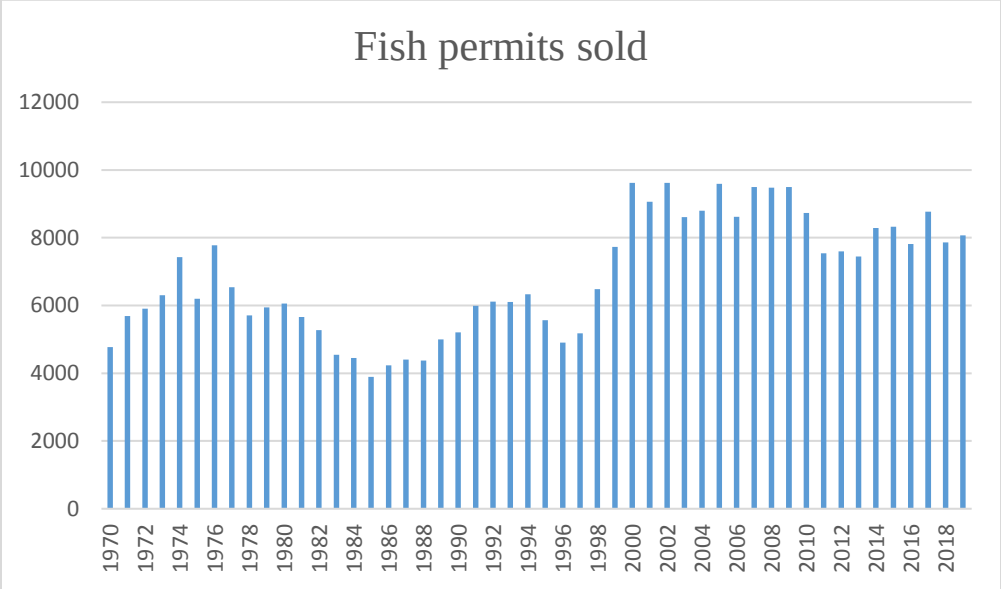

Figure 5: Number of fish permits sold by OFA, 1970-2019.
Source: own graph based on data from Heyerdahl (2011) and OFA (2019).

5.1.4.2. Hunting

A study by Aasetre (1994) indicates that hunting is of limited importance as a recreational activity in Oslomarka finding that only 3 % of the users of the forests surrounding Oslo went hunting within the last year. In 1976, this share was estimated to be 4 % of the users of Oslomarka from Oslo commercial district (Ministry of Environment, 1976).

The number of felled elk and roe dear was chosen as an indicator for hunting in Oslomarka. Yearly data for the time period 1995-2018 was found for the areas of Oslomarka owned by Løvenskiold-Vækerø (430 km^2) and Oslo municipality (167 km^2) indicating a decreasing trend in this time period (Naturdata, 2019) (Figure 6).

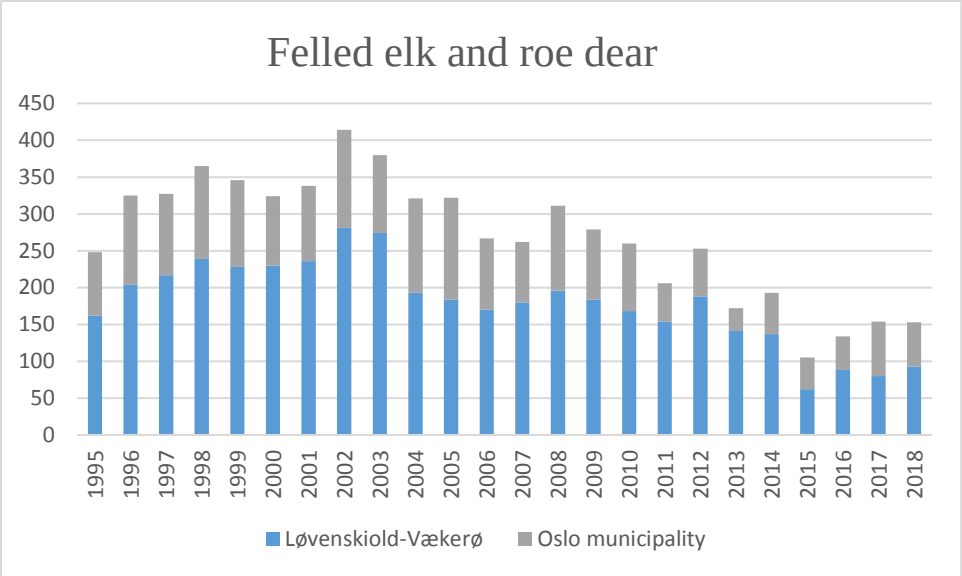

Figure 6: Number of felled elk and roe dear in areas of Oslomarka owned by Løvenskiold-Vækerø and Oslo municipality, 1995-2018.
Source: own graph based on data from Naturdata (2019).

Sources of hunting in Oslomarka before 1995 indicate that there was an increasing trend in the populations of elk and roe dear from very low levels after the World War II (Christophersen & Svensson, 1984; Jerman, 2004). Chistophersen & Svensson (1984) indicate that this was driven by the increase in clear-felling which improved grazing opportunities for wild animals. As numbers of felling permits typically follow the trend in populations, this could suggest an increasing trend in hunting from 1970-1995. Statistics of felled elk within the borders of Oslo municipality shows this trend: the data shows an increasing trend in felled elk from 1970 until reaching a peak in 2004 (Statistics Norway, 2020f). After 2004 the trend is decreasing. Looking at the overall trend in this data from 1970 to 2019 shows that the number of felled elk is higher in 2019 than it was in 1970 indicating an increase in the overall trend from 1970 to 2019 (ibid.).

5.1.4.3. Mushrooms and wild berries

According to the Outdoor Recreation Act (1957), everyone has the right to pick wild berries and mushrooms in uncultivated land with an exception of cloudberries in northern Norway (Ministry of Climate and Environment, 2015b). There is no commercial activity related to wild berries and mushrooms in Oslomarka, so berries and mushrooms are picked for own use only (Lindhjem & Magnussen, 2012).

The share of the number of users of Oslomarka picking mushrooms and wild berries per year was chosen as an indicator of flow and trend. In 1976, 48 % of the users of Oslomarka from Oslo commercial district went mushroom- and berry picking (Ministry of Environment, 1976). In 1993, according to Aasetre (1994), 42 % of the users of Oslomarka from Oslo went mushroom- and berry picking. Synnovate (2011) found that 45 % of the Oslo users of Oslomarka stated that mushroom- and berry picking was an important reason for using the forest. This share was 49 % in a similar study from 2005 (Synnovate, 2011). These studies indicate that mushroom- and berry picking is an important recreational activity in Oslomarka and that the flow of this service has remained fairly stable during the studied time period.

5.1.5. Cultural heritage

Cultural monuments are defined by Oslo municipality (2005) as traces of human activity in the physical environment, including places connected to historical events, faith and tradition. The preservation of cultural monuments in Oslomarka is stated in the Marka Act as having equal importance as the preservation of the natural environment (Marka Act, 2009). Oslomarka is rich with cultural monuments that are traces of travelling, settlements and resource use through thousands of years (Bugge & Reusch, 2010). These cultural monuments are often connected to known stories about historical life in Oslomarka and give important contributions to experience values for users of the forest (ibid.; Ministry of Climate and Environment, 2015b).

The number of registered cultural heritage sites was chosen as an indicator of cultural heritage in Oslomarka. In 1973, a report (Holmen, 1973) was published to provide an overview of cultural monuments with conservation value in Oslomarka connected to a multiple use plan for the area made by the Ministry of Environment in 1976. Based on literature and visits to the area, this report registered a total of 387 cultural heritage sites with conservation value in Oslomarka including mountain pastures (*setre*), places of settlement with or without remaining buildings, old roads, graveyards (connected to church or other), mines, charcoal plants (*kølabonner*), installations to float timber (*fløtningsanlegg*), and animal graves.

A similar updated overview was not found, however, a digital mapping function provided by the Norwegian Environment Agency (2020c) allowed to draw a coarse line of the Oslomarka border and getting an estimation of the number of cultural heritage sites within this border today. This produced a coarse estimation of 986 registered cultural heritage sites with one or

more cultural monuments including places of settlement and farmyards with or without different types of buildings, old roads, graveyards, charcoal plants (*kølabonner*), installations to float timber (*fløtningsanlegg*), iron works, places of archeological findings, and churches. This indicates that the number of registered cultural heritage sites has increased during the time period under study.

5.1.5.1. Folklore

Two centuries ago, beliefs in mythological creatures like trolls, the wood nymph and other supernatural beings (*troll, huldra, tusser, nisser*) was a common part of the folklore in Oslomarka (Saugstad, 2017). The presence of these beings was commonly used to explain strange phenomena and events happening in the farms and forests. They were also common features in folktales and stories which had an important function as entertainment (ibid.).

As modernity expanded to the rural life with electricity, glasses and better education, the folklore in Oslomarka became less prominent (Saugstad, 2017). However, stories, folktales, legends and myths connected to Oslomarka have over time been collected and written down by several writers wandering the forests of Oslomarka. This literature is an important part of the cultural history of Oslomarka. In 1845, the famous Norwegian writer Peter Christen Asbjørnsen published 'En nat i Nordmarken' and 'Kvarnsagn' and five years later Bernhard Herre published 'I Nordmarken' (Heyerdahl, 2011). These three texts stand today as the original texts about Nordmarka and contributed to the perception of mystery and fairytale in the forest awaking the curiosity of the urban population to the area (ibid.; Gangdal, 2011). Other important gatherers and writers of stories, folklore and mystery in Oslomarka are Johan Henrik Borrebæk (1860-1921), H. O. Christophersen (1902-1980), Reidar Holtveit (1904-1985), Paul Bukier (1875-1957), Otto Blehr (born 1927) and Ørnulf Hodne (born 1935) (Saugstad, 2017). Folktales and mythological creatures were illustrated by the artists Theodor Kittelsen (1857-1914) and Erik Werenskiold (1855-1938) who contributed to people's imaginations of the looks of these creatures.

In recent years, the term 'fairytale forest' has been applied to describe "forested areas of soul and mystery, where you find silence, and where imagination comes to life" (NOA, s.a.(a)). These are forests with particularly high experience values, high biological age and low impacts from felling (Andersen, 2014). Moreover, they are characterized by a range of characteristics including 'untouched and natural', 'variation and diversity in species and tree

size and age', 'wild and dramatic terrain', 'traces of human history', 'experience of water and space', 'silence', 'distinctive, mystical and dreamlike'. (NOA, s.a.(a)).

Since 2002, more than 100 areas in Oslomarka has been characterized as a 'fairytale forest'. Studies indicate that people have higher experience values of forests with these characteristics emphasizing the importance of preserving them (Andersen, 2014; Aalstad, 2012; Oslo municipality 2005).

Data was not found to allow for a quantitative assessment of flow and trend of the ecosystem service 'folklore' in Oslomarka. However, the data indicates that there has been a qualitative change in this service in the studied time period from being mainly a feature in literature to inspiring the use of the term 'fairytale forest'.

5.1.6. Sense of place and community

"The concept of sense of place embeds all dimensions of peoples' perceptions and interpretations of the environment, such as attachment, identity or symbolic meaning" (Hausmann et al., 2016, p. 117) and is referred to as the relationship between humans and ecosystems (MEA, 2005). Urban and peri-urban forests can foster a sense of place and community as they provide spaces where people can meet and interact socially (de Vries et al., 2013). Moreover, people incorporate places in which they feel relaxed and comfortable into their self-identity (Dobbs et al., 2018).

Oslomarka played an important role in the building of the Norwegian identity from the 1850s with nature-based recreation and skiing becoming part of the Norwegian identity and culture (Heyerdahl, 2011). With the increase in leisure time and income, nature-based recreation expanded across age, gender and social classes in Oslo becoming a leisure activity that large segments of the Oslo population have in common today (Oslo municipality, 2005). According to Hofmann et al. (2018), 'friluftsliv' in Norway is about more than just a set of activities, it entails a philosophy and a way of life characterized by simplicity and environmentally friendly practices affecting Norwegian identity in a deeper way than merely being something people do.

Studies find that people form relationships with the places they visit in Oslomarka such as specific areas, trees and other physical features of the forest (Andersen, 2014; Oslo municipality, 2005; Christophersen & Svensson, 1984). A key finding is that users of

Oslomarka want the areas they use to be recognizable and relivable so that they can experience places repeatedly without them having radically changed (Oslo municipality, 2005). This aspect is crucial for the development of personal relationships with nature. Moreover, they prefer their outdoor recreational areas to be characterized by being 'natural', 'untouched', with 'species diversity' and 'variation' (nature in all stages of growth and decay) (ibid.).

Synnovate (2011) found that 74 % of the Oslo population using Oslomarka visited the area along with friends and/or family. The use of Oslomarka thus provides an arena for connecting people together and strengthening social cohesion (Oslo municipality, 2005). Moreover, a common trait in Norway is that of greeting strangers you meet in nature typically driven by a feeling of having something in common and sharing similar interests indicating a sense of community arising from pursuing recreation together and sharing common spaces (Skjervold, 2011; Sveen, 2017).

It is difficult (and possibly meaningless) to quantitatively assess the ecosystem service 'sense of place and community' (Hausmann et al., 2016). Data was not found to allow us to quantitatively assess its flow and trend in Oslomarka. However, as the use of Oslomarka for recreational purposes has increased as stated in the assessment of the ecosystem service 'outdoor recreation', a stable or increasing trend might be suggested in the time period under study.

5.1.7. Science and education

Oslomarka is largely used for educational purposes. Oslo municipality actively encourages the use of Oslomarka as an arena for environmental and cultural historical education for kindergartens, schools and universities, and offer opportunities to schools and kindergartens to establish permanent bases (such as a *lavvo*[6]) for outdoor schooling (Oslo municipality, 2005; 2007). There are three visit farms in Oslomarka (Bogstad, Sørbråten and Losby) which are open to the public and offer guided tours and learning about the farm history, agriculture and their livestock for kindergartens and school classes (OOF, 2014). The outdoor recreational council of Oslo and surrounding areas (OOF) offer teaching courses in nature-

[6] Traditional Sami tent commonly used in nature-based recreation in Norway today

based education for teachers, introduction courses in nature-based recreation for immigrants, and nature-based camps for children in the Oslomarka area (OOF, s.a.).

As no data was found for the total number of educational programs, excursions, visits or the number of users of these educational opportunities, the number of publications per year was chosen as an indicator of trends in the scientific and educational values of Oslomarka.

A search in the Norwegian National Library database using the search term 'Oslomarka' gave a total number of 2491 publications in the categories books (2454), theses (6) and articles (31) for the studied time period. Frequent themes of these publications are nature-based recreation (including guides to Oslomarka), nature and cultural history, and nature conservation. Sorted in publications per decade shows a clear peak in the 1990s followed by a decreasing trend in the following decades (Figure 7). The data indicate an overall decreasing trend during the studied time period.

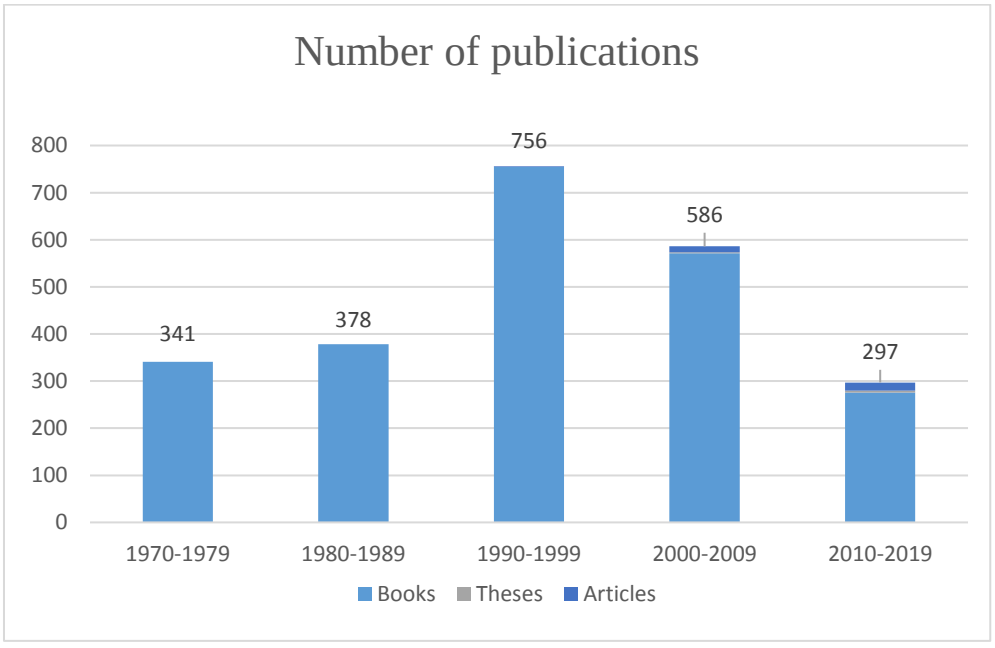

Figure 7: Number of published books, theses and articles about Oslomarka, 1970-2020.
Source: own graph based on data from the Norwegian National Library database (2020).

5.1.8. Climate regulation

To our knowledge, there are no studies of carbon capture and storage in Oslomarka. However, it is possible to make some estimations of flow and trend based on sources covering parts of

the Oslomarka area. A report from Oslo and Akershus[7] county (the County Governor of Oslo and Akershus, 2016) which covers 57 % (975 km^2) of the Oslomarka forest provides estimations of carbon capture and storage and thus hold a certain representativity for Oslomarka. According to OOF (2014), Oslomarka has 1176 km^2 productive forest[8]. This is 35 % of the total area of productive forest in Oslo and Akershus (3386 km^2). Based on this, and assuming that Oslomarka has rates of carbon capture and storage similar to that of Oslo and Akershus, we calculated a 35 % share of the carbon sequestered and stored in Oslo and Akershus (500 000 tons/year and 50 million tons respectively). This produced a coarse estimate of 175 000 tons CO_2 equivalents sequestered yearly and 17,5 million tons CO_2 equivalents stored in the tree biomass in the Oslomarka forest[9]. By comparison, total CO_2 emissions in Oslo was 1,1 million CO_2 equivalents in 2017 (Oslo municipality, s.a.(c)).

When it comes to trends, forest volume in Oslo and Akershus county has increased by 73 % since 1920 (The County Governor of Oslo and Akershus, 2016). Data for the Oslomarka forest owned by Oslo municipality (167 km^2 shows an even larger increase in the forest volume of 93,1 % from 1959 to 2005 (Oslo municipality, 2005). This increase in forest volume indicates an increasing trend in carbon sequestered and stored in Oslomarka for the time period under study. However, it is important to note that these findings do not say anything about the amount of carbon sequestered and stored in soil which, as noted in chapter 2, typically accounts for 75 % of total carbon storage (Grønlund et al., 2010; Haugland et al., 2011).

5.1.9. Habitat provision

The area of Norway in which Oslomarka resides is habitat for about 80 % of Norwegian species and is the region with the highest number of red-listed species (1527) in Norway (NOA, s.a.(b); Henriksen & Silmo, 2015). The Species Data Bank (Artsdatabanken, 2020) gather data on species observations in Norway over time. Using their digital mapping function to draw a coarse line of the Oslomarka border revealed a total number of 479 378 species observations of 12 069 species from 1970 to 2019 (Figure 8). 6,9 % of these observations

[7] Neighboring county to Oslo now part of Viken as of 01.01.2020.
[8] Productive forest is defined as forest that can produce a minimum of 1 m^3 wood with bark per hectare per year under favorable growth conditions (NIBIO, 2020a).
[9] 500 000 tons/year x 35 % = 175 000 tons/year. 50 million tons x 35 % = 17,5 million tons.

were of species that are red-listed species in the categories near threatened, vulnerable, endangered, critically endangered, or regionally extinct.

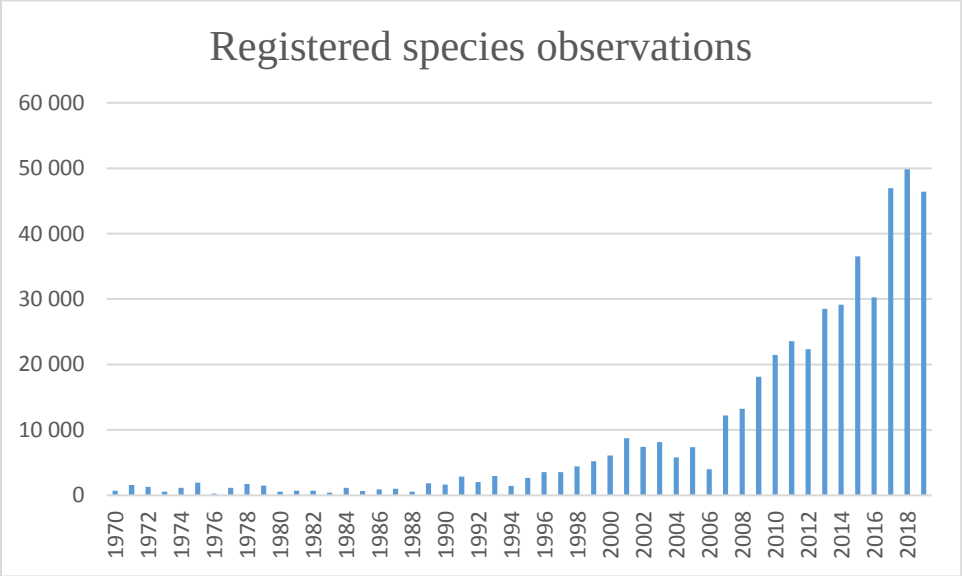

Figure 8: number of registered species observations, 1970-2019.
Source: own graph based on data from Artsdatabanken (2020).

Figure 8 shows a sharp upward trend in species observations. This is likely related to the highly uneven efforts in mapping over time, place, and for different species groups. The mapping efforts have increased over time, and there is more mapping done the past ten years than earlier times.

The share of natural forest was chosen as a coarse indicator of habitat provision in Oslomarka indicating a decline in habitat provision for the time period under study. As stated in chapter two, natural forests are of particularly high importance for habitat provision as 48 % of red-listed species in Norway have their habitats in these forests (Henriksen & Silmo, 2015; Lindhjem & Magnussen, 2012; NOU 2013:10). Several sources show a decreasing trend in the share of natural forest in Oslomarka. Data for the 167 km^2 of Oslomarka forest owned by Oslo municipality shows that the share of forest more than 60 years old have decreased from 79 % in 1949 to 42 % in 1980 and 32 % in 1994 (Oslo municipality, 2005). Modelling from the National Forest Inventory (2017; Mathismoen, 2018) measuring the share of natural forest in Oslomarka indicate a similar downward trend measuring a share of 19,1 % natural forest for 1994-1998 and 14,3 % for 2012-2016. By comparison, the eastern region (Østlandet) of Norway which is the region with most forestry has comparable shares of 29,8 % in 1994-1998 and 21,9 % in 2012-2016 (National Forest Inventory, 2017).

5.2. Socio-cultural valuation

5.2.1. Ecosystem services perceived by users

The ecosystem services most widely perceived (mentioned the highest number of times) in the survey when asked to list reasons why Oslomarka is important were cultural ecosystem services followed by regulating ones. No provisioning or supporting services were mentioned. Table 3 provides an overview of the listed ecosystem services and the number (n) and share (%) of the respondents listing them as providing benefits at individual and city scale. Results confirmed our expectation that the perceived importance of Oslomarka varies across scales. At the individual scale, the services with the highest frequency of listing were 'physical recreation' (100 %), 'mental recreation' (73,7 %) and 'aesthetic information' (41,1 %). By contrast, at the city scale 'physical recreation' (57,9 %), 'sense of place and community' (53,9 %) and 'mental recreation' (47,7 %) were mentioned the highest number of times.

Table 3: Identification of ecosystem services.

Source: Ecosystem services categories and descriptions based on Maestre-Andrés et al. (2016)

Ecosystem service	**Description**	**Individual**	**City**
Cultural services			
Physical recreation	Arena for practicing different physical activities that maintain/enhance physical health	n=95 (100 %)	n=55 (57,9 %)
Mental recreation	Arena for relaxing, disconnecting and diminishing stress that maintain/enhance mental health	n=70 (73,7 %)	n=45 (47,7 %)
Aesthetic information	Unique and attractive landscapes providing aesthetic values	n=39 (41,1 %)	n=16 (16,8 %)
Maintenance of social relations	Space to maintain or create social relationships among family and friends	n=17 (17,9 %)	n=9 (9,4 %)
Sense of place and community	Identifying oneself in relation to a place and community contributes to strengthening social cohesion	n=10 (10,5 %)	n=51 (53,9 %)
Regulating services			
Climate regulation	Carbon sequestration and storage contributing to mitigation of climate change	n=0 (0 %)	n=6 (6,3 %)
Air purification	Provision of fresh and clean air	n=27 (28,4 %)	n=10 (10,5 %)

The most notable difference between the individual and city scale is the large difference in listing of the ecosystem service 'sense of place and community' (10,5 % versus 53,9 %).

When asked about the importance of Oslomarka for Oslo, the respondents emphasized the uniqueness of having such a large area of nature with its proximity to Oslo and high accessibility. Moreover, people emphasized the importance of Oslomarka for Oslo's identity and the use of Oslomarka as an important common element of people's lives strengthening feelings of community across age and different social groups, emphasizing that Oslomarka is something that is "accessible to all".

5.2.2. Perceived importance of ecosystem services

Figure 9 presents results from section two of the survey: the average value assigned to each ecosystem service (on a scale of 1-5) identified in the literature review. Out of the 13 ecosystem services assessed, nine obtained an average value between 4 and 5 indicating that the respondents perceive these services as very important. Two ecosystem services obtained an average value between 3 and 4 and two ecosystem services an average value between 2 and 3. None had an average value below 2. The most highly valued ecosystem service was 'outdoor recreation' with an average score of 4,99 in the 1-5 scale. The least valued ecosystem services were 'agriculture and animal farming' (2,99) and 'hunting' (2,86). These were also the services the respondents found most difficult to value (number of respondents answering 'don't know' was 7 (7,3 %) for 'agriculture and animal farming' and 10 (10,5 %) for 'hunting') due to lack of knowledge about their prominence in Oslomarka.

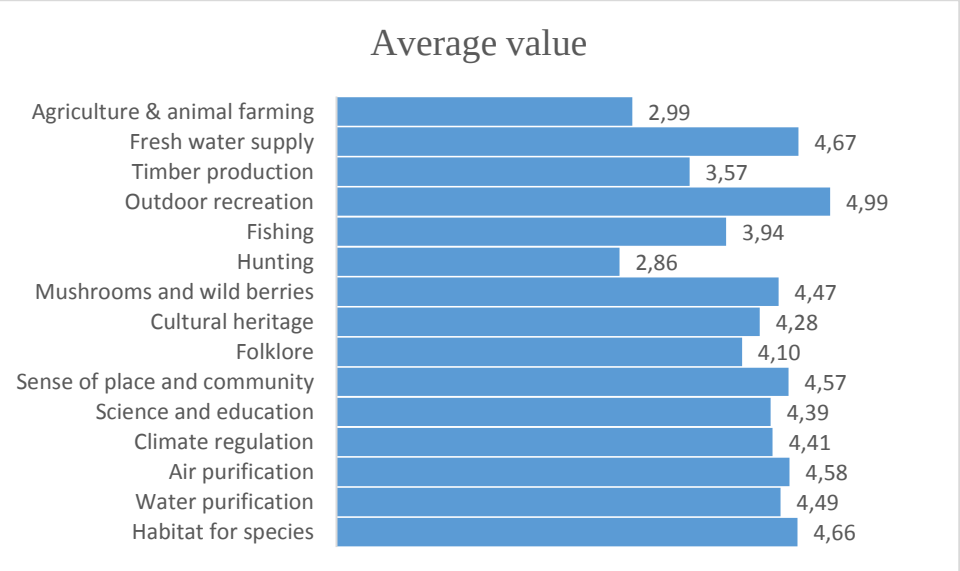

Figure 9: Average value assigned to each ecosystem service.

Comparing the relative importance of the four categories of ecosystem services revealed that the respondents gave on average the highest value to supporting services (4,66) followed by regulating services (4,49) and cultural services (4,20). Provisioning services obtained on

average the lowest value (3,74) (Figure 10). This stands in contrast with the finding from section one where cultural services were the most frequently listed reasons of importance of Oslomarka.

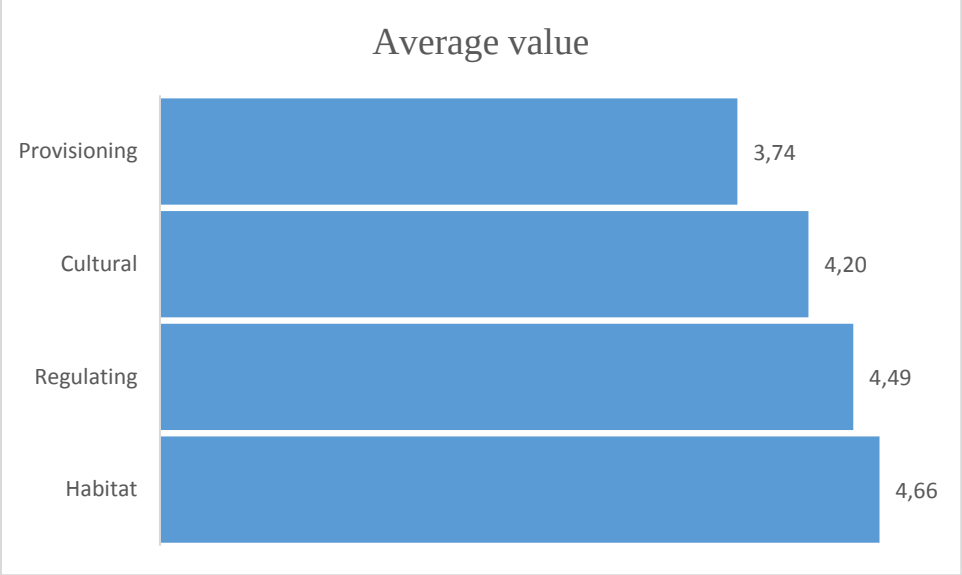

Figure 10: Average value assigned to the four main ecosystem service categories.

5.2.3. Socio-economic profile of the users

Our sample included 51,6 % male and 48,4 % female respondents. Their ages ranged from 20 to 83 years and were distributed as follows: 20-34 years (48,9 %), 35-49 years (24,5 %), 50-64 years (16,0 %), and more than 64 years old (10,6 %). 92,6 % were permanent residents of Oslo, 5,3 % of another neighboring municipality to Oslomarka and 2,1 % lived elsewhere in Norway. 88,4 % of the respondents had higher education distributed as follows: 1-3 years (22,4 %), 4-6 years (57,5 %) and more than 6 years (8,5 %). 70 % had a net monthly income of more than 30 000 NOK (300 EUR). 80 % were full-time employees, 6,3 % part-time employees, 3,2 % students and 10,5 % retired.

6. Discussion

Overall, our data indicate that provisioning (except for freshwater supply) and supporting services have declined while cultural services and regulating services increased in Oslomarka during the studied time period (1970-2020). As the focus of this study is on ecosystem flow, declines in ecosystem services should not necessarily be identified as the result of ecosystem

degradation as they could be related to decreasing human demand or restrictions related to environmental management. Our finding differs from trends found in global assessments of ecosystem services by the Millennium Ecosystem Assessment (MEA, 2005) and the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES, 2019) where the observed pattern is that provisioning services have increased while regulating and supporting services have decreased. However, this finding is consistent with the fact that Oslomarka has been managed as a peri-urban forest for recreational purposes during the studied time period (Gundersen et al., 2015). Moreover, this may explain the finding of the high number of cultural services in the literature review relative to the other ecosystem service categories. Also, this may indicate that a key driver of change in the ecosystem services during the study period is that of legal regulations of Oslomarka. As stated by Oslo City Council in 1974, in cases of conflicts between different interests in the forest owned by Oslo municipality, considerations for nature conservation, nature-based recreation and freshwater supply shall be of higher importance than that of economic gains from forestry (Oslo municipality, 2007). Similarly, the Marka Act place recreational use of the forest and preservation of the natural and cultural landscape above other uses (Markaloven, 2009, §1). This provides a foundation for the increasing trend in cultural services during the studied time period. The priority given to nature conservation would indicate that supporting services should have a similar upward trend, however, this is not found to be the case in this assessment.

The results for individual ecosystem services should be taken with care due to the high level of uncertainty involved (table 1) typically emanating from lacking and incomplete data as well as from the coarseness of the indicators used for assessment. Moreover, we recognize that quantitative indicators as used in this study may be limited in their ability to capture cultural phenomena. For example, the use of the indicator ‘number of publications’ to capture the flow of the ecosystem service ‘science and education’ captures only a limited part of the many ways in which Oslomarka provides this ecosystem service. Its contribution to children’s, immigrant’s and adult’s learning about nature and mastering of nature-based recreation through recreational visits, educational programs and excursions are clearly important features of this service. The suitability of the quantitative measurement ‘number of publications’ is in this case therefore questionable and may involve the risk of overlooking important features of the service.

Regarding potential biases, the socio-cultural valuation has some methodological limitations that should be considered. First, we recognize its limitation related to its sample size and selection. Its relatively low number of respondents including only recreational users involves the risk of the results being biased. As recreational users are direct beneficiaries of the ecosystem services of Oslomarka, the high importance attributed to the ecosystem services is not entirely surprising. The respondents' appreciation of Oslomarka likely differs from that of people who are connected to Oslomarka in other ways like forestry workers, private owners, organizations connected to Oslomarka, and public administers of the area. Moreover, if people who do not use Oslomarka were included in the sample it is likely that the importance attributed would be substantially lower and it is possible that disservices and preferences for other land uses would be mentioned (Camps-Calvet et al., 2016). In other words, having the sampling points in Oslomarka involves a bias towards people that are likely to have high appreciation of the forest and its services. We recognize that diversifying the sample could provide a more balanced picture of the importance people in Oslo attribute to the ecosystem services of Oslomarka and encourage research in this direction. Second, asking about the importance and contributions of Oslomarka to quality of life (while not addressing e.g. so-called ecosystem disservices) and providing a pre-written positive statement as a basis for giving rank to the ecosystem services may introduce a positive bias resulting in an overvaluation of the services (Calvet-Mir et al., 2012). Third, the Likert scale numbers are qualitative indicators of the level of agreement to a statement (Bryman, 2016). The quantitative analysis of these numbers should therefore be interpreted with care (Calvet-Mir et al., 2012).

Another important point to emphasize is that valuation methods are not neutral tools of revealing pre-existing perceptions of value and importance (Vatn, 2015). Socio-cultural valuation methods such as used in this study are likely to favor ecosystem services that emerge from human interaction with nature (cultural services) (Camps-Calvet et al., 2016; Calvet-Mir et al., 2012). The results from the free listing (section one of the survey) shows that the cultural services 'physical recreation' and 'mental recreation' were the most frequently listed reasons for Oslomarka's importance. Similarly, 'outdoor recreation' obtained the highest average value (4,99) in the Likert scale (section two of the survey). Overall, cultural services were the most frequently mentioned services in the free listing followed by regulating services. However, when asked to assign value to the ecosystem services in the Likert scale, supporting and regulating services obtained a higher average value than that of

cultural services. These findings indicate that i) the services physical and mental recreation/outdoor recreation are perceived as more important than other cultural services and that these are the most important services to the users. ii) In general, provisioning, regulating and supporting services does not immediately come to mind when asked about Oslomarka's importance. In fact, while conducting section two of the survey, a common response from the respondents was the expression of surprise and that they had not thought about the provision of these services by Oslomarka. However, when made 'aware' of these services and asked to value them, the high importance of supporting and regulating services seemed clear and were perceived as more important than several cultural services.

7. Conclusions

Peri-urban forests can provide many ecosystem services that give important contributions to human well-being. Based on our results, we find that Oslomarka provides a wide range of critically important ecosystem services that give important contributions to the well-being of the urban population of Oslo. This is particularly evident through the finding of the large share (86 %) of the Oslo population visiting Oslomarka for recreational purposes and that Oslomarka provides the entire supply of freshwater to Oslo municipality. These findings clearly emphasize Oslo's dependence on its peri-urban forest. Moreover, its high share of users indicate that Oslomarka plays an important role in connecting urban people with nature through providing access to nature experiences on an everyday basis. Our results based on the valuation survey indicate that recreational users attribute a high level of importance to the area and its ecosystem services. Physical and mental recreation was perceived as the most important services by the recreational users indicating that Oslomarka gives vital contributions to the maintenance and enhancement of human physical and mental health. Moreover, the high level of importance attributed to the area suggest that people using Oslomarka exhibit positive emotional connections with the natural area that in turn may trigger positive environmental behavior and attitudes (Soga & Gaston, 2016).

With the expected population growth in Oslo, we expect that Oslomarka will be even more important in the future to secure the access to a healthy environment for urban citizens. Maintaining the forest as an arena for human-nature interactions and delivery of vital ecosystem services is of critical importance. We hope our research will contribute to the rising awareness of the importance of maintaining and sustainably managing Oslomarka and other

peri-urban forests to provide the wide variety of important contributions to the well-being of urban populations.

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9. Appendix

Interview guide: Ecosystem services valuation survey

Information text: Hi! My name is Elisabeth Berglihn and I am conducting a survey connected to my master thesis at the University of Life Sciences. The purpose of this survey is to gather data on people's perception of the importance of Oslomarka.

The survey is anonymous, and the gathered data will only be used for academic purposes. The survey will take approximately 10 minutes. Would you like to participate in the survey?

Sampling point:			
Date:		**Researcher:**	
Start time:	**:**	**Nº interview:**	
Final time:	**:**	**Total tme:**	

Part 1a) Ecosystem services perceived by users, individual level

a) Why do you come to this area? **b) Why is Oslomarka important for you?** **c) How does Oslomarka contribute to your personal quality of life?**

Part 1b) Ecosystem services perceived by users, city level

a) Why is Oslomarka important for the city of Oslo? **b) How does Oslomarka contribute to the quality of life in Oslo?**

Part 2: Perceived importance of ecosystem services

In this part I want to explore people's perception of the importance of the benefits provided by Oslomarka to human well-being, and which benefits are seen as the most important. I therefore want to know your grade of agreement to the following claims on a scale from 1 to 5, where 1 is 'totally disagree' (i.e. according to you it does not seem at all important) and 5 is 'totally agree' (i.e. according to you it is very important).

What is your grade of agreement to the following claims?

Ecosystem services of Oslomarka		*1 = totally disagree, 5 = totally agree*					
		1	**2**	**3**	**4**	**5**	***Don't know***
Provisioning services							
Agriculture and animal farming	'Marka is important because it supplies food in the form of agriculture and animal faming'						
Fresh water supply	'Marka is important because is supplies fresh water'						
Timber production	'Marka is important because it supplies timber'						
Cultural services							
Outdoor recreation	'Marka is important because it is an arena for outdoor recreation and sports'						
Fishing	'Marka is important because it is an arena for recreational fishing'						
Hunting	'Marka is important because it is an arena for recreational hunting'						
Mushrooms and wild berries	'Marka is important because it is an arena for the picking of mushrooms and wild berries'						
Cultural heritage	'Marka is important because it is an area with cultural heritage and historical values'						
Folklore	'Marka is important because it gives and has given inspiration to Norwegian folklore and fairytales'						
Sense of place and community	'Marka is important because it is an area that provides sense of place, identity and community'						
Science and education	'Marka is important because it contributes to research and learning about nature'						
Regulating services							
Climate regulation	'Marka is important because it captures and stores carbon'						
Air purification	'Marka is important because it removes air pollutants'						

Water purification	'Marka is important because it provides water filtration'						
Supporting services							
Habitat for species	'Marka is important because it provides habitat for species'						

Part 3: Socio-economic profile of the respondents

Sex:	○ Female ○ Male	**Year of birth:**	
Municipality of residence:			
Do you have higher education?			○ Yes ○ No
How many years of higher education have you completed?			_____ years
What is your professional status?		**In which interval does your net monthly income lie?**	
○ Student ○ Full-time employee ○ Part-time employee ○ Retired ○ Other		○ 0 - 10 000 NOK ○ 11 000 – 20 000 NOK ○ 21 000 – 30 000 NOK ○ 31 000 – 40 000 NOK ○ More than 40 000 NOK	

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